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NATIONAL INVENTORY DOCUMENT INDONESIA GREENHOUSE GASES INVENTORY 2000-2022

Under the United Nations Framework Convention on Climate Change

> Republic of Indonesia 2024

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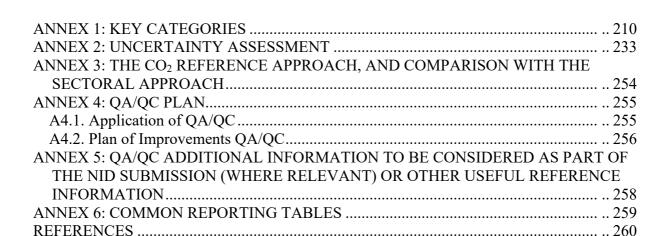
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LIST OF ABBREVIATION

3R Rewetting, Revegetation, Revitalization
AAWS Automatic Aerological Weather Stations

ACA Asuransi Central Asia

ACGF ASEAN Catalytic Green Finance Facility

AD Activity Data

ADB Asian Development Bank ADCOM Adaptation Communication

ADIPURA Anugerah ADIPURA, an award given to districts/cities in

Indonesia that are successful in urban environmental management.

AF Adaptation Fund

AFD Agence Française de Devéloppement / French Development

Agency

AFOLU Agriculture, Forestry, and Other Land Uses

AFR Alternative Fuel and Raw Material
AIIB Asian Infrastructure Investment Bank
AKKM Area Konservasi Kelola Masyarakat

AKSARA Aplikasi Perencanaan dan Pemantauan Rendah Karbon

APBD Anggaran Pendapatan dan Belanja Daerah/ Regional Revenue

and Expenditure Budget

APBN Anggaran Pendapatan dan Belanja Negara/State Revenue and

Expenditure Budget

APIK Adaptasi Perubahan Iklim bidang Kesehatan

APKI Asosiasi Pulp dan Kertas Indonesia

APL Area Penggunaan Lain

APPI Asosiasi Produsen Pupuk Indonesia APTMA Alat Pemantauan Tinggi Muka Air AR Afforestation dan Reforestation

ARG Automatic Rain Gauges

ASEAN The Association of Southeast Asian Nations ASN Aparatur Sipil Negara/ State Civil Apparatus

ASWS Automatic Surface Weather Stations

ATR/BPN Kementerian Agraria dan Tata Ruang/ Badan Pertanahan

Nasional

AUTP Asuransi Usaha Tani Padi

AUTS/K Asuransi Usaha Tani Ternak Sapi/ Kerbau

AWS Automatic Weather Stations
BABS Buang Air Besar Sembarangan

BAPPENAS Badan Perencanaan Pembangunan Nasional/National

Development Planning Agency

BAST Berita Acara Serah Terima/ Handover minutes

BATAN Badan Tenaga Atom Nasional/ National Atomic Energy Agency

BAU Business as Usual BBG Bahan Bakar Gas

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BBM Bahan Bakar Minyak
BBN Bahan Bakar nabati

BBPSI Balai Besar Pengujian Standar Instrumen

BBWS Balai Besar Wilayah Sungai

BI Bank Indonesia/ Central Bank of Indonesia

BIG Badan Informasi Geospasial/Geospatial Information Agency
BMKG Badan Meteorologi Klimatologi dan Geofisika/Meteorological,

Climatological and Geophysical Agency

BNPB Badan Nasional Penanggulangan Bencana/National Agency for

Disaster Management

BOD Biological Oxygen Demand BOE Barrels of Oil Equivalent BOP Biaya Operasional Penyuluh

BPBD Badan Penanggulangan Bencana Daerah/Regional Disaster

Management Agency

BPK Badan Pemeriksa Keuangan / Financial Audit Board

BPKP Badan Pengawasan Keuangan dan Pembangunan/Financial and

Development Supervisory Agency

BPN Badan Pertanahan Nasional BPP Balai Penyuluh Pertanian

BPPT Badan Pengkajian dan Penerapan Teknologi/ Agency for the

Assessment and Application of Technology

BPS Badan Pusat Statistik

BPSDM Badan Pengembangan Sumber Daya Manusia/ Human Resource

Development Agency

BPSDTPH Balai Pengawasan dan Sertifikasi Benih Tanaman Pangan dan

Hortikultura

BPTPH Balai Perlindungan Tanaman Pangan dan Hortikultura

BRG Badan Restorasi Gambut

BRGM Badan Restorasi Gambut dan Mangrove

BRIN Badan Riset dan Inovasi Nasional/National Research and

Innovation Agency)

BRT Bus rapid transit

BTR Biennial Transparency Report

BUMN Badan Usaha Milik Negara/ State-Owned Enterprises

BUR Biennial Update Report
BWS Balai Wilayah Sungai

CAGR Compound annual growth rate

CB Capacity Building

CBCA Community-Based Climate Action

CBIT Capacity Building Initiative for Transparency

CBTNA Capacity Building and Technology Needs Assessment

CDD Consecutive Dry Days

CDM Clean Development Mechanism CEWS Climate Early Warning System

CFS Climate Field School

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CI Cropping Intensity
CKD Cement Kiln Dust

CL Cropland

CMA Conference of the Parties serving as the meeting of the Parties to

the Paris Agreement

CNG Compressed Natural Gas
COD Chemical Oxygen Demand
COP Conference of the Parties

CORDEX Coordinated Regional Climate Downscaling Experiment

CPO Crude Palm Oil

CRIC Climate Resilient and Inclusive Cities

CRF Common Reporting Format
CRT Common Reporting Table

CS Carbon stock

CSA Climate smart agriculture
CTF Common Tabular Format
CWD Consecutive Wet Days
DAS Daerah Aliran Sungai
DBD Demam Berdarah Dengue

DFI Development Financing Institutions

DG Directorate General

DHIS District Health Information System

DIPA Daftar Isian Pelaksanaan Anggaran/ List of Budget

Implementation Items

DJA Direktorat Jenderal Anggaran/ Directorate General of Budget
DJKN Direktorat Jenderal Kekayaan Negara/ Directorate General of

State Assets

DJP Direktorat Jenderal Pajak/ Directorate General of Tax

DJPB Direktorat Jenderal Perbendaharaan/ Directorate General of

Treasury

DJPK Direktorat Jenderal Perimbangan Keuangan/ Directorate General

of Fiscal Balance

DJPPR Direktorat Jenderal Pengelolaan Pembiayaan dan Risiko /

Directorate General of Financing and Risk Management

DK Daftar Kegiatan/ Activity List

DKI Daerah Khusus Ibukota

DMAFS Debt Management and Financial Analysis System

DMC Dry matter content
DMI Daily Feed Intake

DMPG Desa Mandiri Peduli Gambut/Independent Peat Care Village

DRAM Dokumen Rancangan Aksi Mitigasi Perubahan Iklim

DRKH Daftar Rencana Kegiatan Hibah

DRPLN Daftar Rencana Pinjaman Luar Negeri/ List of Foreign Loan Plan
DRPPLN Daftar Rencana Prioritas Pinjaman Luar Negeri/List of Priority

Plans for Foreign Loans

DRR Disaster risk reduction
DWW Domestic wastewater

KIDKDKDKDKDKDKDKDKDKDKDKDK

EbA Ecosystem-based Adaptation

EBT Energi Baru Terbarukan/ Renewable Energy
EDAT Early Diagnosis and Prompt Treatment

EF Emission Factor
EFB Empty Fruit Bunches

EFT Environmentally Friendly Technologies

EMT Emergency Medical Team

ENDC Enhanced Nationally Determined Contributions

ENSO El Niño-Southern Oscillation

EP Environmental Permit

EPANJI Evaluasi Efektivitas Pengelolaan Jenis Ikan Terancam Punah

dan/atau Dilindungi

ESDM Energi dan Sumberdaya Mineral

EVIKA Evaluasi Efektivitas Pengelolaan Kawasan Konservasi

EWRS Early Warning and Response System

EWS Early Warning System

FCPF Forest Carbon Partnership Facility

FDI Foreign direct investment FED Feed Energy Density

FEWS Flood Early Warning System

FFB Fresh Fruit Bunch

FGD Focused Group Discussions
FNC First National Communication
FOLU Forestry and Other Land Use
FPCF Forest Carbon Partnership Facility
FREL Forest Reference Emission Level

FTC Financial, Technology and Capacity Building

FX Flexibility

GAPKI Gabungan Pengusaha Kelapa Sawit Indonesia

GAW Global Atmosphere Watch

GCF Green Climate Fund
GCM Global Climate Model
GDP Gross Domestic Product
GEF Global Environment Facility
GGA Global Goal on Adaptation

GHG Greenhouses Gas

GHGI Greenhouse Gas Inventory

GIZ German Agency for International Cooperation

GL General Ledger

GoI Government of Indonesia

GRDP Gross Regional Domestic Product

GWP Global Warming Potential

HCS High carbon stock

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HCV High conservation value

HCVF High Conservation Value Forest

HFC Hydrofluorocarbon
HK Hutan Konservasi
HL Hutan Lindung
HP Hutan Produksi

HPK Hutan Produksi Konversi
HPT Hutan Produksi Terbatas
IBF Impact-based forecasting

IBRD International Bank for Reconstruction and Development

ICER Indonesia Certificate Emission Reduction

IDR Indonesia Rupiah

IGES Institute for Global Environmental Strategies

IGRK Inventarisasi Gas Rumah Kaca/Greenhouse Gas Inventory

IHN Integrated Health Networks

IISIA Indonesian Iron & Steel Industry Association

IKLH Indeks Kualitas Lingkungan Hidup

IKP Indeks Ketahanan Pangan
IKRO Microclimate Station

INDC Intended National Determined Contribution

INPRES Instruksi Presiden

IPAL Instalasi Pengolahan Air Limbah

IPB Institut Pertanian Bogor

IPCC Intergovernmental Panel on Climate Change

IPLT Instalasi Pengolahan Lumpur Tinja
IPPU Industrial Process and Product Use

IPSDH Direktorat Inventarisasi dan Pemantauan Sumber Daya Hutan

IR Incidence Rate

ISPO Indonesian Sustainable Palm Oil

ISW Industrial Solid Waste
ITB Institut Teknologi Bandung

ITMO Internationally transferred mitigation outcomes

IWW Industrial wastewater

JICA Japan International Cooperation Agency
JITUPASNA Pengkajian Kebutuhan Pascabencana

KATAM Kalender tanam

KBL Kereta Bertenaga Listrik (Electric Fueled Train)

KCA Key Category Analysis

KCPI Knowledge Center Perubahan Iklim

KEMENKES Kementerian Kesehatan/Ministry of Health
KEMENTAN Kementerian Pertanian/Ministry of Agriculture

KESDM Kementerian Energi dan Sumberdaya Mineral/ Ministry of Energy

and Mineral Resources

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KfW Kreditanstalt für Wiederaufbau/ Germany Development Bank

KHG Kesatuan Hidrologis Gambut

KIMONO-CFS Climate Smart Technology for Climate Field School

KKP Kementerian Kelautan dan Perikanan/Ministry of Maritime and

Fisheries Affairs

KLB Kejadian Luar Biasa

KLHK Kementerian Lingkungan Hidup dan Kehutanan/Ministry of

Environment and Forestry

KLHS Kajian Lingkungan Hidup Strategis

KOMPAK Kelompok Masyarakat Penggerak Kawasan Konservasi

KOTAKU Kota Tanpa Kumuh

KPA Kawasan Pelestarian Alam

KPBU Kerjasama Pemerintah dengan Badan Usaha

KPH Kesatuan Pemangkuan Hutan

KPPN Kantor Pelayanan Perbendaharaan Negara/ State Treasury

Service Office

KRL Kereta Rel Listrik

KSA Kerangka Sample Area/Area Sampling Frame

KSP Kawasan Pelestarian Alam KUA Kredit Usaha Alat Pertanian

KUR Kredit Usaha Rakyat
L&D Loss and Damage

LAPAN Lembaga Penerbangan dan Antariksa Nasional/ National Institute

of Aeronautics and Spaces

LCEV Low Carbon Emission Vehicle

LCGC Low-Cost Green Car

LDKPI Lembaga Dana Kerjasama Pembangunan Internasional/

International Development Cooperation Fund

LEWS Landslide Early Warning System

LFG Landfill Gas

LHK Lingkungan Hidup dan Kehutanan

LIPI Lembaga Ilmu Pengetahuan Indonesia/ Indonesian Institute of

Science

LNG Liquefied Natural Gas
LPG Liquid Petrolium Gas
LRT Light rapid transit

LULUCF Land-use change and forest
M&E Monitoring and Evaluation
MDB Multilateral Development Banks

MEMR Ministry of Energy and Mineral Resources

MEWS Meteorology Early Warning System

MJ Mega Joules

MKG Meteorologi, Klimatologi dan Geofisika

MODIS Moderate Resolution Imaging Spectroradiometer

MoEF Ministry of Environment and Forestry

MoF Ministry of Finance
MoI Ministry of Industry
MOL Mikro Organisme Lokal
MOMAL Makan Obat Malaria Massal
MONEV Monitoring and evaluation

MoU Memorandum of Understanding

MPG Modalities, Procedures, and Guidelines

Ministry of Public Works

KUKUKUKUKUKUKUKUKUKUK

MPTS Multi-purpose tree species

MPV Monitoring, Pelaporan, dan Verifikasi

MRT Mass rapid transit

MoPW

MRV Monitoring, reporting, and verification

MSG Melanesian Spearhead Group

MSW Municipal Solid Waste NC National Communication

NDC Nationally Determined Contributions
NFMS National Forest Monitoring Systems
NGHGI National Greenhouse Gases Inventory

NMVOC Non-Methane Volatile Organic Compounds NPK Nitrogen (N), Fosfor (P), dan Kalium (K)

NPL Non-Performing Loan
NPS Non-Party Stakeholders
NTB Nusa Tenggara Barat
NTT Nusa Tenggara Timur

ODA Official Development Assistance
ODS Ozone-depleting substances
OMC Operasi Modifikasi Cuaca

OMDC Oceans, Marine Debris, and Coastal

OOF Other Official Flows

OPD Organisasi Perangkat Daerah
OPT Organisme Pengganggu Tumbuhan

PA Paris Agreement

PBI Pembangunan Berketahanan Iklim

PBP Performance-based payment

PDASRH Pengendalian Daerah Aliran Sungai dan Rehabilitasi Hutan

PDB Produk Domestik Bruto

PEEB Program for Energy Efficiency in Buildings

PEMDA Pemerintah Daerah
PFC Perfluorocarbon

PHPL Pengelolaan Hutan Produksi Lestari

PIH Pusat Industri Hijau / Green Industry Center
PJU Penerangan Jalan Umum/Street Lighting

PPI Pengendalian Perubahan Iklim

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PKHL Pengendalian Kebakaran Hutan dan Lahan

PLN Perusahaan Listrik Negara/ State Electricity Company
PLTA Pembangkit Listrik Tenaga Air/ Hydroelectric Power Plant

PLTB Pembangkit Listrik Tenaga Bayu

PLTM Pembangkit Listrik Tenaga Minihidro/ Minihydro Power Plant

PLTP Pembangkit Listrik Tenaga Panas Bumi

PLTS Pembangkit Listrik Tenaga Surya/ Solar Power Plant

PMK Peraturan Menteri Keuangan PMU Project Management Unit

PN Prioritas Nasional

PNBP Pendapatan Negara Bukan Pajak/ State Revenue Non-Tax

POPT Pengendali Organisme Pengganggu Tumbuhan

PP Priority Programs/Program Prioritas

PP Peraturan Pemerintah/ Government Regulation

PPP Public-Private Partnerships

PPTB Pusat Pengelolaan Transportasi Berkelanjutan
PPTI Pusat Pengembangan Teknologi Informasi

PPV Positive predictive value

PROPER Program Penilaian Peringkat Kinerja Perusahaan dalam

Pengelolaan Lingkungan Hidup

PSDA Pengelolaan Sumberdaya Air

PT Perseroan Terbatas

PUPR Pekerjaan Umum dan Perumahan Rakyat/ Ministry of Public

Work and Public Housing

PV Photovoltaic

R&DB Research and Development for Business
R20MM Annual Count of Days When PRCP≥ 20mm
R50MM Annual Count of Days When PRCP≥ 50mm

RAPBN Rencana Anggaran Pendapatan dan Belanja Negara/ Plant for

State Revenue and *Budget*

RBC Result Based Contribution
RBP Results-Based Payments

RCP Representative Concentration Pathway

RDF Refuse-derived fuels

REDD Reduction Emission from Deforestation and Forest Degradation

RENSTRA Rencana Strategis

RHL Rehabilitasi Hutan dan Lahan

RIL Reduce Impact Logging

RIPIN Rencana Induk Pembangunan Industri Nasional

RJIT Rehabilitasi Jaringan Irigasi Tersier RKPD Rencana Kerja Pemerintah Daerah

RMS Remote Monitoring System

RPJMD Rencana Pembangunan Jangka Menengah Daerah

RPJMN Rencana Pembangunan Jangka Menengah Nasional/ National

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Medium Term Development Plan

RPPLH Rencana Perlindungan dan Pengelolaan Lingkungan Hidup
RPPLN Rencana Prioritas Pinjaman Luar Negeri/ Foreign Loan Priority

Plan

RX1DAY Monthly Maximum 1-day Precipitation

RX5DAY Monthly Maximum Consecutive 5-day Precipitation SADEWA Satellite-based Disaster Early Warning System

SAI Sistem Akuntansi Instansi/ Agency Accounting System

SAKTI Sistem Aplikasi Keuangan Tingkat Instansi

SANTANU Sistem Pemantauan Hujan

SAR The Second Assessment Report
SDG Sustainable Development Goals
SFM Sustainable Forest Management
SIAP Sistem Informasi Asuransi Pertanian

SIAP TANAM Sistem Informasi Adaptif untuk Perencanaan Tanam

SIATAB Sistem Informasi Air Tanah dan Air Baku

SID Survey Investigasi dan Desain

SIDIK Sistem Informasi Data Indek Kerentanan

SIGN Sistem Inventarisasi Gas Rumah Kaca Nasional

SIINAS Sistem Informasi Industri Nasional

SILIN Silviculture Intensive

SIPONGI Sistem Pengawasan Kebakaran Hutan dan lahan SIPSN Sistem Informasi Pengelolaan Sampah Nasional

SIRAMI KEBUNKU Sistem Informasi Rencana Tanam dan Infrastruktur Air

Perkebunan Komoditas Utama

SISMAL Sistem Informasi Malaria

SKDR Sistem Kewaspadaan Dini dan Respon SKEM Standar Kinerja Energi Minimal

SKK Satuan Kerja Khusus

SL Settlements

SLCN Sekolah Lapang Cuaca Nelayan

SLI Sekolah Lapang Iklim (Climate Field School/CFS)

SLM Sustainable Landscape Management

SME Small Medium Enterprise SNI Standar Nasional Indonesia

SOC Soil Organic Carbon SOE State-owned enterprises

SPAB Satuan Pendidikan Aman Bencana

SPALD Sistem Pengelolaan Air Limbah Domestik
SPEI Sertifikasi Penurunan Emisi Indonesia

SRF Solid recovered fuel

SRGI Sistem Referensi Geospasial Indonesia

SRMI Sustainable Renewables Risk Mitigation Initiative

SRN Sistem Registri Nasional/National Registry System

SSP Shared Socioeconomic Pathways

ST Settlement

SWDS Solid waste disposal site TA Technical Assistance

TCK Tenaga Cadangan Kesehatan

TGC Tim Gerak Cepat

THPB
Tebang Habis Permudaan Buatan
TKKS
Tandan Kosong Kelapa Sawit
TMC
Teknologi Modifikasi Cuaca
TNA
Technology Needs Assessment
TNC
Third National Communication

TOE Ton Oil Equivalent

TOW Total organically degradable material in wastewater

TPA Tempat Pemrosesan Akhir
TPES Total primary energy supply
TPT Tingkat Pengangguran Terbuka

TTD Technology Transfer and Development

UE Urinary Energy

UNDP United Nations Development Program
UNEP United Nations Environment Program

UNFCCC United Nations Framework Convention on Climate Change

UPT Unit Pelaksanaan Teknis

USDA United States Department of Agriculture

UU Undang-Undang

VAWS Vessel Automatic Weather Station

VS Volatile Solids

VUB Varietas Unggul Baru WG Working Groups

WL Wetlands

WMT Weather Modification Technology

WWT Waste Water Treatment

WWTP Waste Water Treatment Plant

EXECUTIVE SUMMARY

Background Information on the GHG Inventory

Indonesia, as a Party to the United Nations Framework Convention on Climate Change (UNFCCC), has submitted six reports of its National GHG Emission Inventory since 2019. The Sixth National GHG Emission Inventory was submitted in 2021 as part of the Third Biennial Update Report (BUR3). The Indonesia National Inventory Document provides data on GHG emissions and removals, including perfluorocarbons (PFCs), as well as CO₂, CH₄, and N₂O for the period from 2000 to FY 2022. The National GHG Inventory is submitted in compliance with Articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC) and the Modalities, Procedures and Guidelines for the Transparency Framework for Action and Support Referred to in Article 13 of the Paris Agreement: Decision 18/CMA.1 Annex and Decision 5/CMA.3.

The GHG emissions inventory has been prepared in accordance with the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines, the 2013 Supplement to the 2006 IPCC Guidelines: Wetlands, the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, which provides the requisite approaches, methods, default emission factors, and information essential for constructing a transparent, accurate, complete, comparable, and consistent inventor

Summary of National Emission and Removal Related Trends by Sector

In 2022, Indonesia's total emissions across the five sectors- energy, Industrial Processes and Product Use (IPPU), agriculture, Land Use, Land-Use Change and Forestry (LULUCF), and waste- reached 1,382,854.50 kt CO₂e. The contribution of these sectors to the total 2022 emissions were 53.42%, 4.15%, 9.80%, 22.58%, and 10.04% respectively. Meanwhile, without LULUCF, the total emissions reached 1,070,542.93 kt CO₂e, with contributions from the energy sector at 68.01%, IPPU at 5.36%, agriculture at 12.66%, and waste at 12.97% (Table 1).

Table 1 Summary of net GHG emissions for the period 2000 - 2022

Source of	2000	2005	2010	2015	2019	2022
Emissions and Removals	kt CO ₂ e					
Energy	305,290.56	377,182.69	454,958.50	549,955.87	655,567.89	738,753.39
IPPU	39,804.94	39,017.26	31,550.31	47,847.23	58,681.57	57,361.63
Agriculture	107,188.93	110,131.56	108,081.76	128,045.26	126,675.16	135,565.84
Waste	59,227.57	71,102.81	88,657.23	99,694.68	128,107.25	138,862.07
Total without						
LULUCF	511,512.00	597,434.32	683,247.80	825,543.04	969,031.86	1,070,542.93
LULUCF	342,991.31	709,681.07	529,522.17	1,730,275.90	818,653.99	312,311.57
Total with						
LULUCF	854,503.31	1,307,115.39	1,212,769.97	2,555,818.95	1,787,685.85	1,382,854.50

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GHG emissions in 2022 rose by 61.83% compared to 2000, while experiencing a decline of 22.65% since 2019. Additionally, with emissions without LULUCF sector, in 2022 rose by 109.29% relative to 2000 levels and by 10.48% compared to 2019 levels (Figure 1 and 2).

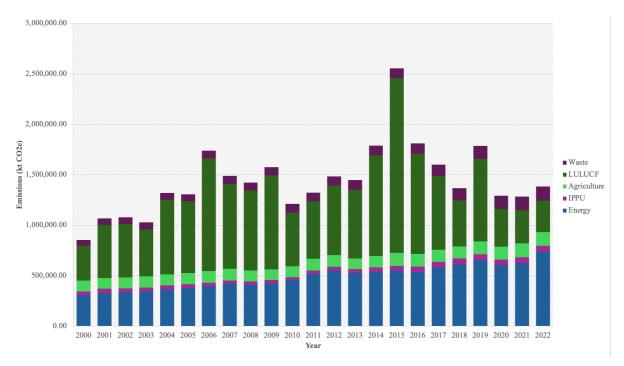


Figure 1 Trends in GHG emissions from 2000 - 2022 by sector (in kt CO₂e)

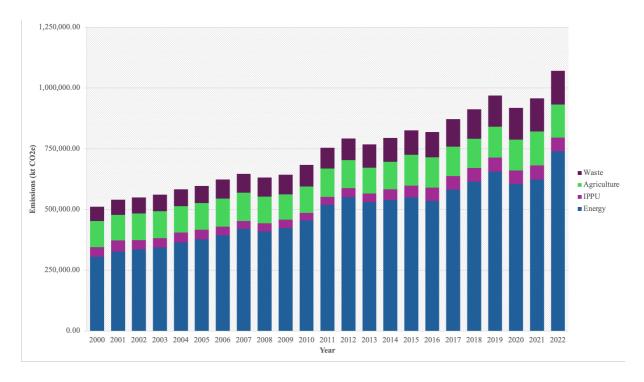


Figure 2 Trends in GHG emissions from 2000 - 2022 by sector without LULUCF (in kt CO₂e)



Overview of Trends in National Emission and Removal by Gas

In 2022, CO₂ accounted for 77.75% of national GHG emissions, indicating a 68.86% increase since 2000 and a 26.02% decrease since 2019. CH₄ emissions were recorded at 18.12%, indicating a 42.11% increase since 2000 and a 8.65% decrease since 2019. N₂O emissions accounted for 4.13%, indicating a 38.58% increase since 2020 and a 4.99% decrease since 2019. PFC emissions accounted for less than 0.004%, indicating an 80.23% reduction since 2000 and a 18.97% increase since 2019 (Table 2).

Table 2 GHG emissions and removals by gas with LULUCF

Source of	2000	2005	2010	2015	2019	2022
Emissions and Removals	kt CO2e					
CO ₂ emissions with LULUF	636,746.28	1,056,773.60	963,673.91	2,218,311.73	1,453,324.70	1,075,194.99
CH ₄ emissions with LULUF	176,275.40	205,363.87	200,907.83	278,805.84	274,224.17	250,509.94
N ₂ O emissions with LULUF	41,200.40	44,696.69	48,029.06	58,650.22	60,090.23	57,093.96
PFCs	281.23	281.23	159.17	51.15	46.74	55.61
Total	854,503.31	1,307,115.39	1,212,769.97	2,555,818.95	1,787,685.85	1,382,854.50

National GHG emissions across the five sectors exhibit fluctuations from 2000 to 2022 (Figure 3). CO_2 emissions increased from 2000 to 2022, showing fluctuations during this timeframe. The increase in petrol emissions is attributed to intensified fossil fuel combustion in the energy sector and an escalating loss of biomass carbon from the LULUCF sector. From 2000 to 2022, emissions of CH_4 and N_2O have increased, primarily attributed to increased CH_4 emissions from the waste sector and both CH_4 and N_2O emissions from the agriculture sector.

Table 3 presents a summary of the trend of GHG emissions for the year 2022, without LULUCF. The table indicates that CO₂ emissions in 2022 accounted for 72.61%, reflecting a 154.70% increase since 2000 and a 12.33% increase since 2019. Additionally, 22.55% was derived from CH₄, indicating a 40.80% increase since 2000 and a 6.57% increase since 2019. The N₂O emissions accounted for 4.83%, indicating a 49.67% increase since 2000 and a 2.60% increase since 2019. The residual PFCs constituted less than 0.01%, indicating an 80.23% reduction since 2000 and a 18.97% increase since 2019.

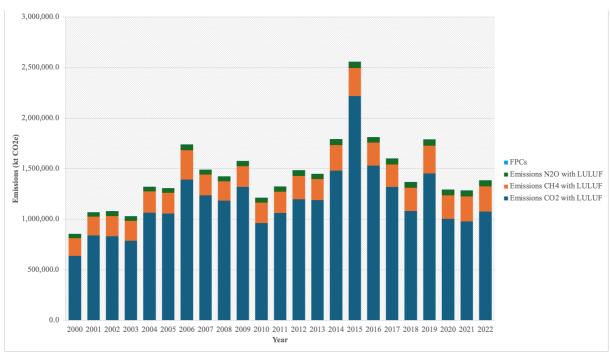


Figure 3 Trends in GHG emissions by gas type with LULUCF for the period 2000 – 2022 (in kt CO₂e)

Table 3 GHG emissions and removals by type of GHG without LULUCF

Sources of Emissions and	2000	2005	2010	2015	2019	2022
Removals	kt CO ₂ e					
CO ₂ emissions						_
without						
LULUF	305,176.63	381,133.97	451,633.45	562,928.12	691,999.87	777,299.21
CH ₄ emissions						_
without						
LULUF	171,490.18	179,604.76	189,267.01	215,266.88	226,561.59	241,455.69
N ₂ O emissions						_
without						
LULUF	34,563.96	36,414.36	42,188.18	47,296.89	50,423.65	51,732.42
PFCs	281.23	281.23	159.17	51.15	46.74	55.61
Total	511,512.00	597,434.32	683,247.80	825,543.04	969,031.86	1,070,542.93

Figure 4 illustrates that CO₂ emissions represent the predominant component of national GHG emissions, exhibiting a steady rise from 2000 to 2022. The main sources of petrol emissions are the energy and IPPU sectors, which have demonstrated a consistent year-on-year increase attributed to ongoing development. CH₄ and N₂O emissions exhibit a trend similar to CO₂ emissions, significantly influenced by the agricultural sector. The trend of PFC emissions is indiscernible in Figure 2-6 due to the minimal values.

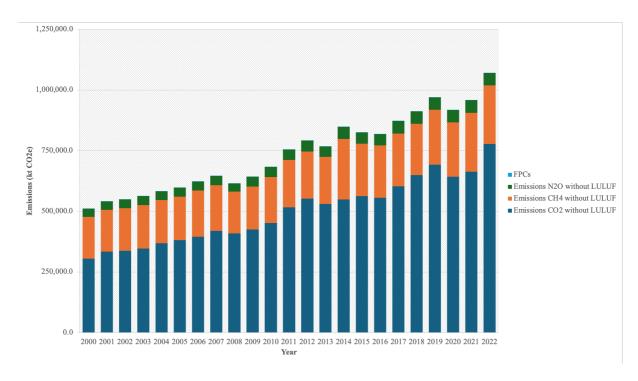


Figure 4 Trends in GHG emissions by gas type without LULUCF for the period 2000 – 2022 (in kt CO₂e)

Brief Description of Key Categories and Improvements

The assessment of key categories was performed using Approach 1, in accordance with the 2006 IPCC Guidelines, which encompass level and trend assessments. Key categories are delineated with and without emissions and removals from LULUCF, utilizing a cumulative emission threshold of 95% of the total level.

Consequently, when considering the LULUCF sector, 19 and 17 sources and sinks were identified as key categories based on level assessment for years 2000 and 2022, respectively. Conversely, in the case of without LULUCF sector, 15 sources and sinks were identified as the key categories for year 2000, while 14 were identified for the year 2022. Additional information is provided in Annex 1.

Brief Description of Recalculation and Improvements

The prior GHG Inventory utilized global warming potentials (GWP) from the Second Assessment Report (AR2), while the National GHG Inventory in BTR1 employed the most recent Fifth Assessment Report (AR5) over a 100-year timeframe. Consequently, a recalculation indicates an increase in total GHG emissions from the BTR1 Report utilizing the AR5 GRP in comparison to the BUR3 Report employing AR2, both with and without LULUCF. Chapter 9 presents the improvements and recalculation justification following the prior GHG Inventory submission.



NATIONAL INVENTORY REPORT ON ANTHROPOGENIC EMISSIONS BY SOURCES AND REMOVALS BY SINKS OF GREENHOUSE GASES

I. NATIONAL CIRCUMSTANCES, INSTITUTIONAL ARRANGEMENTS AND CROSS-CUTTING INFORMATION

Introduction

The national greenhouse gas inventory (NGHGI) is one of the important actions in addressing climate change, involving the reporting of greenhouse gas (GHG) emissions and removals within the national territory. The NGHGI reports the effects of a nation's development activities and its domestic carbon footprint. It serves as a foundation for formulating emission reduction strategies and policies, as well as for monitoring the effectiveness of those policies.

Indonesia, as a Party to the United Nations Framework Convention on Climate Change (UNFCCC), submitted its First National Communication in 1999. This document included the country's inaugural GHGI, encompassing the years 1990 to 1994 and detailing emissions of carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O). In 2010, the Second National Communication, which encompassed the Second NGHGI, was submitted to the UNFCCC, addressing the period from 2000 to 2005. The Third NGHGI was carried out in 2015 and documented in the First Biennial Update Report, encompassing the period from 2000 to 2012. The Fourth and Fifth GHG Inventories were conducted in 2017 and 2018, respectively, and were included in the Third National Communication and the Second Biennial Update Report. These reports cover the periods 2013-2014 and 2016, incorporating data from 2000-2012. The Third, Fourth, and Fifth GHG Inventories additionally reported on perfluorocarbons (PFCs) alongside CO₂, CH₄, and N₂O.

In 2021, the Sixth National GHG Emission Inventory was submitted in the Third Biennial Update Report (BUR3), which provided an update of GHG emission data from 2000 to 2019.

1.1. National Circumstances and Institutional Arrangements

The GHG emissions inventory is compiled as part of the Biennial Transparency Report (BTR) and is conducted under the coordination of the *Kementerian Lingkungan Hidup dan Kehutanan* (Ministry of Environment and Forestry, MoEF), serving as the national focal point for the UNFCCC. MoEF has established procedures, roles, and responsibilities for the National GHG Inventory (NGHGI) through Ministerial Regulation No. 73 of 2017 to ensure continuous improvement in the NGHGI system and to provide transparent, accurate, complete, comparable, and consistent information in a timely manner. Ministerial Regulation No. 73 of 2017 has been revoked and superseded by Ministerial Regulation No. 12 of 2024, which addresses the Implementation of Nationally Determined Contributions in Climate Change

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Mitigation. The institutional arrangements for the GHG emissions inventory, detailing the responsibilities and roles of each ministry and agency, are outlined in Table 1-1 in accordance with Ministerial Regulation No. 12 of 2024.

Table 1- 1 Institutional arrangements for the GHG emissions inventory

1. GHG Emission Sources - I	Energy Sector
Sector Coordinator: Ministr	y responsible for Energy and Mineral Resources (ESDM)
Emission Source	Data Provider
Power Generation	Work Unit responsible for Data and Information Technology, Ministry
Oil and Gas (Fuel +	responsible for Energy and Mineral Resources
Fugitive)	•
Coal Mining (Fuel +	
Fugitive)	
,	Work Unit responsible for Sustainable Transportation Management, Ministry
Too o o o o o o o o o o o o o o o o o o	responsible for
Transportation	Work Unit responsible for Data and Information Technology, Ministry
	responsible for Energy and Mineral Resources
	Work Unit responsible for Green Industry, Data and Information Center,
F : C : 1	Ministry responsible for Industry
Energy in Commercial	Work Unit responsible for Industrial Statistics, Statistics Indonesia (BPS)
Areas	Work Unit responsible for Data and Information Technology, Ministry
	responsible for Energy and Mineral Resources
Energy in Commercial	Work Unit responsible for Data and Information Technology, Ministry
Areas	responsible for Energy and Mineral Resources
Energy in Residential Areas	Work Unit responsible for Industrial Statistics, Statistics Indonesia (BPS)
2. GHG Emission Sources -	
	y responsible for Industry (Kemenperin), Center for Green Industry
	Work Unit responsible for Environmental Assessment and Green Industry,
	Data and Information Center, Ministry responsible for Industry
Industrial Processes	Work Unit responsible for Industrial Statistics, Statistics Indonesia (BPS)
	Work Unit responsible for Data and Information Technology, Ministry
	responsible for Energy and Mineral Resources
Product Use	Work Unit responsible for Data and Information Technology, Ministry
1104401 050	responsible for Energy and Mineral Resources
3. GHG Emission Sources –	Agriculture, Forestry and Other Land Use (AFOLU) Sector
A. Agriculture	
	ry responsible for Agriculture
Sector Coordinator, William	Work Unit responsible for Livestock and Animal Health
	Work Unit responsible for Standardization of Livestock and Animal Health
Livestock	Instruments
Livestock	Work Unit responsible for Livestock, Fisheries and Forestry Statistics,
	Statistics Indonesia (BPS)
	Work Unit responsible for Food Crops
	Work Unit responsible for Agricultural Infrastructure and Facilities
	Work Unit responsible for Plantations
	Work Unit responsible for Testing of Agricultural Land Resource Instruments,
Aggregate Sources and Non-	Ministry of Agriculture
CO ₂ Emissions	Work Unit responsible for Testing of Agricultural Environment Instruments,
	_
	Ministry of Agriculture World Unit representation for Statistics on Food Crops, Harticulture and
	Work Unit responsible for Statistics on Food Crops, Horticulture and Plantations
D. Foundame and Other I	1
B. Forestry and Other Land	
Sector Coordinator: Ministr	
Biomass	Work Unit responsible for sustainable forest management
Biomass Burning	Work Unit responsible for forest resource inventory and monitoring
Peat Decomposition	Work Unit responsible for forest and land fire control. Peat Fires Work Unit
	responsible for peatland damage control

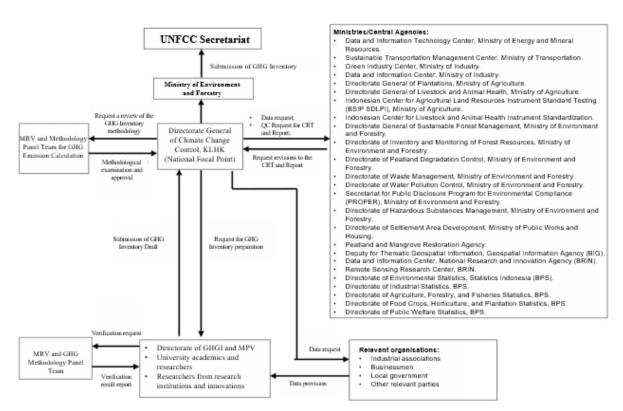
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Work Unit responsible for peatland damage control Work Unit responsible for Peat and Mangrove Restoration Work Unit responsible for Testing of Agricultural Land Resource Instruments, Ministry responsible for Agriculture Peat Fires Work Unit responsible for Thematic Geospatial Information, Geospatial Information Agency (BIG) Work Unit responsible for Data and Information, National Research and Innovation Agency (BRIN) Work Unit responsible for Geoinformatics Research (BRIN)
Work Unit responsible for Testing of Agricultural Land Resource Instruments, Ministry responsible for Agriculture Peat Fires Work Unit responsible for Thematic Geospatial Information, Geospatial Information Agency (BIG) Work Unit responsible for Data and Information, National Research and Innovation Agency (BRIN) Work Unit responsible for Geoinformatics Research (BRIN)
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4. GHG Emission Sources - Waste Management Sector
Sector Coordinator: Ministry responsible for Environment
Work Unit responsible for Waste Management, Ministry responsible for
Domestic Solid Waste Environment
Municipal Solid Waste Work Unit responsible for Social Statistics, Statistics Indonesia (BPS)
(MSW) Work Unit responsible for Settlement Area Development
Work Unit responsible for Social Statistics, Statistics Indonesia (BPS)
Work Unit responsible for Water Pollution Control, Ministry responsible for
Domestic Wastewater Environment
Work Unit responsible for Development
Work Unit responsible for Pollution and Environmental Damage Control
Industrial Solid Waste (PROPER Secretariat) Ministry responsible for Environment and Forestry
(including Work Unit responsible for Hazardous and Toxic Materials Management
pnarmaceutical/medical Ministry responsible for Environment and Forestry
waste) Work Unit responsible for Green Industry, Ministry responsible for Industry
Work Unit responsible for Green Industry, Ministry responsible for Industry
Work Unit responsible for Pollution and Environmental Damage Control
Industrial Wastewater (PROPER Secretariat), Ministry responsible for Environment and Forestry
Work Unit responsible for Social Statistics, Statistics Indonesia (BPS)

According to Article 6 of Presidential Regulation No. 92 of 2020, which pertains to the Ministry of Environment and Forestry, the Directorate General of Climate Change (DG PPI) operates under the Minister of Environment and Forestry and is accountable for NGHGI (GHGI), Mitigation, and Adaptation. According to this regulation, the DG PPI KLHK is designated as the national focal point(https://unfccc.int/process/parties-non-party-stakeholders/parties/national-focal-point), tasked with the following responsibilities:

- Preparing the Indonesian GHGI;
- Conducting the editing process and submitting the national inventory report to the UNFCCC;
- Preparing a plan and coordinating Quality Control (QC) activities for the NGHGI; and
- Preparing a plan for improving the NGHGI.

Figure 1 - 1 presents the institutional arrangements involved in the preparation of the Indonesian GHGI. As shown in Figure 1-1, the Directorate of NGHGI and Monitoring, Reporting, and Verification (MRV) (IGRK-MPV), under the DG PPI within the MoEF, is responsible for conducting GHG inventories and overseeing MRV activities. The Directorate of GHGI-MRV collaborates with Expert Teams composed of academics and research institutions in the execution of its functions



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Figure 1 - 1 Institutional arrangements for the NGHGI

Data providers prepare information and respond to inquiries from the Verification Team, which includes the MRV Team and the GHG Methodology Panel, concerning the data and information submitted.

The NGHGI System (SIGN) utilizes Information Technology to assess the status, level, and trends of emission reductions across various time units and regions, including national, regional, provincial, and district/city levels (https://signsmart.menlhk.go.id/v2.1/app/). The SIGN coordinator conducts data updating and QC utilizing information technology. The coordinator conducts Quality Assurance through data validation and estimation of GHG emission levels performed by the Inventory Implementers. QC and assurance are conducted at least annually.

Businesses are required to report their implementation of the GHG emission inventory annually to the regent/mayor, governor, or relevant Minister by March. Regents/mayors must report to the governor by March, while governors must submit their reports to the Minister via the Director General of Climate Change (DG PPI) by June. Relevant Ministers are to report to the Minister of Environment and Forestry through the DG PPI by June.

1.1.1. Description of Institutional Arrangements for GHG Inventory and MRV

Article 6 of Presidential Regulation No. 92 of 2020 concerning the Ministry of Environment and Forestry states that the Directorate General of Climate Change (DG PPI) functions under the authority of the Minister of Environment and Forestry. Article 30 of the Regulation designates the Director General of PPI as responsible for the formulation and implementation



of policies concerning GHGI, Mitigation, and Adaptation in relation to climate change management. Article 396 of Minister of Environment and Forestry Regulation No. 15 of 2021 specifies the organizational structure of the Directorate General of Climate Change.:

- 1. Secretariat of the Directorate General:
- 2. Directorate of Climate Change Mitigation;
- 3. Directorate of Climate Change Adaptation;
- 4. Directorate of Greenhouse Gas Inventory and Monitoring, Reporting and Verification;
- 5. Directorate of Sectoral and Regional Resource Mobilization; and
- 6. Directorate of Forest and Land Fire Control.

The Minister of Environment and Forestry Regulation No. 15 of 2021 (Article 422) designates the Directorate of Greenhouse Gas Inventory and Monitoring, Reporting and Verification (Directorate of GHGI and MRV) with the responsibility of formulating and implementing policies related to GHGI and MRV, in addition to maintaining a GHG emissions register for mitigation and adaptation actions, as well as climate change resources.

The role of local governments in the NGHGI cycle is being progressively enhanced. Future projections of national emission levels and trends, derived from top-down calculations, can be compared with the aggregated results of local government calculations, which are based on bottom-up approaches. The Ministry of Environment and Forestry conducts regular meetings concerning the implementation and reporting of GHG inventories at the sub-national level. Additionally, it consistently requests Sub-National GHGI reports via both hardcopy submissions and the SIGN SMART portal.

Directorate of GHG Inventory and MRV

Based on Article 423 of the Minister of Environment and Forestry Regulation No. 15 of 2021, the Directorate of GHGI and MRV performs the following function:

- Preparation of policy formulation and data management;
- Implementation of policies;
- Preparation of coordination and synchronization of policy implementation;
- Preparation of the development of norms, standards, procedures, and criteria;
- Provision of technical guidance and supervision;
- Implementation of evaluation and reporting; and
- Data management.

Relevant Ministries and Agencies

Relevant ministries and agencies have the following roles and responsibilities:

- Preparation and provision of validated activity data and emission factors;
- Calculation of sectoral GHG emissions;



- Support for the preparation of national and international report documents (NC and BTR);
- Support in the implementation of the technical expert review/Multilateral Assessment;
- Confirmation of data that can be provided for the GHGI.

Relevant Organizations

Relevant organizations, such as: Industry Associations, Businesses and Industry, Local Governments, Higher Education Research Centers, and other relevant stakeholders, have the following roles and responsibilities related to GHGI:

- Confirmation of data that can be provided for the preparation of the GHGI;
- Preparation and provision of activity data, emission factors, including their uncertainty values; and
- Responses to questions about statistics issued by relevant organizations, or about specific data they have prepared.

MRV Team and GHG Emissions Calculation Methodology Panel

The MRV Team and GHG Emissions Calculation Methodology Panel were established and operated by the Ministry of Environment and Forestry based on the Decree of the Minister of Environment and Forestry No. 1444/MENLHK/SETJEN/KUM.1/12/2023.

The Monitoring, Reporting and Verification team functions to:(a) Request information and/or clarification from the responsible parties for climate change mitigation actions, (b) Examine the quality and accuracy of the data on the achievements of climate change mitigation actions, (c) Develop procedures for the assessment of measurement, reporting and verification of climate change mitigation actions, (d) Perform a final review of the validation and verification results by the Validation and Verification Body (LV/V).

The GHG Emissions Calculation Methodology Panel is tasked with (a) assisting the MRV Team in identifying, compiling, and reviewing GHG emissions calculation methodologies developed by various entities focused on emissions reduction and carbon sequestration enhancement, (b) reviewing the establishment of IPCC methodologies and other compatible methodologies for implementation, (c) formulating and establishing the outcomes of the methodology review for use in climate change mitigation actions, and (d) conducting assessments and suitability studies of methodologies from certification schemes beyond the Indonesian Emission Reduction Certification (SPEI) scheme, including bilateral and voluntary/private standards.

The MRV Team and Methodology Panel is chaired by the Director of GHGI and MRV, with support from a Deputy Chairperson. The MRV Team and Methodology Panel's leadership comprises members categorized into five sectors: (a) forestry and other land use, (b)

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agriculture, (c) energy, (d) IPPU, and (e) waste. The team comprises specialists in each of these sectors.

The issuance of Land Regulation No. 12 of 2024 will result in an adjustment to the structure of the MRV Team. According to Article 80, the MRV Team must include at least (a) the person in charge, (b) the secretary, (c) the technical team, and (d) the methodology panel.

The technical team comprises (a) the echelon I work unit tasked with climate change control; (b) various ministries and agencies; (c) local government representatives; and (d) practitioners specializing in climate change. The methodology panel consists of (a) experts, (b) academics, and (c) researchers.

The technical team is responsible for the following duties and functions:

- a. Request information and/or clarification from the individual overseeing climate change mitigation and adaptation actions being undertaken;
- b. Provide MRV procedures for climate change mitigation and adaptation actions;
- c. Conduct Validation and Verification of Climate Change Mitigation Actions and Climate Change Adaptation Actions; and
- d. Submit the results of Validation and Verification to the Director General.

The methodology panel is responsible for the following duties and functions:

- a. Identify, compile, and review methodologies for calculating GHG emissions from various individuals, agencies or institutions that have developed GHG emissions reduction and/or carbon sequestration enhancement methodologies;
- b. Analyze the implementation of IPCC methodologies and other methodologies aligned with IPCC that can be applied in Indonesia;
- c. Formulate and establish the results of the methodology review applicable to the development and implementation of Climate Change Mitigation Actions and Climate Change Adaptation Actions;
- d. Conduct assessment and suitability analyses of methodologies from certification schemes distinct from the SPE-GRK scheme; and
- e. Submit the review results to the Director General for the establishment of the methodology review outcomes.

1.1.2. Brief Description of the GHGI Preparation Process

Annual GHGI Preparation Cycle

The annual cycle for GHGI preparation aligns with the fiscal year calendar, spanning from January 1 to December 31. The stages, along with descriptions for each, are detailed in Table 1-2.



Table 1-2 Stages in the annual GHGI cycle

Stages	Annual Description
Evaluation of Improvements to the NGHGI (previous year)	The Director General of Climate Change (DG PPI) of the MoEF, in collaboration with the Expert Team, identifies areas needing enhancement based on findings from the prior GHGI review.
Evaluation of GHGI Emissions Estimation Methods	The DG PPI of MoEF, in collaboration with the Expert Team, convenes a meeting to address the estimation methodology for the annual GHGI, including the selection of Tier levels, and to identify issues necessitating technical review by experts possessing relevant scientific expertise for the sectors included in the GHGI.
Collection of GHGI Data	In this stage, the DG PPI of MoEF collaborates with Ministries and Agencies (K/L), Industry Associations, the Business Sector, Local Governments, and the Expert Team to gather essential data for the NGHGI, along with supplementary information mandated by the Minister of Environment and Forestry Regulation No. 12 of 2024 regarding the Implementation of Nationally Determined Contributions in Climate Change Mitigation.
Preparation of draft Common Reporting Tables (CRT), Key Category Analysis (KCA), and Uncertainty Assessment	Data input and estimation of emissions and removals are done in the GHGI Worksheet (excel-based) with interconnected links based on the emission and removal calculation formulas. Following this, an assessment of uncertainty and an analysis of key categories are performed.
Preparation of draft National GHGI (NGHGI)Report	The NGHGI Report is prepared following the Minister of Environment and Forestry Regulation No. 12 of 2024. The GHGI Sub-Directorate, together with the Expert Team, prepares the GHGI Report by adding, updating, or revising data from the previous year's GHGI Report.
Implementation of Quality Assurance (QA) and coordination with relevant Ministries and Agencies (K/L)	As a QA activity, the MRV Sub-Directorate, Directorate of GHGI and MRV (together with the MRV Team and GHG Emissions Calculation Methodology Panel) check the Worksheet and draft CRT prepared by the GHGI Sub-Directorate. The MRV Team verifies the input data and calculation formulas in the Worksheet.
Correction of draft CRF and NGHGI Report	If revision requests arise from the review results concerning the draft GHGI, the Worksheet and/or draft GHGI Report will be returned to the relevant Ministries and/or Agencies for final confirmation.
Official Publication of the NGHGI Report	The DG PPI of MoEF archives and stores inventory in the database, subsequently publishing it on the MoEF website. (https://www.ditjenppi.org/indonesia/dokumen).

Stages in the Annual NGHGI Cycle

Table 1- 3 outlines the stages in the annual NGHGI cycle, beginning with the assessment of the prior year's NGHGI preparation and concluding with the official release of the NGHGI Report. To enhance the plan for improvement, a GHGI QA Working Group should be established, comprising experts and/or academics who are not directly engaged in the preparation of the NGHGI. This team is responsible for applying expert judgment to establish uncertainty values for emission factors and activity data, and has the capacity to invite qualified resource individuals.

QA/QC Process Information

The quality of the NGHGI is ensured through QC activities, including the verification of calculation accuracy and the systematic archiving of documents. Internal verification conducted by the GHGI Sub-Directorate, pertinent ministries and agencies, and the Methodology Panel, which is not directly engaged in the preparation of the GHGI, is regarded as a component of the QA process. At present, there is an absence of a QA process that includes external review by experts beyond the Directorate of GHGI and MRV.



Table 1- 3 Annual NGHGI preparation cycle

Nia	D	Relevant Entities						Mon	th					
No.	Processes	Relevant Entitles	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Evaluation of the previous year's NGHGI implementation	DG PPI MoEF, Expert Team		X	X									
2	Evaluation of GHG emissions estimation methods	DG PPI MoEF, Expert Team				X								
3	Collection of NGHGI data	DG PPI MoEF, K/L, Industry					х	X	X					
		Associations, Expert Team												
1	Calculation of emissions and removals, including	g Dir IGRK & MPV, Expert									v			
	KCA and Uncertainty Analysis	Team									X			
5	Duranting of the durat NCHCLD and	Dir IGRK & MPV, Expert												
	Preparation of the draft NGHGI Report	Team										X		
6	Implementation of QA/QC and coordination wit	h DG PPI MoEF, K/L, Industry									••	••		
6	relevant Ministries and Agencies (K/L)	Associations, Supporting Team									X	X		
	Correction of draft emissions and removals, as	Dir IGRK & MPV, Expert												
/	well as the National NGHGI Report	Team											X	
0	Submission and official publication of the													
8	NGHGI Report	DG PPI MoEF												X



1.2. Description of Methodologies

The GHG emissions inventory has been prepared following the 2006 IPCC Guidelines (IPCC 2006), which outline the necessary approaches, methods, default emission factors, and information required to prepare a transparent, accurate, complete, comparable, and consistent inventory. This methodology is internationally recognized and required to be used for preparing the NGHGI (Decision 18/CMA.1). Indonesia has utilized the 2006 IPCC Guidelines since the development of its Second National Communication.

The estimates of GHG emissions in this BTR1 utilize the IPCC inventory software version 2.93. This methodology has been tailored to align with the country's specific conditions and characteristics, addressing the following categories of emission and removal sources:

- Energy encompasses all activities associated with fuel combustions in energy industries, manufacturing industries and construction, transportation, and other, which covers commercial/institutional, residential, and agriculture/forestry/fishing activities, as well as fugitive emissions from fuels. Fuel combustions in not-specified activities are not included.
- Industrial Processes and Product Use (IPPU), pertains to emissions originating from
 industrial process activities involving minerals, chemicals, metals, electronics, and nonenergy products from fuels and solvent use, as well as emissions from the product use
 such as non-energy products from fuels. Emissions from non-energy products from
 solvents use and products use as substitutes for Ozone Depleting Substances are not
 included.
- Agriculture, encompasses emissions from livestock, rice cultivation, agricultural soils, prescribed burning of savannahs, field burning of agricultural residues, liming and urea application.
- Land Use, Land-Use Change and Forestry (LULUCF), pertains to the assessment of
 emissions and removals from land-use changes resulting from conversions and
 disturbances, including timber harvesting, fires, and pests/diseases, as well as peat fires,
 peat decomposition, and the quantifying removals from a land remaining in the same
 land-use category.
- Waste, related to the management of solid and liquid waste, both domestic and industrial, and its integration with the environment.

Table 1- 4 below presents a summary of the GHGI methodologies (Tiers) employed in the development of the NGHGI in this report.



Table 1- 4 Levels of methodology for the national GHG emissions inventory from 2000 to 2022

CREENHOUSE CAS SOURCE AND SINV	(CO ₂	c	H ₄	N	₂ O	н	PCs .	P	FCs		ied mix of nd PFCs	s	F ₆	N	IF ₃
GREENHOUSE GAS SOURCE AND SINK	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor										
1. Energy																
1.A. Fuel combustion																
1.A.1. Energy industries	T1, T2	D, CS	T1	D	T1	D										
1.A.2. Manufacturing industries and construction	T1, T2	D, CS	T1	D	T1	D										
1.A.3. Transport	T1, T2	D, CS	T1	D	T1	D										
1.A.4. Other sectors (residential, commercial, agro/fishing/etc.)	T1, T2	D, CS	T1	D	T1	D										
1.A.5. Non-specified (military and multilateral institution)*	NE	NE	NE	NE	NE	NE										
1.B. Fugitive emissions from fuels																
1.B.1. Solid fuels	T1	D	T1	D	T1	D										
1.B.2. Oil & natural gas, and other emissions from energy production	T1	D	T1	D	T1	D										
1.C. CO ₂ transport and storage	NO	NO														
2. Industrial processes	1.0															
2. A. Mineral industry	T1, T2	D, CS														
2.B. Chemical industry	T1, T2	D, CS	T1	D	T1	D										
2.C. Metal industry**	T1	D, CS	T1	D	NE	NE			T1	D						
2.D. Non-energy products from fuels and solvent use	TI	D	- 11	Б	NE	NE			11	D						
2.E. Electronic Industry		Б														
2.F. Product uses as ODS substitutes																
2.G. Other product manufacture and use																
2.H. Other	T1	D														
3. Agriculture	T1	D	T1, T2	D, CS	T1	D										
3.A. Enteric fermentation			T2	CS												
3.B. Manure management			T2	CS	T1	D										
3.C. Rice cultivation			T2	CS												
3.D. Agricultural soils					T1	D										
3.E. Prescribed burning of savannahs			T1	D	T1	D										
3.F. Field burning of agricultural residues			T1	D	T1	D										
3.G. Liming	Tl	D														
3.H. Urea application	T1	D														
3.I. Other carbon-containing fertilizers	NO	NO														
3.J. Other	NO	NO														
4. Land use, land-use change and forestry	T1, T2	D, CS	T1	D	T1	D										
4.A. Forest land	T2	CS														
4.B. Cropland	T2	CS														
4.C. Grassland	T2	CS														
4.D. Wetlands	T1	D	T1	D	T1	D										
4.E. Settlements	T2	CS														
4.F. Other land	T2	CS														
4.G. Harvested wood products	IE	IE														
4.H. Other:																
Peat Fire	T2	CS	T1	D	T1	D										
Peat Oxidation	T2	CS														
5. Waste	T1, T2	D	T1, T2	D	T1, T2	D										
5.A. Solid waste disposal			T1, T2	D												
5.B. Biological treatment of solid waste			T1, T2	D	T1, T2	D										
5.C. Incineration and open burning of waste	T1, T2	D	T1, T2	D	T1, T2	D										
5.D. Waste water treatment and discharge			T1, T2	D	T1, T2	D										
5.E. Other	T1, T2	D	T1, T2	D	T1, T2	D										
6. Other (as specified in summary 1)																

Notes:

T1 (IPCC Tier 1); T2 (IPCC Tier 2); T3 (IPCC Tier 3); D (IPCC default); CS (country-specific); *data of this category is difficult to be accessed



1.3. Uncertainty Analysis

Uncertainty analysis is a critical component of the GHGI and is necessary for quantitatively evaluating the inventory's accuracy. Uncertainty is influenced by the activity data linked to data collection and the utilization of emission factors in the emissions reporting process. Aggregation of uncertainty is permissible only upon the completion of the pertinent inventory or emissions reporting cycle. Uncertainty analysis facilitates the identification and prioritization of GHG emission and removal sources that exhibit high uncertainty, thereby enhancing quality through improved data collection. Furthermore, uncertainty analysis underpins the development of advanced Tier methodologies, particularly for major emission sources characterized by substantial uncertainty. Uncertainty is consolidated annually, at the conclusion of the reporting preparation cycle for the current fiscal year.

The accuracy of Indonesia's GHGI has been evaluated since the submission of the Second National Communication (SNC), revealing limitations in the uncertainty values for activity data and country-specific emission factors. In the calculation and aggregation of uncertainty, the uncertainties associated with activity data and emission factors—typically derived from expert estimates, statistics from data providers, or 2006 IPCC default values—are transformed into uncertainties for emissions and subsequently aggregated. Uncertainty is consolidated annually, at the conclusion of the reporting preparation cycle for the current fiscal year.

In the national context, the uncertainty of activity data derived from national statistics or sectoral information centers remains incomplete, necessitating the estimation of certain uncertainties through expert judgment. Emission factor uncertainties are similarly addressed in the absence of available data. The variability in activity data and emission factors derived from expert judgment is significant, often resulting in substantial errors and varying levels of uncertainty across emission sources. Additional factors that contribute to the variations in uncertainty include:

- Use of assumptions, default data, and splicing techniques due to the limited availability of high-quality, complete, and country-specific data.
- Model estimates that simplify the real world.
- Random errors from measurements, studies, and statistics used.

The GHGI uncertainty for BTR1 employs the Approach 1: error propagation as outlined in the 2006 IPCC Guidelines, Volume 1, Chapter 3, Section 3.7.1. This method relies on the uncertainties associated with activity data, emission factors, emission estimates, and various estimation parameters. The parameters allow for the determination of uncertainty levels for each sub-category, the overall inventory, and the trend between the most recent inventory year (2022) and the base year (2000).



1.4. Key Categories Analysis

Key categories represent the primary classifications that significantly influence inventory levels. The analysis and identification of key categories utilize Approach 1 from the 2006 IPCC Guidelines, as outlined in Volume 1, Chapter 4, Section 4.3.1. The analysis encompasses an assessment of both level and trend, utilizing 1990 as the base year and 2022 as the most recent inventory year. Trend analysis involves identifying categories that may be insignificant in level analysis due to their minimal contribution, yet exhibit trends that significantly diverge from the overall inventory trend, necessitating focused attention. The trend assessment identifies categories with trends that diverge from the overall inventory trend, irrespective of whether these trends are increasing or decreasing, or whether they represent sources of emissions or sinks.

The level assessment utilizes 95% of the total absolute emission value from the most recent inventory year, comparing it across all inventory categories for 2022. In contrast, the trend analysis for 2022 is assessed relative to the base year of 2000 across all categories. Key categories are delineated with and without emissions and removals from LULUCF. In Approach 1, key categories are identified according to previously established cumulative emission thresholds. The cumulative sum of these categories, arranged by magnitude, represents 95% of the total level.

1.5. Quality Assurance and Quality Control

The preparation of the GHGI adheres to the principles of QA/QC. Appendix I of the Minister of Environment and Forestry Regulation No. 12 of 2024 provides general guidelines for QA and QC in sections F and G. The QA/QC guidelines within the NGHGI system assist organizers in ensuring the assurance and control of NGHGI data.

QC constitutes a systematic approach to regularly assess the technical processes associated with measurement and inventory quality during the preparation phase conducted by the GHGI organizers. The QC system aims to (a) conduct regular checks to maintain data integrity, accuracy, and completeness; (b) detect and rectify errors; and (c) document and archive inventory materials while recording all QC activities. QA encompasses the activities designed to confirm that the implementation of the GHGI adheres to relevant procedures and standards, employing optimal methods based on the most current knowledge and data availability, and is underpinned by a robust QC program. QA activities are conducted by individuals not engaged in the execution of the GHGI.

QC at the national level is conducted by the Sub-Directorate of MRV, Directorate of GHGI, and MRV, in collaboration with the Expert Team and GHG Emissions Calculation Methodology Panel, to review the worksheets and CRF drafts prepared by the Sub-Directorate of GHGI. The Sub-Directorate of GHGI conducts uncertainty analysis, addresses missing data, and performs KCA. Additionally, the Sub-Directorate of MRV, in collaboration with the MRV

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Team and Methodology Panel, verifies the input data and calculation formulas within the Worksheet. The Sub-Directorate of MRV may request enhancements and/or modifications to the estimated emission levels and trends, with the updated emission levels and trends designated as "verified emission levels."

Figure 1- 2

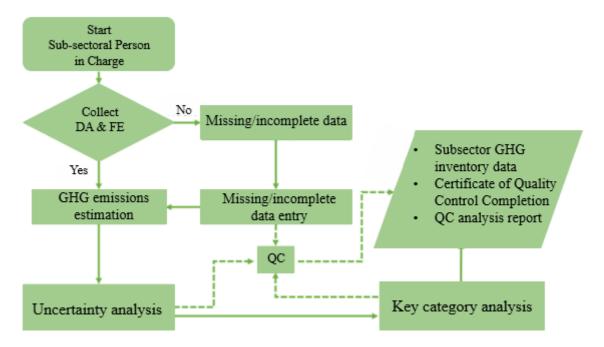


Figure 1-2 The Quality Control process flow for the NGHGI responsible party

In general, the QC carried out by the Directorate of GHGI and MRV includes:

- Review of source/sink categories, activity data, emission factors, estimator parameters, and methods used in the implementation of the GHGI;
- Checking the accuracy and completeness of the data;
- Checking the accuracy of data and calculations;
- Checking the use of approved methods in calculating GHG emissions and removals (Point C of Appendix I, Minister of Environment and Forestry Regulation No. 12 of 2024);
- Identification of data that is indicated to be incorrect and missing data. The data gap filling mechanism can use one of the techniques, namely the overlap technique, surrogate method, interpolation method, extrapolation method, or other appropriate methods (Point A of Appendix I, Minister of Environment and Forestry Regulation No. 12 of 2024);
- Conducting KCA using Approach 1: Level Assessment, to identify key categories that contribute at least 95% to the total national emissions (Point E of Appendix I, Minister of Environment and Forestry Regulation No. 12 of 2024);

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- Calculating the uncertainty using the error propagation Approach 1 from the 2006 IPCC Guidelines (Point D of Appendix I, Minister of Environment and Forestry Regulation No. 12 of 2024);
- Documentation and storage of data and information as well as reporting of the GHGI, along with all QC activities carried out.

The QC procedures are conducted by data stewards, including the Central Statistics Agency (BPS) and the Data and Information Center (Pusdatin) of various Ministries and Agencies, which play a crucial role in coordinating data and information provision and recording. These institutions oversee the QC function of the data collected, recorded, and provided by their subordinate technical units, verifying consistency and ensuring the continuous collection of systematic data and information. The objective is to systematize the information collection for the preparation of the GHGI. The Directorate General of Climate Change will be tasked with ensuring the quality of the inventory and its data, as well as performing double checks or recalculations and estimates required to accurately assess GHG emissions and removals.

Indonesia has developed a QC/QC Guide (Minister of Environment and Forestry Regulation No. 12 of 2024). However, the QA procedure has yet to be implemented. To enhance this process, the formation of a QA Team is necessary to perform cross-checks on the consistency of emission levels and trends using QA tools (Figure 1- 3).

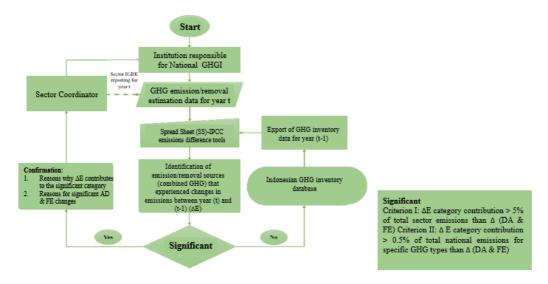


Figure 1-3 Using the IPCC emission difference tools for the plan of improvements related to the QA of the NGHGI

1.6. Description of Metrics

In prior inventories, the GWPs from the Second Assessment Report (AR2) were utilized. In this NGHGI within the BUR1, the most recent GWPs for the 100-year period, as outlined in the IPCC Fifth Assessment Report (AR5), have been employed, as detailed in the table below (IPCC 2014).



Table 1-5 GWP in AR5

GHG	GWP
CO_2	1
CH ₄	28
N_2O	265
CF ₄	6.630
C_2F_6	11.100

1.7. Flexibility

Table 1-6 below presents the areas of flexibility resulting from the country's capacity limitations.

Table 1-6 Areas of flexibility

GHGI Obligation	Area of Flexibility	Reason
Reporting base year starting from 1990	2000	Limitations in activity data, resources and modalities
GHG types (CO ₂ , CH ₄ , N ₂ O, HFC, PFC, SF ₆ dan NF ₃)	HFC, SF ₆ , NF ₃	Limitations in activity data, resources and modalities
QA/QC system	Limited to QC	Limitations in resources and modalities
Completeness of emission estimates NE (not estimated): • Less than 0.05% of national GHG emissions (without LULUCF) or 500 kt CO ₂ e, and	• Less than 0.1% or 1000 kt CO ₂ e, and	Limitations in activity data, resources and modalities
• Total of all insignificant gases (without LULUCF) less than 0.1% of total GHG emissions	• Total of all insignificant gases (without LULUCF) less than 0.2% of total GHG emissions	



II. TRENDS IN GREENHOUSE GAS EMISSIONS AND REMOVALS

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

Indonesia's total emissions for the 5 sectors, energy; IPPU; agriculture; LULUCF; and waste, in 2022 amounted to 1,382,854.50 kt CO₂e. These emissions/removals consist of 1,075,194.99 kt CO₂ (77.75%), 8,946.78 kt CH₄ equivalent to 250,509.94 kt CO₂e (18.12%), 215.45 kt N₂O, equivalent to 57,093.96 kt CO₂e (4.13%), and the remaining less than 0.01% PFCs at 55.61 kt CO₂e (Table 2-1). This indicates that CO₂ emissions are the most dominant compared to CH₄, N₂O and PFCs emissions. In addition to these 4 gases, NOx emissions are estimated at 30.60 kt and CO emissions at 876.22 kt. Meanwhile, HFCs, SF6, NF3, NMVOC and SOx emissions are not estimated in this report due to data limitations. The total emissions in 2022 reached 1,070,542.93 kt CO₂e without LULUCF, where CO₂ emissions contribute 72.61%, followed by CH₄ emissions at 22.55%, N₂O emissions at 4.83%, and PFCs emissions at 0.01%. The magnitude of emissions by GHG type with and without LULUCF is presented in Figure 2-1.

Table 2 - 1 Emissions and removals in 2022 by sector and type of gas

	CO ₂	CH ₄	N ₂ O	PFCs	Total
Source of Emissions and Removals		kt CO26	e		
Energy	712,371.82	21,813.50	4,568.07	0.00	738,753.39
IPPU	56,337.73	102.84	865.45	55.61	57,361.63
Agriculture	6,206.43	86,197.38	43,162.03	0.00	135,565.84
Waste	2,383.23	133,341.96	3,136.87	0.00	138,862.07
Total without LULUCF	777,299.21	241,455.69	51,732.42	55.61	1,070,542.93
LULUCF	297,895.78	9,054.25	5,361.54	0.00	312,311.57
Total with LULUCF	1,075,194.99	250,509.94	57,093.96	55.61	1,382,854.50

The contribution of the energy, IPPU, agriculture, LULUCF and waste sectors to the total 2022 emissions in Indonesia is 53.42%, 4.15%, 9.80%, 22.58%, and 10.04% respectively. Without including the emissions from the LULUCF sector, the energy sector contributes 68.01%, IPPU 5.36%, agriculture 12.66%, and waste 12.97% (Figure 2-2). A summary of emissions and removals by sub-category and GHG type can be seen in Table 2-2 and 2-3 (in kt CO₂e).



	Net CO ₂					HFCs							Total GHG
GREENHOUSE GAS SOURCE AND SINK	emissions/	CH ₄	N ₂ O	HFCs (1)	PFCs	and	SF ₆	NF ₃	NOx	CO	NMVOC	SOx	emissions/
CATEGORIES	removals				(1)	PFCs (1)							removals (2)
		kt		CO ₂ e (kt) (3)			(kt)						CO ₂ e (kt) (3)
Total national emissions and removals	1,075,194.99	8,946.78	215.45	FX	55.61	FX	FX	FX	30.60	876.22	IE,NA,	IE,NA,	1,382,854.50
											NE,NO	NE,NO	
1. Energy	712,371.82	779.05	17.24						NE,NO	NE,NO	NE,NO	NE,NO	738,753.39
1.A. Fuel combustion	707,721.11	112.97	17.21						NE	NE	NE	NE	715,444.74
1.A.1. Energy industries	314,393.28	3.97	4.11						NE	NE	NE	NE	315,594.43
1.A.2. Manufacturing industries and	204,612.78	28.84	4.16						NE	NE	NE	NE	206,523.52
construction													
1.A.3. Transport	154,955.56	44.83	8.03						NE	NE	NE	NE	158,339.40
1.A.4. Other sectors	33,759.49	35.34	0.90						NE	NE	NE	NE	34,987.39
1.A.5. Not-Specified	NE	NE	NE						NE	NE	NE	NE	NE
1.B. Fugitive emissions from fuels	4,650.71	666.09	0.03						NE,NO	NE,NO	NE,NO	NE,NO	23,308.65
1.B.1. Solid fuels	NO	151.57	NO						NO	NO	NO	NO	4,243.97
1.B.2. Oil and natural gas and other emissions	4,650.71	514.51	0.03						NE	NE	NE	NE	19,064.69
from energy production													
1.C. CO ₂ Transport and storage	NO												NO
2. Industrial processes and product use	56,337.73	3.67	3.27	NO	55.61	NO	NO	NO	NO	NO	NO	NO	57,361.63
2.A. Mineral industry	31,480.03	NO	NO						NO	NO	NO	NO	31,480.03
2.B. Chemical industry	9,366.80	3.67	3.27	NO	NO	NO	NO	NO	NO	NO	NO	NO	10,335.09
2.C. Metal industry	10,981.37	NO	NO	NO	55.61	NO	NO	NO	NO	NO	NO	NO	11,036.98
2.D. Non-energy products from fuels and solvent	4,358.07	NO	NO						NO	NO	NO	NO	4,358.07
use													
2.E. Electronic industry			NO	NO	NO	NO	NO	NO					NO
2.F. Product uses as substitutes for ODS				FX	FX	FX	FX	FX					FX
2.G. Other product manufacture and use	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.H. Other (4)	151.46	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	151.46
3. Agriculture	6,206.43	3,078.48	162.88						3.74	63.08	NO	NO	135,565.84
3.A. Enteric fermentation		1,311.46											36,720.88
3.B. Manure management		90.38	48.91								NO		15,492.83
3.C. Rice cultivation		1,672.91									NO		46,841.59
3.D. Agricultural soils		NA	113.76						NA	NA	NA		30,146.09
3.E. Prescribed burning of savannahs		3.69	0.20						3.70	61.68	NO	NO	156.19
3.F. Field burning of agricultural residues		0.03	0.00						0.04	1.40	NO	NO	1.83
3.G. Liming	2,159.22												2,159.22
3.H. Urea application	4,047.21												4,047.21
3.I. Other carbon-containing fertilizers	NO												NE
3.J. Other	NO	NO	NO						NO	NO	NO	NO	NO
4. Land use, land-use change and forestry (5)	297,895.78	323.37	20.23						26.86	813.13	NA,NE	NA	312,311.57
4.A. Forest land (5)	-266,741.53	84.69	18.94						3.12	202.99	NE		-259,351.80
4.B. Cropland (5)	412,258.89	199.48	0.59						10.65	392.02	NE		418,000.87
4.C. Grassland (5)	86,099.06	38.49	0.70						13.09	218.12	NE		87,363.54

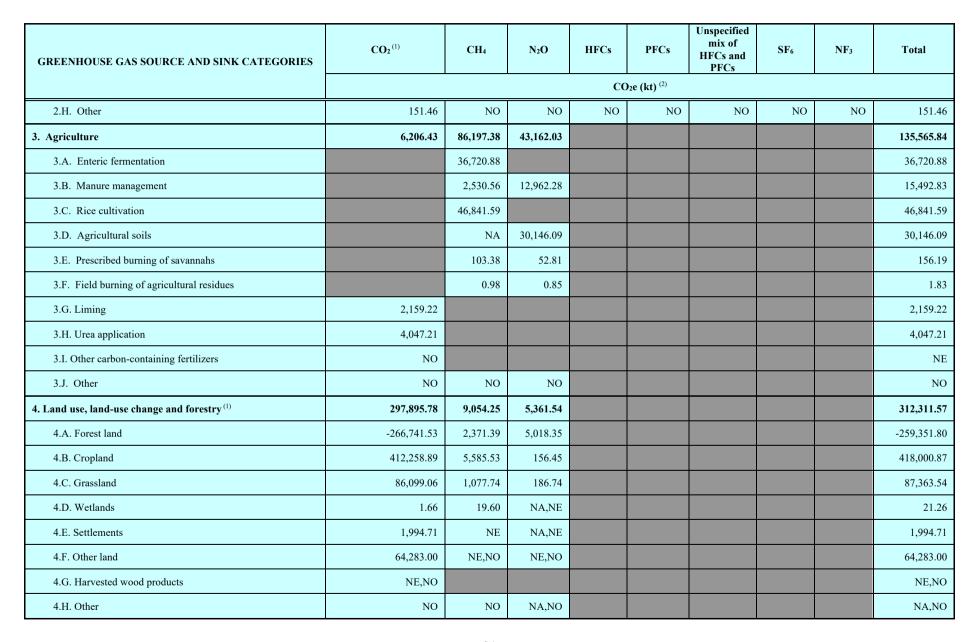
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO ₂ emissions/ removals	CH ₄	N ₂ O	HFCs (1)	PFCs	HFCs and PFCs ⁽¹⁾	SF ₆	NF ₃	NOx	со	NMVOC	SOx	Total GHG emissions/ removals (2)
		kt		CO ₂ e (kt) (3)			(kt)						CO ₂ e (kt) (3)
4.D. Wetlands (5)	1.66	0.70	NA,NE						NE	NE	NE		21.26
4.E. Settlements ⁽⁵⁾	1,994.71	NE	NA,NE						NE	NE	NE		1,994.71
4.F. Other land ⁽⁵⁾	64,283.00	NE,NO	NE,NO						NE	NE	NE		64,283.00
4.G. Harvested wood products (5)	NE,NO												NE,NO
4.H. Other ⁽⁵⁾	NO	NO	NA,NO						NA,NE	NA,NE	NA,NE	NA	NA,NO
5. Waste	2,383.23	4,762.21	11.84										138,862.07
5.A. Solid waste disposal ⁽⁶⁾		775.88							NA	NA	NA		21,724.54
5.B. Biological treatment of solid waste		0.07	0.13						NA	NA	NA		36.15
5.C. Incineration and open burning of waste (6)	2,381.81	72.12	0.88						NA	NA	NA	NA	4,635.09
5.D. Wastewater treatment and discharge		3,907.99	10.83						NA	NA	NA		112,292.62
5.E. Other ⁽⁶⁾	1.43	6.15	NO						NA	NA	NA	NA	173.68
6. Other (please specify) (7)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other sources of emissions/removals [IPCC Software 5.C]	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Memo items: (8)													
1.D.1. International bunkers	NE,NO	NE,NO	NE,NO						NE	NE	NE	NE	NE,NO
1.D.1.a. Aviation	NE,NO	NE,NO	NE,NO						NE NE	NE NE	NE NE	NE NE	NE,NO
1.D.1.a. Aviation	NE NE	NE	NE						NE	NE	NE	NE	NE

Memo items: (8)										
1.D.1. International bunkers	NE,NO	NE,NO	NE,NO			NE	NE	NE	NE	NE,NO
1.D.1.a. Aviation	NE	NE	NE			NE	NE	NE	NE	NE
1.D.1.b. Navigation	NE	NE	NE			NE	NE	NE	NE	NE
1.D.2. Multilateral operations	NE	NE	NE			NE	NE	NE	NE	NE
1.D.3. CO ₂ emissions from biomass	73,181.06									73,181.06
1.D.4. CO ₂ captured	NO									NO
5.F.1. Long-term storage of C in waste disposal	113,680.44									113,680.44
sites										
Indirect N ₂ O			NE							NE
Indirect CO ₂	NE									NE

[&]quot;FX" (flexibility), NA" (not applicable), "NE" (not estimated), "NO" (not occurring), "IE" (included elsewhere)

Table 2 - 3 Summary of emissions by source and sink in 2022 (in kt CO₂e)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂ (1)	СН4	N ₂ O	HFCs	PFCs	Unspecified mix of HFCs and PFCs	SF ₆	NF ₃	Total
				CC	2 ₂ e (kt) (2)				
Total (net emissions) (1)	1,075,194.99	250,509.94	57,093.96	FX	55.61	FX	FX	FX	1,382,854.50
1. Energy	712,371.82	21,813.50	4,568.07						738,753.39
1.A. Fuel combustion	707,721.11	3,163.12	4,560.51						715,444.74
1.A.1. Energy industries	314,393.28	111.07	1,090.08						315,594.43
1.A.2. Manufacturing industries and construction	204,612.78	807.54	1,103.20						206,523.52
1.A.3. Transport	154,955.56	1,255.10	2,128.74						158,339.40
1.A.4. Other sectors	33,759.49	989.40	238.50						34,987.39
1.A.5. Not-Specified	NE	NE	NE						NE
1.B. Fugitive emissions from fuels	4,650.71	18,650.38	7.56						23,308.65
1.B.1. Solid fuels	NO	4,243.97	NO						4,243.97
1.B.2. Oil and natural gas and other emissions from energy production	4,650.71	14,406.42	7.56						19,064.69
1.C. CO ₂ transport and storage	NO								NO
2. Industrial processes and product use	56,337.73	102.84	865.45	NO	55.61	NO	NO	NO	57,361.63
2.A. Mineral industry	31,480.03	NO	NO						31,480.03
2.B. Chemical industry	9,366.80	102.84	865.45	NO	NO	NO	NO	NO	10,335.09
2.C. Metal industry	10,981.37	NO	NO	NO	55.61	NO	NO	NO	11,036.98
2.D. Non-energy products from fuels and solvent use	4,358.07	NO	NO						4,358.07
2.E. Electronic Industry			NO	NO	NO	NO	NO	NO	NO
2.F. Product uses as ODS substitutes				FX	FX	FX	FX	FX	FX
2.G. Other product manufacture and use	NO	NO	NO	NO	NO	NO	NO	NO	NO

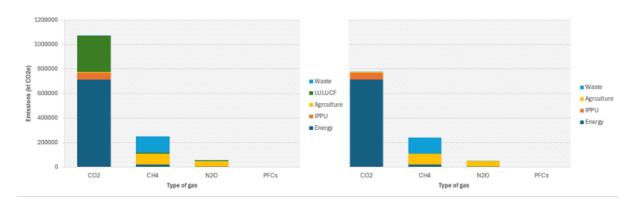


GREENHOUSE GAS SOURCE AND SINK CATEGORIES	$\mathbf{CO_2}^{(1)}$	CH ₄	N ₂ O	HFCs	PFCs	Unspecified mix of HFCs and PFCs	SF ₆	NF ₃	Total
				CC) ₂ e (kt) ⁽²⁾				
5. Waste	2,383.23	133,341.96	3,136.87						138,862.07
5.A. Solid waste disposal		21,724.54							21,724.54
5.B. Biological treatment of solid waste		2.09	34.06						36.15
5.C. Incineration and open burning of waste	2,381.81	2,019.29	233.99						4,635.09
5.D. Waste water treatment and discharge		109,423.80	2,868.82						112,292.62
5.E. Other	1.43	172.25	NO						173.68
6. Other (as specified in summary 1)	NO	NO	NO	NO	NO	NO	NO	NO	NO

Memo items: (3)						
1.D.1. International bunkers	NE,NO	NE,NO	NE,NO			NE,NO
1.D.1.a. Aviation	NE	NE	NE			NE
1.D.1.b. Navigation	NE	NE	NE			NE
1.D.2. Multilateral operations	NE	NE	NE			NE
1.D.3. CO ₂ emissions from biomass	73,181.06					73,181.06
1.D.4. CO ₂ captured	NO					NO
5.F.1. Long-term storage of C in waste disposal sites	113,680.44					113,680.44
Indirect N2O			NE			

Indirect CO ₂ ⁽⁴⁾	NE								
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[&]quot;FX" (flexibility), NA" (not applicable), "NE" (not estimated), "NO" (not occurring), "IE" (included elsewhere)



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Figure 2 - 1 Contribution of emissions in 2022 by GHG type with LULUCF (left) and without LULUCF (right)

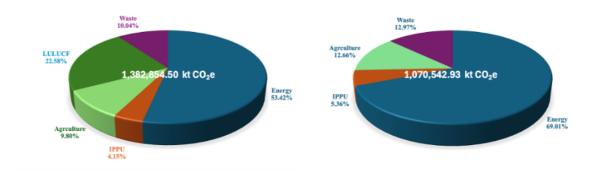


Figure 2 - 2 Contribution of emissions in 2022 by sector with LULUCF (left) and without LULUCF (right)

2.2. Description of Emission and Removal Trends by Sectors and GHG

Table 2-4 presents a summary of net GHG emissions for the period 2000 to 2022, while Figures 2-3 and 2-4 illustrate the emission trends by sector. In 2022, emissions were reported in descending order as follows: the energy sector contributed 738,753.39 kt CO₂e, the LULUCF sector contributed 312,311.57 kt CO₂e, the waste sector contributed 138,862.07 kt CO₂e, the agriculture sector contributed 135,565.84 kt CO₂e, and the IPPU sector contributed 57,361.63 kt CO₂e. In 2022, emissions rose by 61.83% compared to 2000, while experiencing a decline of 22.65% since 2019. Additionally, with emissions without LULUCF sector, in 2022 rose by 109.29% relative to 2000 levels and by 10.48% compared to 2019 levels. The year 2000 serves as the base year for the GHGI, while 2019 is referenced as it represents the final year in the preceding GHGI Report (BUR3).

Table 2- 4 Summary of net GHG emissions for the period 2000 - 2022

Source of	2000	2005	2010	2015	2019	2022
Emissions and Removals			kt CO	O ₂ e		
Energy	305,290.56	377,182.69	454,958.50	549,955.87	655,567.89	738,753.39
IPPU	39,804.94	39,017.26	31,550.31	47,847.23	58,681.57	57,361.63
Agriculture	107,188.93	110,131.56	108,081.76	128,045.26	126,675.16	135,565.84
Waste	59,227.57	71,102.81	88,657.23	99,694.68	128,107.25	138,862.07

Source of	2000	2005	2010	2015	2019	2022
Emissions and Removals			kt C	O ₂ e		
Total without						
LULUCF	511,512.00	597,434.32	683,247.80	825,543.04	969,031.86	1,070,542.93
LULUCF	342,991.31	709,681.07	529,522.17	1,730,275.90	818,653.99	312,311.57
Total with		•		•	•	
LULUCF	854,503.31	1,307,115.39	1,212,769.97	2,555,818.95	1,787,685.85	1,382,854.50

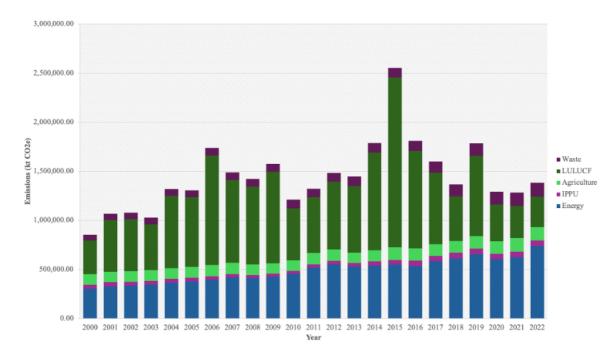


Figure 2 - 3 Trends in GHG emissions from 2000 - 2022 by sector (in kt CO_2e)

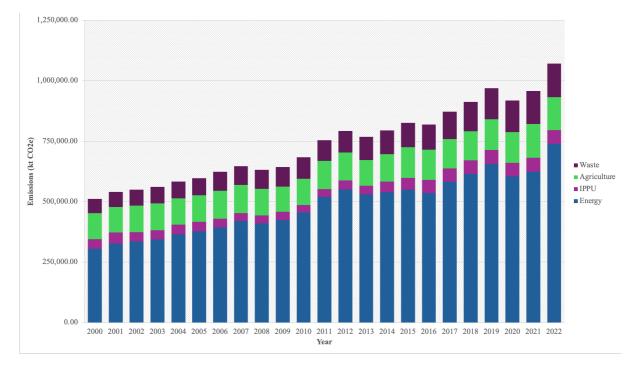


Figure 2-4 Trends in GHG emissions from 2000 - 2022 by sector without LULUCF (in kt $\mathrm{CO}_2\mathrm{e}$)

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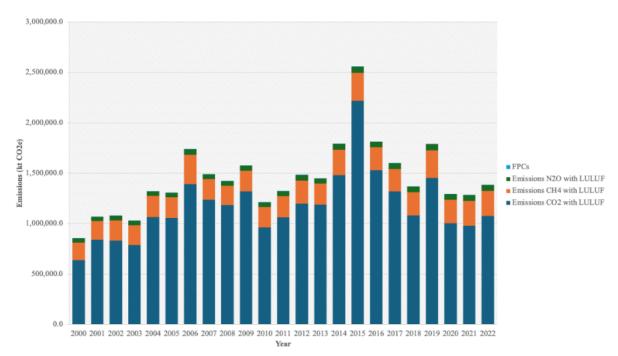
Figure 2-3 illustrates the fluctuations in emissions and removals from 2000 to 2022, with peak emissions recorded in 2015 at 2,555,818.95 kt CO₂e and the lowest emissions noted in 2000 at 854,503.31 kt CO₂e. In 2015, the primary sources of emissions were the LULUCF sector at 67.70%, largely attributed to land conversion to other land (L-OL), land conversion to croplands (L-CL), croplands remaining croplands (CL-CL), and grassland remaining grassland (GL-GL) including many forest and land fire incidents as a result of the El Niño year. This was followed by the energy sector at 21.52%, the agriculture sector at 5.01%, the waste sector at 3.90%, and the IPPU sector at 1.87%. Detailed information regarding emissions changes from 2000 to 2022 is presented in the subsequent sections, which address individual sectors. Without LULUCF sector (Figure 2-4), the emission trend has shown a consistent increase since 2000, peaking in the final reporting year (2022) and reaching its lowest point in the base year (2000).

Table 2-5 presents the total emissions and removals categorized by GHG type across five categories. In 2022 CO₂ constituted 77.75% of national GHG emissions, reflecting a 68.86% increase since 2000 and a 26.02% decrease since 2019. CH₄ emissions were recorded at 18.12%, reflecting a 42.11% increase since 2000 and a 8.65% decrease since 2019. N₂O emissions accounted for 4.13%, reflecting a 38.58% increase since 2020 and a 4.99% decrease since 2019. PFC emissions accounted for less than 0.004%, reflecting an 80.23% reduction since 2000 and a 18.97% increase since 2019.

Table 2-5 GHG emissions and removals by gas type with LULUCF

Source of Emissions and	2000	2005	2010	2015	2019	2022
Removals			kt C	O ₂ e		
CO ₂ emissions with LULUF	636,746.28	1,056,773.60	963,673.91	2,218,311.73	1,453,324.70	1,075,194.99
CH ₄ emissions with LULUF	176,275.40	205,363.87	200,907.83	278,805.84	274,224.17	250,509.94
N ₂ O emissions with LULUF	41,200.40	44,696.69	48,029.06	58,650.22	60,090.23	57,093.96
PFCs	281.23	281.23	159.17	51.15	46.74	55.61
Total	854,503.31	1,307,115.39	1,212,769.97	2,555,818.95	1,787,685.85	1,382,854.50

The trend of national GHG emissions across the five sectors exhibits fluctuations from 2000 to 2022 (Figure 2-5). Overall, CO₂ emissions have risen from 2000 to 2022, exhibiting variable increases throughout this period. The rise in petrol emissions is attributed to heightened fossil fuel combustion in the energy sector and a growing loss of biomass carbon from the LULUCF sector. El Niño years were associated with notable increases in CO₂ emissions, which contributed to the expansion of land and forest fires, as observed in 2006, 2015, and 2019. This phenomenon subsequently led to a heightened loss of biomass carbon within the LULUCF sector. Emissions of CH₄ and N₂O have increased from 2000 to 2022, primarily attributed to rising CH₄ emissions from the waste sector and both CH₄ and N₂O emissions from the agriculture sector.



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Figure 2 - 5 Trends in GHG emissions by gas type with LULUCF for the period 2000 - 2022, (in kt CO₂e)

Table 2-6 summarizes the trend of GHG emissions in 2022, without LULUCF. The table indicates that CO_2 emissions in 2022 accounted for 72.61%, reflecting a 154.70% increase since 2000 and a 12.33% increase since 2019. Additionally, 22.55% originated from CH₄, reflecting a 40.80% increase since 2000 and a 6.57% increase since 2019. N₂O emissions accounted for 4.83%, reflecting a 49.67% increase since 2000 and a 2.60% increase since 2019. The residual PFCs constituted less than 0.01%, reflecting an 80.23% reduction since 2000 and a 18.97% increase since 2019.

Table 2- 6 GHG emissions and removals by gas without LULUCF

-						
Sources of	2000	2005	2010	2015	2019	2022
Emissions and			1-+ (CO ₂ e		
Removals			Kt C	JO26		
CO ₂ emissions						
without						
LULUF	305,176.63	381,133.97	451,633.45	562,928.12	691,999.87	777,299.21
CH ₄ emissions						
without						
LULUF	171,490.18	179,604.76	189,267.01	215,266.88	226,561.59	241,455.69
N ₂ O emissions						
without						
LULUF	34,563.96	36,414.36	42,188.18	47,296.89	50,423.65	51,732.42
PFCs	281.23	281.23	159.17	51.15	46.74	55.61
Total	511,512.00	597,434.32	683,247.80	825,543.04	969,031.86	1,070,542.93

Figure 2-6 illustrates that CO₂ emissions constitute the predominant component of national GHG emissions, exhibiting a consistent increase from 2000 to 2022. The primary contributors to these emissions are the energy and IPPU sectors, which have shown a year-on-year increase

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due to ongoing development. Emissions of CH₄ and N₂O exhibit a trend analogous to that of CO₂ emissions, with significant influence from the agricultural sector. The trend of PFC emissions is not discernible in Figure 2-6 due to the minimal values. Emissions originating from the IPPU sector have exhibited fluctuations.

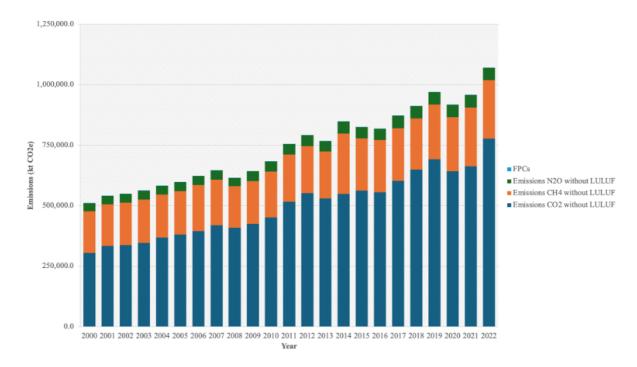


Figure 2- 6 Trends in GHG emissions by gas type without LULUCF for the period 2000 – 2022 (in kt CO₂e)

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III. ENERGY (CRT SECTOR 1)

3.1. General Overview (CRT Sector 1)

3.1.1. Sector Description

Greenhouse Gas (GHG) emissions from Fuel Combustion activities (1A) cover emissions from fuels combustion for electricity generation (1A1a1), petroleum refining (1A1b), manufacture of coal (1A1ci), other energy industries such as natural gas refining (1A1cii), manufacturing industries and construction (1A2), and transportation (1A3). The National GHG Inventory (NGHGI) does not cover emissions from not-specified category such as stationary (1A5a), mobile aviation, waterborn, others (1A5b), and multi-lateral (1A5c). In the previous NGHGI, emission from other categories, i.e. commercial (1A4a), residential (1A4b), as well as agriculture, forestry, fishing and fish farms (1A4c) were included in not-specified category (1A5). However, improvement has been made, in which GHG emissions from fuel combustions in commercial (1A4a), residential (1A4b), as well as agriculture, forestry, fishing and fish farms (1A4c) are included in other sectors (1A4). Fugitive emissions are also included in NGHGI. The fugitive covers emissions from coal production (1B1) and oil and natural gas production and transport (1B2).

3.1.2. Categories and Total Emissions

In 2022, the energy sector contributed 53.42% to total national emissions, with total emissions reaching 738,753.41 kt CO₂e. GHG emissions from the energy sector by GHG type in 2022 were 712,371.82 kt CO₂, 779.05 kt CH₄ and 17.24 kt N₂O. The CO₂ is the most dominant gas, accounting for 99.89% of total energy sector emissions. Further and more detailed information on GHG emissions can be found in the specific section of each category.

Table 3- 1 Summary of GHG emissions from the energy sector in 2022

Code	Category of GHG Source	CO ₂ (kt)	CH ₄ (kt)	N ₂ O (kt)
1.A.1	Energy industries		3.97	4.11
		314,393.28		
1.A.2	Manufacturing and construction		28.84	4.16
	industries	204,612.78		
1.A.3	Transport		44.83	8.03
		154,955.56		
1.A.4	Other sectors	33,759.49	35.34	0.90
1.B.1	Solid fuels (Fugitive)	-	151.57	-
1.B.2	Oil and natural gas (Fugitive)	4,650.71	514.51	0.03

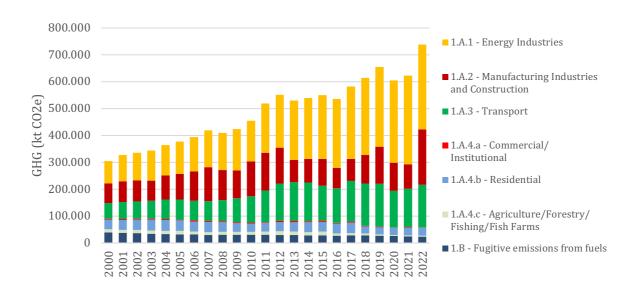
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Table 3 - 2 shows that CO_2 and N_2O emissions have increased from 2000 to 2022 in line with the increasing activity in the energy sector, while CH_4 has decreased due to the continuous decline in natural gas production.

Table 3 - 2 Energy sector emissions by GHG type (kt CO₂e)

GHG	2000	2005	2010	2015	2019	2022
CO_2	259,915.77	336,225.24	412,942.19	508,509.46	626,722.35	712,371.82
CH ₄	42,446.69	37,610.12	38,033.05	36,755.50	24,852.27	21,813.50
N ₂ O	2,928.15	3,347.37	3,983.29	4,690.94	3,993.30	4,568.09

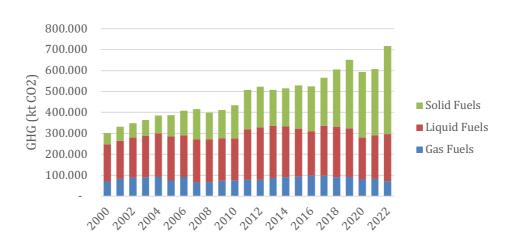
Figure 3-1 below shows the annual GHG emission levels of the Energy Sector for the period 2000-2022. It is evident that the GHG emission levels have fluctuated but with an increasing trend, at an average of 4.10% per year from 305,290.61 kt CO₂e in 2000 to 738,753.41 kt CO₂e in 2022 during this period. There was a revision of statistical data on coal consumption in 2013-2017 that was lower, while the data for 2010-2012 has not been revised. As a result, GHG emissions in 2013-2017 were lower compared to 2010-2012. In 2018 to 2019, there was an increase in coal consumption in the manufacturing industry, but in 2020 and 2021 this consumption decreased due to restrictions on activities because of the COVID-19 pandemic. In 2022, after activities returned to normal, GHG emissions from coal consumption in the manufacturing industry increased in line with the significant increase in the activity of this sector. The significant increase in coal consumption was due to the operation of new smelters and coal-fired power plants in the fertilizer industry.



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Figure 3 - 1 Trend of energy sector GHG emissions in 2000-2022 by source (in kt CO₂e)

As part of Reference Approach, GHGI is compiled based on the type of fuel utilized nationally. GHG emissions were estimated using the Reference Approach, based on national fuel data supply from 2000 to 2022. Figure 3-2 presents the results of the estimation. The figure indicates that GHG emissions exhibit fluctuations from 2000-2022, yet there is an overall upward trend. In 2020, the emission level was 301,474.61 kt CO₂, which rose to 717,757.27 kt CO₂ by 2022. From 2000-2022, emission increased at an average annual rate of 4.02%. From 2000 to 2017, liquid fuels were the primary source of GHG emissions; however, starting in 2018, solid fuels (coal), became the predominant source. This was a result of increased electricity generation, with coal serving as the most economical fuel source. In 2022, coal combustion accounted for 58.63% of the total emissions, which amounted to 717,757.27 kt CO₂, equating to 420,807.12 kt CO₂. Other emission sources included oil fuels, contributing 225,602.95 kt CO₂, which accounts for 31.43% of total emissions, and natural gas contributing 71,347.21 kt CO₂, representing the remaining 9.94% of total emissions.



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Figure 3 - 2 GHG emissions of the energy sector by fuel phase/type

3.2. Energy Industries (1.A.1)

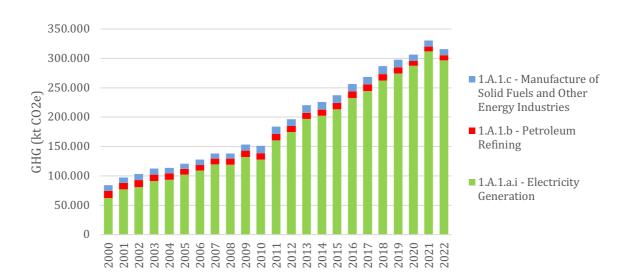
3.2.1. Category Description

Referring to IPCC 2006, the sources of GHG emissions from energy industries encompass several categories: Main activities include electricity and heat production (1.A.1.a), petroleum refining (1.A.1.b), and the manufacture of solid fuels and other energy industries (1.A.1.c). The Main Activity of Electricity and Heat Production includes Electricity Generation (1.A.1.a.i), Combined Heat and Power Generation (1.A.1.a.ii), and Heat Plants (1.A.1.a.iii). The NGHGI Report indicates that emissions from the energy industry category Main Activity Electricity and Heat Production (1.A.1.a) are limited to Electricity Generation (1.A.1.a.i). GHG emissions from Combined Heat and Power Generation and Heat Plants are included in the GHG emissions of Manufacturing Industries and Construction (1.A.2).

GHG emissions from petroleum refining (1.A.1.b) encompass emissions resulting from the combustion of fuels within oil and gas refineries. GHG emissions from the manufacture of solid fuels and other energy industries (1.A.1.c) arise from the combustion of fuels during the processing of coal into briquettes (1.A.1.c.i) and from fuel combustion in oil and gas extraction activities (upstream oil and gas), which also includes the other energy industries category (1.A.1.c.ii).

3.2.2. Trends in Greenhouse Gas Emissions by Category

GHG emissions from fuel combustion in the energy sector primarily originate from electricity generation activities. The contributions of fuel combustion in petroleum refining and solid fuel manufacturing are comparatively minor. GHG emissions from electricity generation are primarily attributed to coal-fired power plants. Figure 3-3 illustrates the GHG emissions levels associated with various energy industry activities.



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Figure 3 - 3 GHG emissions of the energy industries sub-sector

In 2000, coal constituted 42.85% of the total fuel used in power plants, while natural gas accounted for 31.31% and oil fuels represented 25.83%. The share of renewable biomass fuel was minimal and had ceased to exist by 2018. In 2022, coal constituted 78.13% of the total fuels used in power plants, with natural gas accounting for 18.70% and oil fuels comprising 3.00%. The proportion of renewable biofuels was 0.18%, having been utilized since 2018. The proportion of fuel use in power plants from 2000-2022 is presented in Figure 3-4.

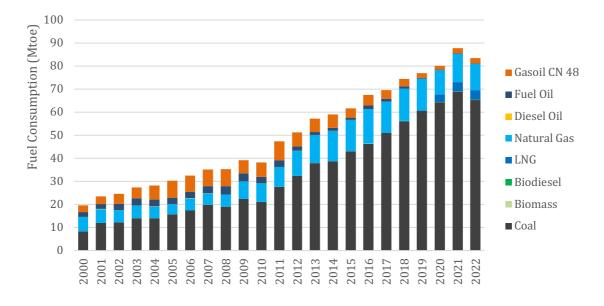
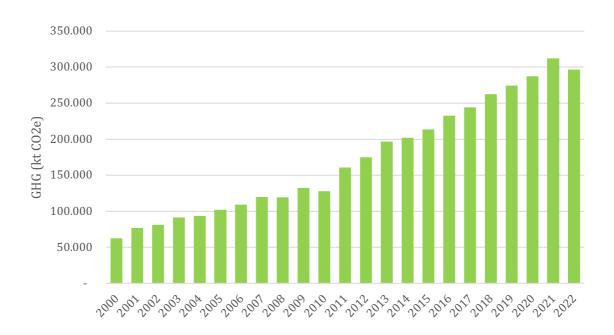


Figure 3 - 4 Fuel use in power plants in 2000-2022

Under these conditions, GHG emissions from power plants rose from 62,337.70 kt CO₂e in 2000 to 296,762.33 kt CO₂e in 2022, reflecting an average annual increase of 7.40%. Figure 3-5 illustrates the GHG emissions from power plants according to the type of fuel utilized.



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Figure 3 - 5 GHG emission levels of electricity generation (1.A.1.a.i Electricity Generation)

The emission sources from fuel combustion in energy industries (1A) include the oil refinery and LNG refinery sub-sectors (1A1b). Oil refineries convert crude oil into fuel and non-fuel products, whereas LNG refineries transform natural gas into LNG for long-distance transportation. In oil refineries, fuel oil and/or fuel petrol consumption primarily serves the refinery's internal needs and captive power generation. In LNG refineries, the primary fuel utilized is natural gas, which serves both refinery operations and captive power generation. Figure 3-6 illustrates the fuels utilized in oil and LNG refineries.



Figure 3 - 6 Fuels used in oil refineries and LNG refineries

Figure 3-6 illustrates that fuel consumption from 2000 to 2022 varied in relation to refinery production levels. The variability in fuel consumption and types influences the extent of GHG

emissions produced by refineries. Figure 3-7 illustrates the extent of GHG emissions originating from refineries.

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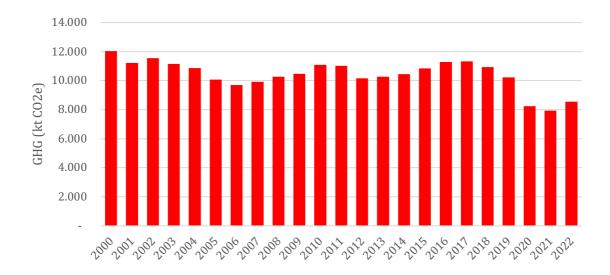


Figure 3 - 7 GHG emissions from refinery processing, kt CO₂e

The third sector of the energy industry is the coal briquette sector. The coal briquette industry in Indonesia is relatively recent, having commenced in 1993, in contrast to power plants, oil refineries, and LNG refineries, which have been operational since before 1990. Figure 3-8 illustrates coal briquette consumption data in Indonesia from 2000 to 2022. Figure 3-9 illustrates the GHG emissions produced from fuel combustion within the coal briquette industry.

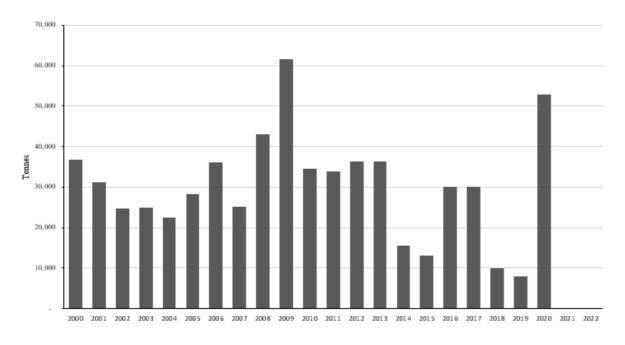
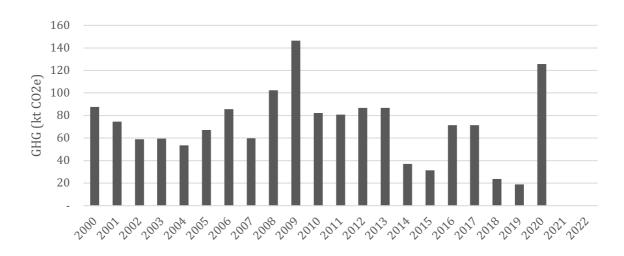


Figure 3 - 8 Coal consumption for briquettes 2000-2022



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Figure 3 - 9 GHG emissions from fuel combustion in the coal briquette industry 2000-2022

3.2.3. Methodological Issues

The calculation of GHG emissions employs Equation 2.1 and Equation 2.2 from the IPCC-2006, utilizing Tier 2 Emission Factors for petrol, LPG, CNG, and liquid fuels (refer to Table 3-3). In contrast, Tier 1 emission factors are applied for coal, biomass, biodiesel, and biogasoline. In the power generation sub-sector, a significant issue is the application of the net calorific value (NCV) of coal, as actual coal consumption derives from various coal types, whereas the available data pertains solely to total coal.

Table 3 - 3 Tier 2 Emission Factors for fuels

		Tier 2	
Fuels	FE National	NCV National	Berat Jenis
	(Ton CO ₂ /TJ)	(TJ/Gg)	Nasional (Kg/m ³)
Gasoline RON 98	68.91	44.62	751.3
Gasoline RON 92	69.04	44.61	748.4
Gasoline RON 90	69.29	44.61	747.0
Gasoline RON 88	69.67	44.61	744.8
Avtur	72.36	43.81	804.1
Kerosene	72.43	43.75	805.6
Diesel Oil CN 53	72.85	43.55	827.7
Diesel Oil CN 51	72.93	43.43	836.7
Diesel Oil CN 48	73.28	43.27	843.1
Diesel Fuel	74.52	42.63	874.8
Fuel Oil	77.90	40.79	975.5
Piped Gas	57.64	45.20	
LNG	57.27	47.30	
LPG	65.40	46.10	

^{*}Source: Lemigas and Tekmira KESDM



3.2.4. Uncertainty Assessment and Time-Series Consistency

The evaluation of uncertainty is conducted through the error propagation method. The uncertainty calculation for Tier 1 emission factors employs the default values from IPCC-2006, while the uncertainty for Tier 2 Emission Factors utilizes the national default values presented in Table 3 - 4. The uncertainty of the Activity Data (AD) is evaluated using expert judgment, incorporating input from data stakeholders within the Technical and Environmental Directorates and the Data and Information Center of the Ministry of Energy and Mineral Resources (KESDM).

Table 3 - 4 Fuel uncertainty values (national default)

Fuels		Tier 2	
rueis	NCV	Density	FE CO ₂
Gasoline RON>95	$\pm 4.75\%$	$\pm 4.83\%$	$\pm 1.50\%$
Gasoline RON 92	±4.73%	±4.46%	$\pm 2.47\%$
Gasoline RON 90	±4.73%	±4.28%	$\pm 2.56\%$
Gasoline RON 88	$\pm 4.73\%$	$\pm 4.00\%$	±2.38%
Avtur	±4.13%	±11.65%	$\pm 0.89\%$
Kerosene	$\pm 3.09\%$	$\pm 3.65\%$	$\pm 0.95\%$
Solar Fuel CN 53	±4.94%	±0.93%	±1.01%
Solar Fuel CN 51	±4.67%	±2.99%	$\pm 1.06\%$
Solar Fuel CN 48	±4.32%	±3.33%	±1.21%
Diesel Fuel	$\pm 2.89\%$	$\pm 2.88\%$	$\pm 0.64\%$
Fuel Oil	±2.43%	±1.59%	$\pm 1.56\%$
Natural Gas	$\pm 8.34\%$	±10.18%	±5.73%

The calculation of GHG emissions from the power generation sub-sector is conducted consistently. If a new emission source, AD, is identified that has not been previously considered, a comprehensive recalculation is performed in accordance with the GHG emissions reporting data series. It is essential to recalculate the BTR1 Report for oil refineries and LNG, given the variability in GHG emissions recorded from 2007 to 2009.

3.2.5. Category-specific QA/QC and Verification

GHG emissions resulting from fuel combustion in the energy sector, specifically within the category of Main Activity Electricity and Heat Production from Electricity Generation (1.A.1.a.i), are determined using AD (fuel quantity) sourced from the Handbook of Energy Economic Statistics of Indonesia (HEESI). The HEESI statistical data for power plants is provided directly by business entities, including PT PLN (Persero), Independent Power Producers (IPP), Power Purchase Utilities, and other organizations. The collection of HEESI statistical data has undergone a QC process involving each business actor. QA occurs



subsequent to the data validation and verification process conducted by stakeholders via focus group discussions or workshops organized by PUSDATIN ESDM prior to the publication of statistical data in HEESI.

GHG emissions from fuel combustion in the energy industry are accounted for not in category 1.A.1.a.ii but rather in the manufacturing industry (1.A.2), which typically includes power generation that produces heat through combined heat and power systems.

GHG emissions resulting from fuel combustion in the oil refinery and LNG refinery sector of Petroleum Refining (1.A.1.b) are determined using AD (fuel quantity) for fuel gas and fuel oil sourced from HEESI. The HEESI statistical data for oil and LNG refineries is provided by industry participants in the form of consolidated data, covering a minimum of two years prior, specifically from PT Pertamina and other institutions. The collection of HEESI statistical data has undergone a QC process involving each business actor. QA is conducted subsequent to the data validation and verification process by stakeholders via focus group discussions or workshops organized by PUSDATIN ESDM prior to the publication of statistical data in HEESI.

3.2.6. Category-specific Recalculations

No recalculation has been performed to estimate GHG emissions for the power generation subsector from 2000 to 2022, as all fuel consumption data has been accounted for and aligns with the available information. A recalculation was conducted to finalize the coal consumption data for the coal briquette industry sub-sector from 2000 to 2005. For the oil refinery and LNG refinery sub-sectors, a recalculation was carried out due to the availability of updated data on oil and gas consumption during the petroleum refining process since 2019.

3.2.7. Plan of Improvements

- The calculation of GHG emissions for the Power Generation Sector (1A1ai), oil refineries and LNG refineries (1A1b), and coal industries (1A1c) must be conducted in a consistent time-series beginning in 1990, which is related to flexibility. A recalculation of GHG emission levels is necessary for the petroleum refining and LNG refinery sub-sectors. Fuel data for refineries is accessible from 2020 to 2022, allowing for extrapolation using this data alongside refinery production to generate estimates for the years 2000 to 2019.
- The fuel consumption of the petrochemical industry, when integrated with oil refineries, is inseparable; thus, the GHG emission levels from fuel combustion in this integrated sector are encompassed within those of oil refineries and LNG refineries (1A1b). In non-

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integrated petrochemical industries, the GHG emissions resulting from fuel combustion are reported, if available, as GHG emissions within the manufacturing industry sub-sector (1A2c).

- Improving the coal emission factor is essential, as it was previously high in comparison to the lowest quality coal emission factor outlined in the IPCC 2006 report.
- The provision of national Tier 2 Emission Factors for CH₄ and N₂O is essential.
- The assessment of GHG emissions from own-use fuel combustion in the upstream oil and gas sector (1.A.1.c.ii) requires enhancement, as current data on own-use fuel is limited to natural gas, neglecting the presence of liquid fuels. SKK Migas can provide the upstream oil and gas fuel data.

3.3. Manufacturing and Construction Industries (1.A.2)

3.3.1. Category Description

The IPCC-2006 categorizes the manufacturing and construction industry sub-sector (1A2) into thirteen distinct industry sub-sectors. The BUR3 Report categorizes the industry sub-sector into six sub-sectors: the iron and steel industry (1A2a), the chemical industry (1A2c), the pulp, paper, and printing industry (1A2d), the food, beverage, and tobacco industry (1A2e), the non-metallic mineral industry (1A2f), and other industries (1A2m). The industrial grouping in the BTR1 Report remains unchanged.

3.3.2. Trends in Greenhouse Gas Emission by Category

The total fuel consumption data for the manufacturing and construction industry sub-sector is derived from the HEESI data published by the Center for Data and Information (Pusdatin) of the Ministry of Energy and Mineral Resources, which serves as sales data. The HEESI data is sourced from energy suppliers, organized by relevant directorates: coal is managed by the Directorate of Coal, while fuel and gas are overseen by Pertamina's Directorate of Oil and Gas. Fuel consumption data across various industries can be categorized into distinct industrial classifications, available from the National Industrial Information System (SIINAS) overseen by the Center for Green Industry, Ministry of Industry.

GHG emissions from the industrial sub-sector rose by an average of 4.87% from 2000 to 2022 (Figure 3 - 10). Throughout this period, GHG emissions from the industrial sub-sector varied as a result of heightened coal consumption, the adoption of biogasoline over the past four years, the global economic recession, and changes in public purchasing power. In 2013, GHG emissions underwent a significant reduction attributed to a revision of coal consumption in the industrial sector by Pusdatin. The years 2020 and 2021 witnessed a decline attributed to the COVID-19 pandemic. In 2022, industrial activity normalized post-COVID-19, leading to a

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significant rise in coal consumption driven by new smelters, fertilizer industry power plants, and other factors. This surge contributed to an increase in GHG emissions from the iron and steel sector in 2022.

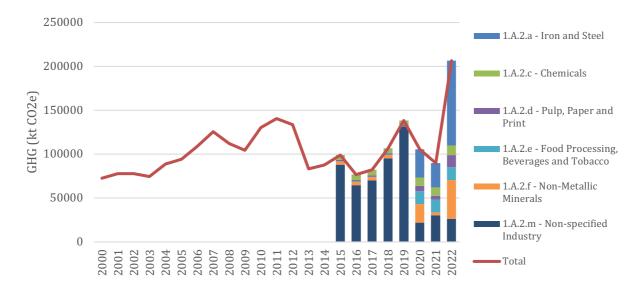
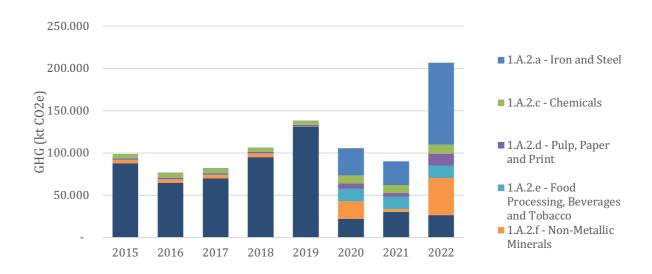


Figure 3 - 10 GHG emissions from the industrial sub-sector in 2000 – 2022 (in kt CO₂e)

Over the past eight years, GHG emissions from the iron and steel industry sub-sector have risen by an average of 119% annually, attributed to the inability to separate the non-ferrous metal industry group (1A2b) from the iron and steel industry (1A2a). Indonesia is currently advancing the downstream processing of the non-ferrous metal industry, including tin, copper, and bauxite, to enhance industrial added value and support the policy of utilizing battery-based electric vehicles. Furthermore, GHG emissions from the non-metallic mineral industry (1A2f) rose in 2022, attributed to the production of cement, ceramics, glass, and lime. This increase was linked to heightened production driven by infrastructure development and export activities, which in turn led to greater coal consumption.

The manufacturing sub-sector encompasses various industries, including the iron and steel industry, chemical industry, pulp and paper, food and beverage, and non-metallic mineral processing, among others. Figure 3 - 11 illustrates GHG emissions from the manufacturing sub-sector. This figure demonstrates that the primary sources of GHG emissions within the manufacturing sub-sector are iron and steel production, as well as non-metallic mineral processing.



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Figure 3 - 11 GHG emissions from the manufacturing sub-sector in 2000 – 2022 (in kt CO₂e)

3.3.3. Methodological Issues

The calculation of GHG emissions from the industrial sub-sector employs Equation 2.1 and Equation 2.2 from the 2006 IPCC Guidelines, utilizing Tier 1 and Tier 2 Emission Factors for petrol, LPG and fuel (Table 3-2). In the industrial sub-sector, a significant issue is the reliance on the NCV of coal, as coal consumption is derived from multiple coal types, yet the available data only reflects total coal usage.

3.3.4. Uncertainty Assessment and Time-Series Consistency

The evaluation of uncertainty magnitude is conducted through the method of error propagation. The uncertainty associated with the Tier 1 Emission Factor (EF) is derived from the 2006 IPCC default, while the uncertainty for the Tier 2 emission factor is based on the national default presented in Table 3.3. The uncertainty of the AD is assessed through expert judgment, incorporating data stakeholders from the Directorate of Engineering and Environment of the Ministry of Energy and Mineral Resources (MEMR), Pusdatin MEMR, and the Center for Green Industry, Ministry of Industry. The assessment of GHG emissions across six industrial sub-sectors has been conducted systematically, covering the period from 2015 to 2022.

3.3.5. Category-Specific QA/QC and Verification

The AD for the industrial sub-sector category is derived from stakeholders and primary data sources. Furthermore, cross-checks are conducted with the relevant Directorates of Engineering and Environment of the MEMR fuel stakeholders. The AD was acquired following coordination between the Engineering and Environment Directorates of the MEMR and the primary data providers.

The AD for the GHGI calculation is derived from HEESI. HEESI AD is gathered in phases, beginning with business entity reporting to technical units (oil and gas, minerals and coal,

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electricity, and new and renewable energy) via the reporting system or manually. Subsequently, annual data reconstruction occurs between the technical units and business entities, as documented in the meeting minutes, ensuring compliance with MEMR Data 1. The presence of the Minutes of Meeting signifies the implementation of QC and QA in the collection of AD. The MEMR Pusdatin, as the stakeholder responsible for the GHGI calculation, conducts data cross-checks and performs GHGI calculations in accordance with the relevant worksheets.

The allocation of AD across industrial sub-sectors is conducted by the Center for Green Industry, Ministry of Industry, based on survey results obtained from the industrial sub-categories during the GHG Emission Profile Study of the Industrial Sector. Surveys were conducted across various selected industries and subsequently detailed into the total industrial sub-groups.

3.3.6. Category-Specific Recalculations

The specific recalculation carried out in this BTR1 Report is the separation of GHG emissions generated by the petrochemical industry which were previously grouped into natural gas processing (1A1b) transferred to the chemical industry sub-sector (1A2c).

3.3.7. Plan of Improvements

Identified improvements require implementation, though a timeline for their realization has yet to be established:

- The calculation of the GHGI for the industrial sub-sector requires recalibration for the period from 2000 to 2014.
- Segregation of the GHGI calculation for the non-ferrous metal industry sub-sector (1A2b) from the iron and steel industry (1A2a).
- The GHGI calculation for the industrial sub-sector (1A2m) is divided into the transportation equipment industry (1A2g), machinery industry (1A2h), mining (non-energy) and quarrying industry (1A2i), wood and wood products industry (1A2j), construction industry (1A2k), textile and rubber industry (1A2l) and unspecified categories.

3.4. Transport (1.A.3)

3.4.1. Category Description

The transport sector, as a component of an archipelagic nation, contributes significantly to GHG emissions, facilitating the movement of goods and individuals between locations. This sector includes the sub-sectors of air transport (1A3a), road transport (1A3b), rail transport (1A3c), and maritime transport (1A3d).



3.4.2. Trends in Greenhouse Gas Emissions by Category

During the period from 2000 to 2022, energy consumption in the transport sub-sector increased at an average rate of 5.25% per annum. Energy consumption growth in the transport sector exceeded the average economic growth rate of 4.93% during the same period.

In 2000, the transport sub-sector (1A3) accounted for 99.86% of a total fuel consumption of 20,348 ktoe. The remaining components included natural gas at 0.12% and electricity at 0.02%. Petrol accounted for 50% of fuel consumption, followed by petrol oil at 44.00%, aviation fuel/aviation petrol at 5.00%, and the remaining 1% consisting of kerosene and fuel oil. About 94% of the energy consumption in the transport sector was attributed to the road transport subsector. In 2022, fuel consumption totaled 62,662 ktoe, accounting for 99.94% of total energy consumption in the transport sector, with fuel type shares remaining largely unchanged since 2000. Figure 3-12 illustrates a reduction in energy consumption during the period of 2020-2021, attributable to the COVID-19 pandemic. In 2000, the road transport sub-sector accounted for approximately 94.00% of the energy consumption within the transport sector, rising to 95.00% by 2022. The energy consumption of the road transport sub-sector encompasses petrol oil and biogas oil usage, while the maritime transport sub-sector's energy consumption is exclusively derived from fuel oil.

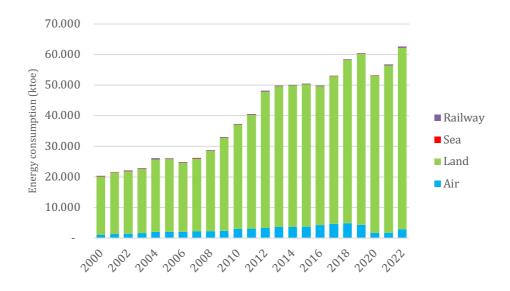


Figure 3 - 12 Energy consumption in the transport sector

In the transport sector, the composition of fuel consumption has led to an increase in GHG emissions from 58,851.22 kt CO₂e in 2000 to 158,339.40 kt CO₂e in 2022. This reflects a 2.69-fold increase, equating to an average annual growth rate of 4.60% (Figure 3-13). The levels of GHG emissions across transport sub-sectors are largely consistent with energy consumption, attributable to comparable EFs. Since 2015, petrol oil consumption has been blended with biodiesel in compliance with existing regulations to produce biogas oil. Since 2020, biogas oil has been classified as containing 30% biodiesel, referred to as B-30, leading to the accounting

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of only 70% of CO₂ emissions from its consumption. The increase in GHG emissions from the transport sector has been less pronounced than the rise in its energy consumption from 2000 to 2022.

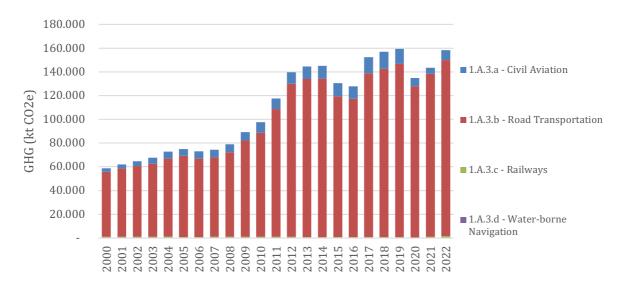


Figure 3 - 13 GHG emissions from the transport sector (in kt CO₂e)

3.4.3. Methodological Issues

The estimation of GHG emissions from the transport sector is conducted using Equation 3.2.3 from the IPCC 2006 Guidelines, applying Tier 2 mobile EFs as outlined in Table 3-3. Exceptions include aviation petrol, biodiesel and biogasoline, which utilize Tier 1 mobile factors.

3.4.4. Uncertainty Assessment and Time-Series Consistency

The uncertainty assessment utilized Approach 1 for error propagation. The uncertainty associated with Tier 1 EFs relies on IPCC 2006 defaults, whereas the uncertainty for Tier 2 EFs is based on national defaults (Table 3-4). The uncertainty of AD was assessed through expert judgment, incorporating input from data stakeholders within the Directorate of Oil and Gas Engineering and Environment of the MEMR and the MEMR's Data and Information Center. GHG emissions have been systematically calculated across four transport sub-sectors from 2000 to 2022.

3.4.5. Category-Specific QA/QC and Verification

The AD for GHGI calculation (GHGI) is obtained from HEESI. HEESI data is collected in a hierarchical manner, beginning with business entities reporting to technical units (oil and gas) via reporting systems or manual methods. This is followed by the annual reconstruction of data from technical units in collaboration with business entities, as recorded in official documents, thereby aligning with MEMR's One Data policy. Official records indicate the application of QC and QA in the collection of AD. The Data and Information Center of MEMR, as a

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stakeholder in the calculation of GHG inventories, conducts data cross-checking and GHGI calculations in accordance with the relevant worksheets.

The distribution of AD across transport sub-sectors is viable, as it corresponds to the fuel types utilized within each sub-sector. The Center for Sustainable Transport Management (PPTB) within the Ministry of Transportation serves as a data stakeholder by supplying AD on diesel fuel consumption for rail transport. This enables the differentiation of sub-sector 1A3b, which was previously aggregated for road and rail transport, into 1A3b (road transport) and 1A3c (rail transport). This suggests that PPTB has implemented reporting activities and data QC, especially within the rail sub-sector.

3.4.6. Category-Specific Recalculations

The recalculation conducted in this BTR1 Report involves distinguishing GHG emissions generated by the rail transport sub-sector (1A3c) from those produced by the road transport sub-sector (1A3b). This action was taken based on the availability of alternative fuels, specifically petrol oil and biogas oil, for consumption in railway operations, encompassing both passenger and freight transport. The recalculation was conducted for the period from 2000 to 2022, despite incomplete data, utilizing data gap filling methods that accounted for the average annual distance traveled between 2000 and 2018. As a result, four transport sub-sectors have been established in accordance with IPCC requirements.

3.4.7. Plan of Improvements

- GHGI calculations for the transport sub-sector require recalibration in a series from 1990 to 1999, taking into account relevant parameters.
- Distinct GHGI calculations for petrol oil/biogas oil consumption in the maritime transport sub-sector (1A3d), which remains categorized under the road transport sub-sector (1A3b) in this BTR1 Report.
- Recalculate the NCV, fuel density, carbon content, and EFs for fuels (petroleum and natural gas) categorized by island or province, given that the most recent data is from 2017.

3.5. Other Sector (1.A.4)

3.5.1. Category Description

This report categorizes 'Other Sectors' to encompass the commercial sub-sector (1A4a), residential sub-sector (1A4b), and agriculture/fishing/forestry sub-sector (1A4c), in accordance with IPCC classifications. The term 'Other Sectors' denotes those sectors that utilize fuel and produce GHG emissions, yet fall outside the scope of sub-sectors 1A1, 1A2, and 1A3. Fuel consumption in these sub-sectors encompasses fuel for cooking (LPG and kerosene), fuel for transportation (tractors, agricultural tools and machinery), land clearing equipment (excavators, bulldozers, etc.), and motorized fishing vessels of varying tonnage.



3.5.2. Trends in Greenhouse Gas Emissions by Category

This report encompasses additional sectors, including the commercial sub-sector (1A4a), residential sub-sector (1A4b), and agriculture/fisheries/plantation sub-sector (1A4c), in accordance with IPCC classifications. Other Sectors include those that utilize fuel and produce GHG emissions but are excluded from sub-sectors 1A1, 1A2, and 1A3. Fuel consumption in these sub-sectors encompasses cooking fuels such as LPG and kerosene, transportation fuels for tractors, agricultural tools and machinery, land clearing equipment including excavators and bulldozers, as well as fishing vessels of varying tonnage.

In 2000, fuel consumption (gas, LPG, petroleum, kerosene, biomass) represented 92.01% of total energy consumption; however, by 2022, this figure had nearly halved to 31.35%. The proportion of petroleum consumption within total commercial fuel consumption (including petroleum, LPG, petrol and kerosene) significantly declined from 14,812 ktoe in 2000 to 2,353 ktoe in 2022. The reduction was accompanied by a tenfold increase in LPG consumption, rising from 1,051 ktoe in 2000 to 10,516 ktoe in 2022. The remainder comprises natural gas, which rose from 31 ktoe in 2000 to 166 ktoe in 2022 (Figure 3 - 14).

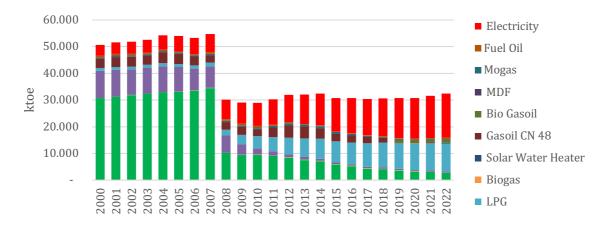
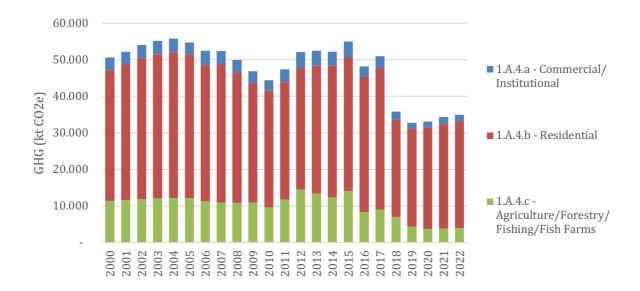


Figure 3 - 14 Energy consumption in other sectors 2000-2022 (in ktoe)

The transition from fuel consumption to electricity and the replacement of kerosene with LPG led to a reduction in GHG emissions from Other Sectors (1A4) by an average of 1.67% annually from 2000 to 2022. This condition was observed in all Other Sectors (1A4), specifically within the commercial sub-sector (1A4a), residential sector (1A4b), and agriculture/plantation/fisheries sub-sector (1A4c).

Figure 3 - 15 illustrates GHG emissions originating from the residential, commercial, and other unspecified sub-sectors. This figure indicates that GHG emissions in this sub-sector primarily stem from residential activities.



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Figure 3 - 15 Emissions from residential, commercial, and agricultural sub-sectors (in kt CO₂e)

3.5.3. Methodological Issues

The assessment of GHG emissions in various sectors utilizes Equations 2.1 and 2.2 from IPCC-2006, applying Tier 2 EFs for petroleum, gas, and LPG, whereas Tier 1 EFs are employed for biomass, coal, biodiesel, and biogas.

3.5.4. Uncertainty Assessment and Time-Series Consistency

The uncertainty assessment utilized Approach 1 for error propagation. The uncertainty associated with Tier 1 EF relies on the IPCC 2006 defaults, whereas the uncertainty for Tier 2 Emission Factors is based on national defaults (Table 3.3). The uncertainty of AD was assessed using expert judgment, incorporating input from data stakeholders within the Directorate of Oil and Gas Engineering and Environment of MEMR and MEMR's Data and Information Center.

3.5.5. Category-Specific QA/QC and Verification

The AD for GHGI calculation is obtained from HEESI. HEESI data is collected in a hierarchical manner, beginning with business entities reporting to technical units (oil and gas) via reporting systems or manual methods. This is followed by annual data reconstruction from technical units in collaboration with business entities, as recorded in official documents, thereby complying with MEMR's One Data policy. Official records indicate the application of QC and QA in the collection of administrative data. The Data and Information Center of MEMR, as a stakeholder in the calculation of GHG inventories, conducts data cross-checking and GHGI calculations in accordance with the relevant worksheet.

3.5.6. Country-Specific Recalculations

The BUR3 Report indicates that the unspecified sub-sector (1A5) encompasses agriculture, plantation, fisheries, construction, and mining sub-sectors. The recalculation conducted in this

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BTR1 Report involves the transfer of GHG emissions from the unspecified sub-sector (1A5) to other sub-sectors (1A4c). Fuel consumption in the construction sub-sector is accounted for within the manufacturing industry sub-sector (1A2k), while energy consumption in the mining sub-sector is incorporated into the mining and quarrying industry (1A3i). The reallocation of emission categories enhances the GHG emission contribution from other sub-sectors (1A4) and removes the unspecified sub-sector.

3.5.7. Plan of Improvements

- GHGI calculations for additional sub-sectors require recalculation for the period from 1990 to 1999, taking into account relevant parameters.
- National Tier 2 should incorporate Tier 2 parameters for petroleum fuels and natural gas, specifically NCV, density, and EF, as provided by LEMIGAS MEMR.
- A recalculation of NCV calculations, petroleum fuel density, carbon content, and EFs for fuels (petroleum and natural gas) categorized by island or province is necessary, as the most recent data is from 2017.

3.6. Fugitive Emissions from Fuels (1.B)

Fugitive emissions denote GHG emissions that are inadvertently released during the processes of fuel production and supply. Emissions in this category encompass flaring and venting operations in oil and gas fields, gas leaks occurring at pipeline joints or valves, and methane (CH₄) emitted from coal seams during coal mining activities. Figure 3-16 below illustrates the development of fugitive gas inventories.

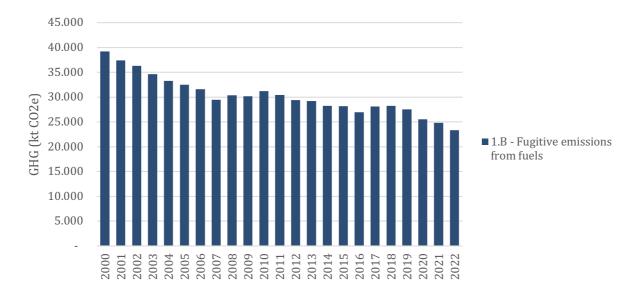


Figure 3 - 16 GHG emissions from fugitive gases in the energy sector (in kt CO₂e)



3.6.1. Fugitives Emissions from Coal Production (1.B.1)

3.6.1.1. Category Description

The BTR1 Report continues to employ the IPCC-2006 methodology, which categorizes all calculations of fugitive CH₄ emissions from coal production as originating from surface mines with a maximum depth of 25 meters.

3.6.1.2. Trends in Greenhouse Gas Emissions by Category

Indonesia possesses substantial coal resources, amounting to 33 billion tons as of 2022. Coal production has been consistently promoted to stimulate national economic growth, rising from 47 million toe in 2000 to 347 million toe in 2022 (Figure 3 - 17). In 2000, approximately 76% of coal production was designated for export, which declined to 68% by 2022.

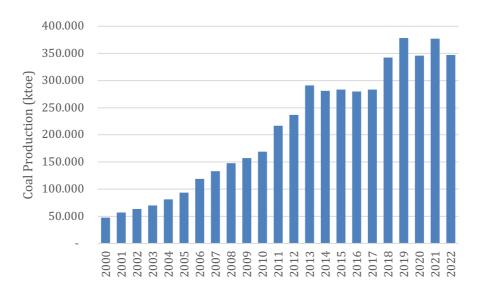
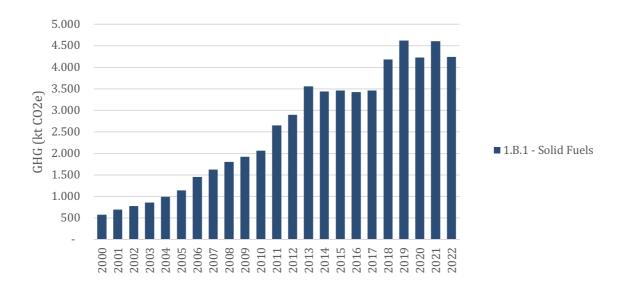


Figure 3 - 17 Coal production during 2000 - 2022 (processed from coal production in the HEESI Energy Balance Table) (in ktoe)

According to the IPCC-2006 methodology, coal production in surface mines with a maximum depth of 25 meters generated GHG emissions of 578.11 kt CO₂e in 2000, which rose to 4,243.97 kt CO₂e in 2022, representing a 7.34-fold increase over this period (Figure 3 - 18).



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Figure 3 - 18 Fugitive emissions from coal production 2000 – 2022 (in kt CO₂e)

3.6.1.3. Methodological Issues

According to the IPCC-2006 methodology, coal production in surface mines with a maximum depth of 25 meters generated GHG emissions of 578 kt CO₂e in 2000, which rose to 4,243.97 kt CO₂e in 2022, representing a 7.34-fold increase over this period.

3.6.1.4. Uncertainty Assessment and Time-Series Consistency

The uncertainty assessment utilized Approach 1 for error propagation. The calculation of GHG emissions employs Tier 1, resulting in the uncertainty of the EF being based on IPCC-2006 defaults. The uncertainty of AD was assessed through expert judgment, incorporating input from data stakeholders at the Directorate of Coal Engineering and Environment of MEMR and the Data and Information Center of MEMR.

3.6.1.5. Category-Specific QA/QC and Verification

The AD for GHGI calculation is obtained from HEESI. HEESI data is collected in a hierarchical manner, beginning with business entities reporting to technical units (oil and gas) via reporting systems or manual methods. This is followed by annual data reconstruction from technical units in collaboration with business entities, which is documented in official records, thereby complying with the MEMR's One Data policy. Official records indicate the application of QC and QA in the collection of AD. The Data and Information Center of MEMR, as a stakeholder in GHGI calculations, conducts data cross-checks and GHGI calculations in accordance with the relevant worksheets.

3.6.1.6. Category-Specific Recalculations

No specific recalculations were performed in this BTR1 Report.



3.6.1.7. Plan of Improvements

- GHGI calculations for fugitive sub-sectors 1B1aii1 (mining) and 1B1aii2 (post-mining) utilize the surface mining approach. Coal production occurred prior to 2000 through underground mining; therefore, when the GHGI reporting data series commences in 1990, fugitive emissions must be calculated utilizing the underground mining methodology.
- Open-pit coal mining has persisted for an extended period, leading to considerable removal of coal overburden. This condition may lead to open-pit depths surpassing 25 meters, requiring EF replacement and recalculation for the complete series of the reporting year.
- The assessment of coal fugitive emissions ought to be retroactively applied to 1990.
- Coal fugitive emission calculations must utilize the most recent fugitive EFs as outlined in the 2019 Refinement to the IPCC-2006 guidelines.

3.6.2. Fugitive Emissions from Oil and Natural Gas Production (1.B.2)

3.6.2.1. Category Description

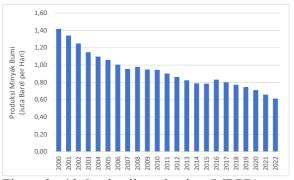
Fugitive emissions associated with crude oil and natural gas production, as well as the upgrading, transportation, processing, transmission, and distribution of petroleum products and natural gas to consumers, fall under sub-sectors 1B2a and 1B2b. The extent of fugitive emissions is indirectly indicated by national production levels of crude oil and natural gas, while also considering the impact of crude oil imports for refinery processing.

3.6.2.2. Trends in Greenhouse Gas Emissions by Category

According to HEESI 2023 data, crude oil production has exhibited a decline of 0.92% annually from 2000 to 2022, decreasing from 1.42 million barrels per day to 0.61 million barrels per day. The decrease in crude oil production results from the aging of wells and the restricted rate of new oil reserve discoveries.

Conversely, natural gas production has undergone a decline rate of roughly 0.92% annually, decreasing from 7.95 BCFD in 2000 to 6.49 BCFD in 2022 (Figure 3 - 19). The decline in production is attributed to the aging of wells, despite a notable increase in natural gas production in 2010, which has since experienced a gradual decrease. As of now, Indonesia has not engaged in the importation of natural gas, making the trend of GHG emissions closely related to the trend of natural gas production (Figure 3 - 20).





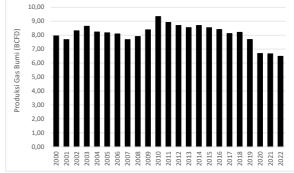


Figure 3 - 19 Crude oil production (MBPD)

Figure 3 - 20 Natural gas production (BCFD)

The conditions of national crude oil and natural gas production have resulted in a notable reduction in fugitive emissions from crude oil production (1B2a) and natural gas production (1B2b), averaging a decrease of 3.15% annually. Fugitive emissions from national oil and gas production declined from 38,593.92 kt CO₂e in 2000 to 19,064.71 kt CO₂e in 2022 (Figure 3 - 21).

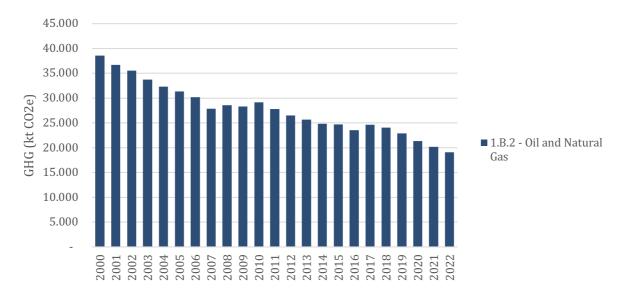


Figure 3 - 21 Fugitive emissions from oil and natural Gas, 2000 – 2022

3.6.2.3. Methodological Issues

The methodology for calculating GHG emissions in the industry sub-sector is sound, utilizing Equation 4.2.2 from IPCC-2006 with Tier 1 EFs.

3.6.2.4. Uncertainty Assessment and Time-Series Consistency

Approach 1 for error propagation. GHG emission calculations were conducted using Tier 1, with the EF uncertainty based on the IPCC-2006 default. The uncertainty of AD was assessed using expert judgment, incorporating input from data stakeholders at the Directorate of Oil and Gas Engineering and Environment of MEMR and the Data and Information Center of MEMR.



3.6.2.5. Category-Specific QA/QC and Verification

AD for GHGI calculation is obtained from HEESI. HEESI data is collected in a hierarchical manner, beginning with business entity reporting to technical units (oil and gas) via reporting systems or manual methods. This is followed by annual data reconciliation between technical units and business entities, which is documented in official records, thereby complying with the MEMR's One Data policy. Official records indicate the application of QC and QA in the collection of AD. The Data and Information Center of MEMR, as a stakeholder in GHGI calculations, conducts data cross-checks and GHGI calculations in accordance with the relevant worksheets.

3.6.2.6. Category-Specific Recalculations

No recalculations were conducted in the assessment of fugitive emissions associated with oil and gas production, upgrading, transportation, processing, and distribution of petroleum products and natural gas in this BTR1 Report.

3.6.2.7. Plan of Improvements

- The calculation of coal fugitive emissions should be extended back to 1990.
- Oil and gas fugitive emission calculations should use the latest fugitive EFs in accordance with the 2019 Refinement to the IPCC-2006.



IV. INDUSTRIAL PROCESSES AND PRODUCT USE (CRT SECTOR 2)

This category includes GHG emissions from: (i) mineral production, such as cement, lime, glass, and other carbonate processes (ceramics and soda ash); (ii) chemical production, including ammonia, nitric acid, carbide, and petrochemicals (methanol, ethylene, ethylene dichloride, and carbon black); (iii) metal production (iron and steel, aluminum, lead, and zinc); (iv) non-energy fuel products and solvent use (lubricants and paraffin wax); and (v) other uses, specifically carbon This chapter presents information on Category Description, Methodological Issues, Uncertainty Assessment and Time-Series Consistency, Category-Specific QA/QC and Verification, Recalculation of Certain Categories, and Plans for Improvement for each category within this sector.

4.1. General Overview (CRT Sector 2)

4.1.1. Sector Description

GHG emissions from IPPU include CO₂, CH₄, N₂O, and perfluorocarbons (PFCs), specifically CF₄ and C₂F₆. GHG emissions from IPPU comprises emissions from industrial processes and product use. Industrial processes include Mineral Industry (2.A), Chemical Industry (2.B), Metal Industry (2.C), Non-Energy Products from Fuels and Solvent Use (2.D), and Other (2.H).

Emissions from Electronics Industry (2E) are not occurs as most of these industries are not produced Integrated Circuit or Semiconductor, TFT Flat Panel Display, Photovoltaics, Heat Transfer Fluid, and Others Most of these industries are assembly industries.

Emissions from the use of Non-energy Products from Fuels and Solvent Use (2D) covers Lubricant Use (2D1), Paraffin Wax Use (2D2) but does not include Solvent Use (2D3) due to limited information of solvent use in Indonesia. From processes within the electronic at present, emissions industry remain.

GHG emissions from chemical production activities, namely adipic acid, caprolactam, glyoxal, titanium oxide, and soda ash industries, are excluded from the scope of the NGHGI, as these industries do not operate within Indonesia. Furthermore, sources of GHG emissions from ferroalloy, electronics, and other manufacturing products, including solvents and other product use, are no longer quantified due to challenges in data acquisition.

GHG emissions associated with the use of ozone-depleting substance substitutes, such as HFCs and SF₆ gases, are excluded from this GHGI and will be reported only after January 2029.

4.1.2. Categories and Total Emissions

In 2022, GHG emissions from the IPPU sector were quantified as 56,337.73 kt CO₂, 3.67 kt CH₄, and 3.27 kt N₂O (Table 4- 1). Data indicates that CO₂ emissions represent the predominant category of greenhouse gases, constituting 98% of total emissions from industrial processes, i.e. cement, ammonia production, iron and steel industries.

Table 4-1 Summary of GHG emissions from the IPPU sector in 2022

Code	GHG Source Categories	CO ₂ (kt)	CH ₄ (kt)	N ₂ O (kt)	PFCs (ktCO ₂ e)
2A	Mineral Industry	31,480.03	NO	NO	NO
2B	Chemical Industry	9.366,80	3,67	3,27	NO
2C	Metal Industry	10.981,37	0	NO	55,61
2D	Non-Energy Products from	4.358,07	0	0	NO
	Fuels and Solvent Use				
2E	Electronics Industry	NO	NO	NO	NO
2F	Product Uses as Substitutes	FX	FX	FX	FX
	for Ozone-Depleting				
	Substances				
2G	Other Product Manufacture	NO	NO	NO	NO
	and Use				
2H	Other	151,45			

In sub-sector 2F Ozone-Depleting Substances (ODS) Substitutes, emissions were not included in the First Biennial Transparency Report (BTR1) and will be reported subsequent to January 2029. Consequently, sub-sector 2F may be classified as flexibility (FX). In 2022, total IPPU emissions amounting to 57,361.63 CO₂e.

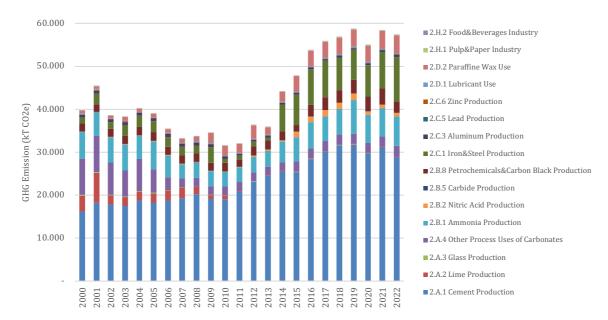


Figure 4- 1 GHG emissions from the IPPU sector in 2000 – 2022 (in kt CO₂e)

In 2022, emissions from the IPPU sector, ranked from largest to smallest, are attributed to the mineral industry, metal industry, chemical industry, non-energy products from fuels and solvent use, and other categories. In the IPPU sector, emissions are primarily composed of CO₂, accounting for 98.22%, followed by CH₄ at 0.18%, N₂O at 1.51%, and a minor contribution of PFCs from the aluminum industry. From 2000 to 2010, emissions in the industrial sector exhibited fluctuations, influenced by a decline in national growth performance within the manufacturing sector, which fell below the overall economic growth rate.

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Consequently, this resulted in a reduction in production capacity within the industry. Following 2010, there was a notable rise in production, with the exception of 2020, which saw a decrease attributed to the COVID-19 pandemic. Subsequently, it experienced an increase once more.

Table 4- 2 IPPU sector emissions by type of ghg (kt CO₂e)

GHG	2000	2005	2010	2015	2019	2022
CO_2	39,264.41	38,448.83	31,204.09	46,433.64	56,948.96	56,337.73
CH ₄	131,71	159,60	110,42	70,56	124,75	102,84
N ₂ O	127,59	127,59	76,64	1.291,89	1.561,11	865,45
PFCs	281,23	281,23	159,17	51,15	46,74	55,61

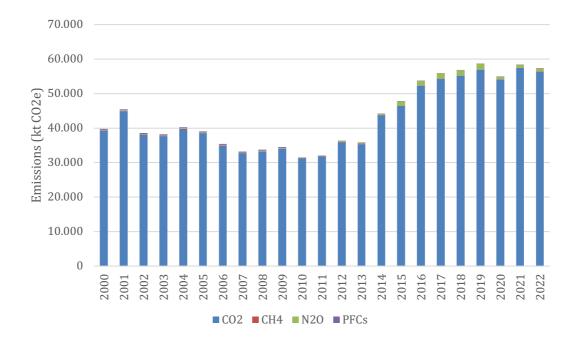


Figure 4- 2 GHG emissions from the IPPU sector (CRT 2) by gas type from 2000 - 2022

4.1.3. Methodological Issues

The methodology employed for calculating these GHG emissions follows the approach outlined in the 2006 IPCC Guidelines. Table 4 - 3 presents the depth of the method and the EFs applied to each IPPU sector category and type of GHG.

Table 4 - 3 Summary of methods and emission factors for IPPU sector in 2000-2022

Category	Emission Factor	Source
2A1 Cement Production	Country-Specific	2006 IPCC GL, Equation 2.3 Volume 3, Chapter 2

Category	Emission Factor	Source
2A2 Lime Production	IPCC 2006 default value	2006 IPCC GL, Table 2.5 Volume 3, Chapter 2
2A3 Glass production	IPCC 2006 default value	2006 IPCC GL, Table 2.6 Volume 3, Chapter 2
2A4 Other Process Uses of Carbonates	IPCC 2006 default value	2006 IPCC GL, Table 2.7 Volume 3, Chapter 2
2B1 Ammonia Production	Country-Specific	2006 IPCC GL, Table 3.1 Volume 3, Chapter 3
2B2 Nitric Acid Production	IPCC 2006 default value	2006 IPCC GL, Table 3.3 Volume 3, Chapter 3
2B5 Carbide Production	IPCC 2006 default value	2006 IPCC GL, Table 3.8 Volume 3, Chapter 3
2B8 Petrochemical & Carbon Black Production	IPCC 2006 default value	2006 IPCC GL, Table 3.27 Volume 3, Chapter 3
2C1 Iron and Steel Production	IPCC 2006 default value	2006 IPCC GL, Table 4.4 Volume 3, Chapter 4
2C3 Aluminium Production	IPCC 2006 default value	2006 IPCC GL, Table 4.15 Volume 3, Chapter 4
2C5 Lead Production	IPCC 2006 default value	2006 IPCC GL, Table 4.23 Volume 3, Chapter 4
2C6 Zinc Production	IPCC 2006 default value	2006 IPCC GL, Table 4.25 Volume 3, Chapter 4
2D1 Lubricant Use	IPCC 2006 default value	2006 IPCC GL, Table 5.2 Volume 3, Chapter 5
2D2 Paraffin Wax Use	IPCC 2006 default value	2006 IPCC GL, Table 5.3 Volume 3, Chapter 5
2H1 Pulp and Paper Industry	IPCC 2006 default value	2006 IPCC GL
2H2 Food and Beverage Industry	IPCC 2006 default value	2006 IPCC GL

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GHG emissions from the cement and ammonia production sectors for the period 2000-2022 are estimated using Tier 2 methodologies, whereas other sectors utilize Tier 1 by applying the default EFs provided in the 2006 IPCC Guidelines.

The data utilized to estimate GHG emissions primarily comprises production figures sourced from the PIH (*Pusat Industri Hijau*) and Pusdatin of the Ministry of Industry, the Industrial Statistics Report published by BPS, and the Energy Handbook released by the MEMR.

4.1.4. Uncertainty Assessment and Time-Series Consistency

A quantitative assessment of uncertainty utilizing the error propagation approach has been conducted, estimating the uncertainty trend for the IPPU sector in sub-categories 2A, 2B, 2C, 2D, and 2H to reach 6.1%. The Annex contains details regarding the uncertainty table for the IPPU sector.

4.2. Mineral Industry (2.A)

4.2.1. Category Description

Emissions from the mineral industry encompass those associated with chemical processes in cement (clinker production), lime, glass, and industrial activities involving carbonates, such as ceramics, soda ash, and other carbonate consumption. The application of carbonates in the

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production of non-metallurgical magnesia and related processes is not assessed, as they are not utilized in Indonesia. Figure 4 - 3 below illustrates GHG emissions from the mineral industry sub-sector.

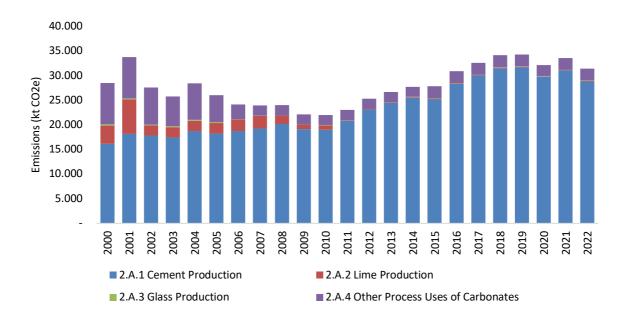


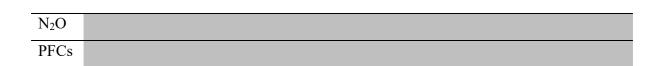
Figure 4 - 3 GHG emissions from mineral industry sub-sector in 2000 – 2022 (in kt CO₂e)

4.2.2. Trends in Greenhouse Gas Emissions by Category

The mineral industry represents the predominant source of emissions within the IPPU category, contributing 55% of total emissions from this sector. In 2022, GHG emissions from the mineral industry totaled 31,480.03 kt CO₂e, with 92% attributed to the cement industry, 8% to other carbonate processes, 0.3% to lime production, and 0.1% to glass production. The cement industry constitutes the predominant component of the mineral industry sub-sector, accounting for 92% of its contribution. The cement industry exhibited a growth rate of 5.8% from 2010 to 2019, followed by a decline during 2020-2021 attributed to the COVID-19 pandemic. Emissions from the lime industry saw a notable reduction in 2011, attributed to a considerable drop in production data relative to the prior year. Emissions from glass production and the utilization of carbonates in the mineral industry have shown minor fluctuations in production levels, with both increases and decreases observed.

Table 4 - 4 Trend of GHG emissions from mineral industry sub-sector by gas type (kt CO₂e)

GHG	2000	2005	2010	2015	2019	2022
CO ₂	28,523.25	26,035.40	22,032.08	27,848.78	34,332.10	31,480.03
CH ₄						



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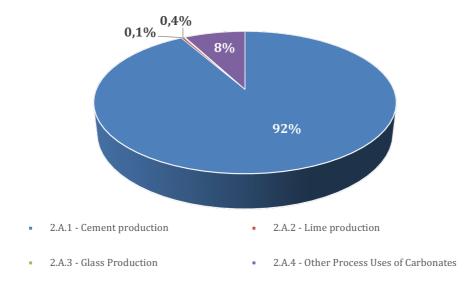


Figure 4 - 4 Percentage of GHG emissions from mineral industry in 2022

4.2.3. Methodological Issues

The assessment of GHG emissions in the mineral sector employs the Tier 1 methodology outlined in the 2006 IPCC Guidelines, with the exception of the cement industry, which utilizes the more advanced Tier 2 approach. The table below presents the methods and EFs applied according to sub-categories and types of GHG.

Table 4 - 5 Summary of methods and emission factors for mineral industry sub-sector in 2000-2022

Category	Method	Emission Factor
2A1 Cement Production	Tier 2	2006 IPCC GL, Equation 2.2 Volume 3, Chapter 2
2A2 Lime Production	Tier 1	2006 IPCC GL, Table 2.5 Volume 3, Chapter 2
2A3 Glass Production	Tier 1	2006 IPCC GL, Table 2.6 Volume 3, Chapter 2
2A4 Other process uses of carbonates	Tier 1	2006 IPCC GL, Table 2.7 Volume 3, Chapter 2

Emissions from the cement industry are estimated using Tier 2 (Equation 2.2 from Chapter 2 of Volume 3 of the 2006 IPCC Guidelines), in which the emissions is calculated using plant level data of clinker production as well as correction factor for CKD and composition of carbonate used as raw material. The correction factor for CKD employed the default value of IPCC 2006 Guidelines, in which the CKD value is 1.02. Emission from cement in the previous NGHI was estimated using cementitious production data and emissions factor of cementitious

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provided by industries. However, this method does not cover emissions from clinker that are exported.

Emissions from mineral industries including lime, glass, and other carbonate are calculated using Tier 1 of the 2006 IPCC Guidelines.

4.2.4. Uncertainty Assessment and Time-Series Consistency

The uncertainty values for EFs and other parameters in the uncertainty assessment for the mineral industry category are derived from Table 2-3 (cement industry), Table 2-5 (lime industry), Table 2-6 (glass/glass industry), and Table 2-7 (other process uses of carbonates) in Volume 3, Chapter 2 of the 2006 IPCC Guidelines (Table 4-6). The proposed improvements in emission calculations involve enhancing the continuity and coherence of AD at the plant level, as well as developing national EFs for additional sub-sectors within the mineral industry at the plant level.

Table 4 - 6 Mineral industry uncertainty assessment

2006 IPCC Categories	Gas	Base Year Emissions Or Removals (Gg CO ₂ e)	Year T Emissions Or Removals (Gg CO ₂ e)	Activity Data Uncertai nty (%)	Emissi on Factor Uncert ainty (%)	Combi ned Uncert ainty (%)	Contribut ion to Variance by Category in Year T	Inventory Trend In National Emissions For Year T Increase With Respect To Base Year (% Of Base Year)	Uncertai nty Introduc ed into The Trend In Total National Emissio ns (%)
2.A.1 - Cement production	CO_2	16,174.11	28,876.76	2.00	5.00	5.39	7.35	178.54	4.70
2.A.2 - Lime production	CO_2	3,688.15	112.55	10.00	2.00	10.20	0.00	3.05	0.07
2.A.3 - Glass Production	CO_2	245.31	45.58	10.00	10.00	14.14	0.00	18.58	0.01
2.A.4 - Other Process Uses of Carbonates	CO ₂	8,415.69	2,445.14	17.32	17.32	24.49	0.34	29.05	5.36

Notes:

Base year for trend uncertainty assessment: 2000, year T: 2022

4.2.5. Category-Specific QA/QC and Verification

In the IPPU sector, QC activities are conducted by the industry sub-sector during the inventory calculation and compilation process. This includes general methods such as verifying the accuracy of data acquisition and calculations, employing standard procedures for emissions and calculations, conducting measurements, estimating uncertainty, and archiving and reporting information. The industry sub-sector submits AD and EFs to the Ministry of Industry via the online reporting system SIINAS.

The Ministry of Industry performs reviews and validations to confirm that EFs and AD are developed in line with established measurement methods and IPCCGL2006. Additionally, it

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conducts KCA to identify the primary emission and sink sources within the sector. The identified key categories will serve as the foundation for quality improvement initiatives in the GHGI.

The Ministry of Industry, serving as the sector coordinator, will submit emission level data and associated QA/QC documents to the Ministry of Environment and Forestry, which is responsible for the NGHGI, via the SIGN SMART system or through direct reporting. The Ministry of Environment and Forestry, as the authority overseeing the NGHGI, will perform QA/QC by verifying emission level data, report formats, and other relevant information prior to submitting the NGHGI data to the UNFCCC.

4.2.6. Category-Specific Recalculations

Recent updates in AD have led to the recalculation of emissions in the cement industry (2A1) for the period 2000 to 2022. Emissions from other industries, specifically the lime industry (2A2), glass (2A3), and various processes utilizing carbonates (ceramics (2A4a), soda ash (2A4b), and other carbonate consumption (2A4d)), remained unchanged in AD.

In the BTR1 reporting, the calculation of GHG emissions from the mineral industry (2A) utilized GWP AR5, in contrast to the previous BUR3 Report, which employed GWP SAR for the emission calculation.

4.2.7. Plan of Improvements

Enhancement of Tier 2 EFs for the cement sector (2A1) through the refinement of the CKD correction factor. Currently, in the absence of data to determine the CKD correction factor, the default value of 1.02 is employed to adjust for CO₂ emissions from CKD, as stipulated by IPCCGL 2006. The improvement plan involves quantifying the CKD released from the system and analyzing the carbonate content within the CKD to derive a more accurate CKD correction factor. The current default IPCC CKD figure of 1.02 remains in use due to the absence of data regarding the quantity of CKD released from the system and the carbonate fraction within the CKD.

4.3. Chemical Industry (2.B)

4.3.1. Category Description

Emissions from the chemical industry encompass ammonia, nitric acid, carbides, adipic acid, caprolactam, glyoxal, glyoxylic acid, titanium dioxide, natural soda ash production, and petrochemicals such as methanol, ethylene, ethylene dichloride, ethylene oxide, and carbon

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black. In certain industries, including adipic acid, caprolactam, glyoxal, glyoxylic acid, titanium dioxide, and soda ash, GHG emissions are not estimated due to the absence of these industries in Indonesia. The current availability and utilization of these products are sourced from imports. The GHG emissions inventory in BTR1 encompasses the ammonia, nitric acid, carbide, methanol, ethylene, ethylene dichloride, ethylene oxide, and carbon black sectors. Figure 4 - 5 below illustrates GHG emissions from the chemical industry.

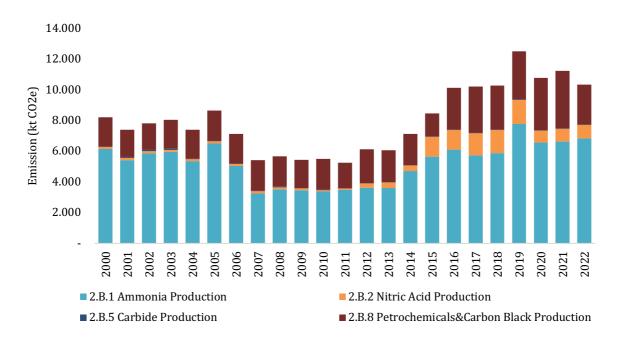


Figure 4 - 5 GHG emissions from chemical industry sub-sector in 2000 – 2022 (in kt CO₂e)

4.3.2. Trends in Greenhouse Gas Emissions by Category

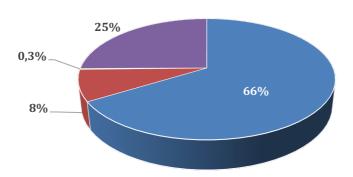
The chemical industry contributes to emissions within the IPPU category, representing 18% of the total emissions from this sector. In 2022, GHG emissions from the chemical industry totaled 10,335.09 kt CO₂e. Of this, 66% originated from the ammonia sector, 25% from petrochemicals and carbon black, 8% from nitric acid, and 0.3% from carbides. The emissions contribution percentage in the chemical industry sub-sector comprises 66% from the ammonia industry, along with contributions from the petrochemical and carbon black industries, nitric acid, and carbides.

Table 4 - 7 Summary of GHG emissions from chemical industry sub-sector in 2022 (in kt CO₂e)

GHG	2000	2005	2010	2015	2019	2022
CO_2	7,989.16	8,421.04	5,345.98	7,103.36	10,821.56	9,366.80
CH ₄	93.75	96.05	80.07	70.56	123.08	102.84

N ₂ O	127.59	127.59	76.64	1,291.89	1.561.11	865.45
PFCs						

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- 2.B.1 Ammonia Production
- 2.B.2 Nitric Acid Production
- 2.B.5 Carbide Production
- 2.B.8 Petrochemical and Carbon Black Production

Figure 4 - 6 Percentage of chemical industry sub-sector emissions in 2022

4.3.3. Methodological Issues

The assessment of GHG emission levels in BTR1 is distinct from those reported in BUR3. In BUR3, emissions from ammonia production were determined using plant data and EFs corresponding to the technology type in each industry, following the IPCC 2006 Tier 2 methodology. The Global Warming Potential utilized in BUR3 was GWP SAR. The BTR1 calculation employs AD derived from ammonia and urea production, utilizing Tier and EFs according to the technology type outlined in the IPCC 2006 Guidelines. The Global Warming Potential utilized in the BTR1 calculation is AR 5. The IPCC 2006 software does not currently support Tier 2 calculations. Therefore, to conduct a Tier 2 calculation for the ammonia industry, it is necessary to adjust the urea production data input to ensure that the CO₂ recovery data aligns with the plant measurement data.

4.3.4. Uncertainty Assessment and Time-Series Consistency

The uncertainty values for EFs and other parameters in the uncertainty assessment for the chemical industry category are derived from Table 3-1 (ammonia industry), Table 3-3 (nitric acid industry), Table 3.8 (carbide industry), and Table 3-27 (petrochemicals and carbon black) in Volume 3, Chapter 3 of the 2006 IPCC Guidelines (Table 4-8).

Table 4 - 8 Uncertainty assessment for chemical industry

2006 IPCC Categories	Gas	Base Year Emissions Or Removals (Gg CO ₂ e)	Year T Emissions Or Removals (Gg CO ₂ e)	Activit y Data Uncert ainty (%)	Emissi on Factor Uncert ainty (%)	Combi ned Uncert ainty (%)	Contribut ion to Variance by Category in Year T	Inventory Trend In National Emissions For Year T Increase With Respect To Base Year (% Of Base Year)	Uncertai nty Introduc ed into The Trend In Total National Emissio ns (%)
2.B.1 - Ammonia Production	CO_2	6,139.06	6,846.42	10.00	6.00	11.66	1.94	111.52	6.01
2.B.2 - Nitric Acid Production	N_2O	127.59	865.45	2.00	10.00	10.20	0.02	678.31	0.03
2.B.5 - Carbide Production	CO_2	24.47	26.25	10.00	10.00	14.14	0.00	107.29	0.00
2.B.8 - Petrochemical and Carbon Black Production	CO ₂	1,825.63	2,494.13	24.49	22.36	33.17	0.18	136.62	0.34
2.B.8 - Petrochemical and Carbon Black Production	CH4	93.75	102.84	22.36	22.36	31.62	0.00	109.70	0.00

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Notes:

Base year for uncertainty assessment in the trend: 2000, year T: 2022

4.3.5. Category -Specific QA/QC and Verification

Refer to the above sub-chapter 4.2.5.

4.3.6. Category-Specific Recalculations

Ammonia industry emissions (2B1) have been recalculated for the years 2000 to 2022, following updates in AD and EFs. The data source for the previous activity has shifted from the NGHGI to SIINAS data. The EF data utilized in the NGHGI was derived from the default Intergovernmental Panel on Climate Change (IPCC) 2006 guidelines (Tier 1). Enhancements were implemented utilizing EFs from the industry (Tier 2). For the GHG emissions calculation from 2000 to 2009, the EF figures were derived through extrapolation due to the unavailability of data on natural gas consumption (feedstock + fuel) by ammonia plants. Emissions from other industries, specifically the nitric acid industry (2B2), the carbide industry (2B3), and the petrochemical and carbon black industry (2B8), remained unchanged in AD. In the BTR1 Report, the calculation of GHG emissions from the mineral industry (2B) utilized GWP AR5, in contrast to the previous BUR3 Report, which employed GWP SAR for emissions calculation. The proposed improvements for the ammonia industry sub-sector involve integrating a higher Tier calculation methodology within the IPCC software, given that emissions calculations at the national level for this sub-sector are currently utilizing Tier 2.

4.3.7. Plan of Improvements

Improvements are required for the IPCC 2006 software utilized in calculating GHG emissions from ammonia production facilities. At present, the Tier 1 method is the sole option available.

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4.4. Metal Industry (2.C)

4.4.1. Category Description

The 2006 IPCC Guidelines categorize the metal industry into several sectors, including iron and steel, ferroalloy, aluminum, magnesium, lead, and zinc. The GHGI for the metal industry is limited to the production activities of iron and steel, aluminum, lead, and zinc. This is due to the unavailability of data for the other industries. Figure 4-7 below illustrates the trend of greenhouse gas emissions from the metal industry sub-sector.

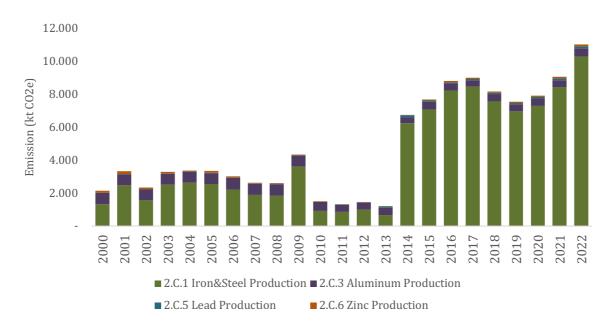


Figure 4- 7 GHG emissions from metal industry sub-sector in 2000 – 2022 (in kt CO₂e)

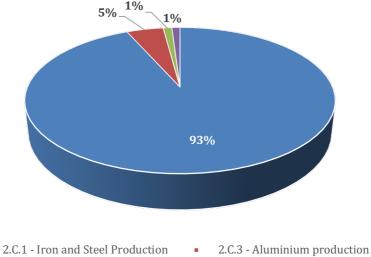
4.4.2. Trends in Greenhouse Emissions by Category

The metal industry contributes to emissions within the IPPU category, representing 19% of the total emissions from this sector. In 2022, greenhouse gas emissions from the metal industry totaled 11,036.98 kt CO₂e, with 93% attributed to the iron and steel sector, 5% to aluminum, and 1% each to lead and zinc. The predominant source of emissions within the metal industry is the iron and steel sector. In 2014, production data in the iron and steel industry increased, coinciding with the commencement of operations by PT Krakatau Posco, resulting in a rise in total national production for the sector.

Table 4 - 9 Summary of GHG Emissions from the Metal Industry Sub-sector in 2022

GHG	2000	2005	2010	2015	2019	2022
CO ₂	1,828.43	2,999.86	1,312.91	7,646.49	7,514.47	10,981.37
CH ₄	37.96	63.56	30.34	0	1.67	0
N ₂ O						

GHG	2000	2005	2010	2015	2019	2022
PFCs	281.23	281.23	159.17	51.15	46.74	55.61



- 2.C.5 Lead Production
- 2.C.6 Zinc Production

Figure 4 - 8 Percentage of metal industry sub-sector emissions in 2022

4.4.3. Methodological Issues

The assessment of GHG emission levels in BUR3 and BTR1 for the metal industry employs a consistent methodology, specifically IPCC 2006 Tier 1. The sole distinction lies in the GWP utilized. BUR3 employed SAR, whereas BTR1 utilized AR5.

4.4.4. Uncertainty Assessment and Time-Series Consistency

The uncertainty values for EFs and other parameters in the uncertainty assessment for the metal industry category are derived from Table 4-4 (iron and steel industry), Table 4-15 (aluminum industry), Table 4-23 (lead industry), and Table 4-25 (zinc industry) in Volume 3, Chapter 4 of the 2006 IPCC Guidelines (Table 4 - 10).

Table 4 - 10 Uncertainty Assessment for the Metal Industry

2006 IPCC Categories	Gas	Base Year Emissions Or Removals (Gg CO ₂ e)	Year T Emissions Or Removals (Gg CO ₂ e)	Activity Data Uncertainty (%)	Emission Factor Uncertaint y (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Inventory Trend In National Emissions For Year T Increase With Respect To Base Year (% Of Base Year)	Uncertainty Introduced into The Trend In Total National Emissions (%)
2.C.1 - Iron and Steel Production	CO_2	1,301.76	10,303.58	10.00	10.00	14.14	6.45	791.51	17.88
2.C.1 - Iron and Steel Production	CH ₄	37.96	-	10.00	10.00	14.14	-	-	0.00
2.C.3 - Aluminum production	CO_2	384.00	447.32	2.00	5.00	5.39	0.00	116.49	0.00
2.C.3 - Aluminum production	CF4	254.59	55.61	2.00	5.00	5.39	0.00	21.84	0.00
2.C.3 - Aluminum production	C2F6	26.64	-	2.00	5.00	5.39	-	-	0.00
2.C.5 - Lead Production	CO_2	19.05	118.83	10.00	10.00	14.14	0.00	623.77	0.00
2.C.6 - Zinc Production	CO_2	123.62	111.64	10.00	10.00	14.14	0.00	90.31	0.00

Notes:

Base year for uncertainty assessment in the trend: 2000, year T: 2022

4.4.5. Category-Specific QA/QC and Verification

Refer to the above sub-chapter 4.2.5.

4.4.6. Category-Specific Recalculations

No recalculation.

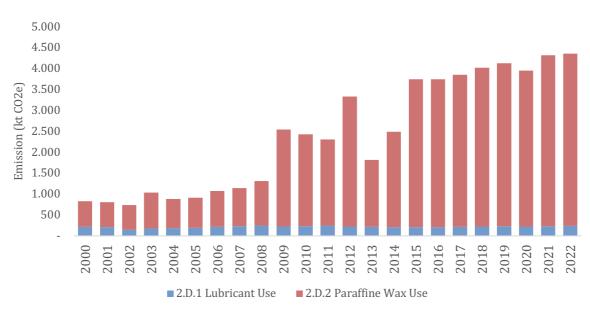
4.4.7. Category-Specific Plan of Improvements

There is no plan of improvements.

4.5. Use of Non-Energy Products from Fuels and Solvents: Lubricants and Paraffin (2.D)

4.5.1. Category Description

This category encompasses lubricants, waxes/paraffin, and solvents. Figure 4 - 9 below illustrates the emissions associated with this 3D category.



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Figure 4 - 9 GHG emissions from product use sub-sector in 2000 – 2022 (in kt CO₂e)

4.5.2. Trends in Greenhouse Gas Emissions by Category

The product use category contributes to emissions within the IPPU sector, representing 8% of the total emissions in this category. In 2022, greenhouse gas emissions from the product use category amounted to 4,358.07 kt CO₂e, with 6% attributed to lubricants and 94% to waxes/paraffin and solvents.

Table 4 - 11 Summary of GHG emissions from non-energy product use and solvent sub-sector in 2022

GHG	2000	2005	2010	2015	2019	2022
CO ₂	831.33	913.52	2,424.46	3,746.39	4,125.97	4,358.07
CH ₄						
N ₂ O						
PFCs						

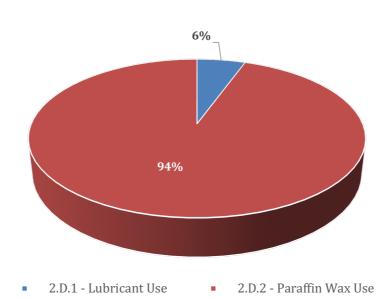


Figure 4 - 10 Percentage of emissions from non-energy product use and solvent sub-sector In 2022

4.5.3. Methodological Issues

The assessment of GHG emission levels in BUR3 and BTR1 for lubricants and paraffin employs a consistent methodology, specifically the IPCC 2006 Tier 1 approach. The sole distinction lies in the GWP utilized. BUR3 employed SAR, whereas BTR1 utilized AR5.

4.5.4. Uncertainty Assessment and Time-Series Consistency

The uncertainty values for EFs and other parameters related to the product use category are derived from Table 5-2 for lubricants and Table 5-2 for paraffin in Volume 3, Chapter 5 of the 2006 IPCC Guidelines (Table 4 - 12)

Table 4 - 12 Uncertainty assessment for the use of lubricant and paraffin products

2006 IPCC Categories	Gas	Base Year Emissions Or Removals (Gg CO ₂ e)	Year T Emissions Or Removals (Gg CO ₂ e)	Activit y Data Uncert ainty (%)	Emissi on Factor Uncert ainty (%)	Combi ned Uncert ainty (%)	Contribut ion to Variance by Category in Year T	Inventory Trend In National Emissions For Year T Increase With Respect To Base Year (% Of Base Year)	Uncertai nty Introduc ed into The Trend In Total National Emissio ns (%)
2.D - Non-Energy Products from Fuels and Solvent Use	CO_2	831.33	4,358.07	14.14	14.14	20.00	1.00	524.23	2.80

Notes:

Base year for uncertainty assessment in the trend: 2000, year T: 2022

4.5.5. Category-Specific QA/QC and Verification

Refer to the above sub-chapter 4.2.5.



4.5.6. Category-Specific Recalculations

No recalculation.

4.5.7. Plan of Improvements

There is no plan of improvements.

4.6. Other Production: Pulp and Paper, Food and Beverages (2.H)

4.6.1. Category Description

GHG emissions from the other industry category include emissions related to the use of carbonates during production activities in the pulp/paper and food/beverage industries. In the pulp/paper industry, carbonates are used in the lime kiln process and the make-up chemical process for the lime kiln. Although the amount of carbonate used is not significant, these processes still release GHG emissions into the atmosphere. The emissions from the other industry sub-sector can be seen in the figure below.

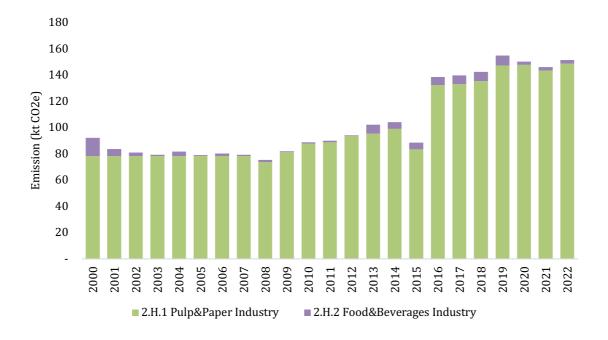


Figure 4 - 11 GHG Emissions from other industry sub-sector, 2000 – 2022 (in kt CO₂e)

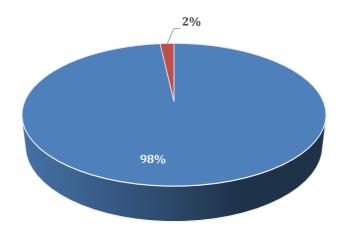
4.6.2. Trends in Greenhouse Gas Emissions by Category

The product use category generates emissions in the IPPU category, accounting for 0.3% of the total IPPU sector emissions. In 2022, GHG emissions from the product use category contributed 151.46 kt CO₂e, with 98% coming from the pulp/paper industry, and 2% from the food/beverage industry.

Table 4 - 13 Summary of GHG emissions from other production sub-sector in 2022

GHG	2000	2005	2010	2015	2019	2022
CO_2	92.25	79.02	88.67	88.62	154.87	151.46
CH ₄						
N ₂ O PFCs						
PFCs						

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2.H.1 - Pulp and Paper Industry

2.H.2 - Food and Beverages Industry

Figure 4 - 12 Percentage of emissions from other production sub-sectors for the year 2022

4.6.3. Methodological Issues

The calculation of GHG emission levels in BUR3 and BTR1 for the use of carbonates in the pulp & paper, and food & beverage industries uses the same methodology, namely IPCC 2006 Tier 1. The only difference is the GWP used. BUR3 used SAR, while BTR1 used AR5.

4.6.4. Uncertainty Assessment and Time-Series Consistency

The uncertainty values for EFs and other parameters for the carbonate use category are based on Volume 3, Chapter 8 of the 2006 IPCC Guidelines (Table 4 - 14).

Table 4 - 14 Uncertainty assessment for other production

2006 IPCC Categories	Gas	Base Year Emissions or Removals (Gg CO ₂ e)	Year T Emissions or Removals (Gg CO ₂ e)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Inventory Trend in National Emissions for Year T Increase with Respect to Base Year (% of Base Year)	Uncertainty Introduced into the Trend in Total National Emissions (%)
2.H - Other	CO_2	92.25	151.46	14.14	2.83	14.42	0.00	164.19	0,00

Notes:

Base year for uncertainty assessment in the trend: 2000, year T: 2022



4.6.5. Category-Specific QA/QC and Verification

Refer to the above sub-chapter 4.2.5.

4.6.6. Category-Specific Recalculations

No recalculation.

4.6.7. Plan of Improvements

There is no plan of improvements.



V. AGRICULTURE (CRT Sector 3)

This category encompasses greenhouse gas emissions resulting from agricultural activities, including livestock and agricultural management, spanning the years 2000 to 2022. This chapter presents information on category description, methodological issues, uncertainty assessment and time-series consistency, category-specific QA/QC and verification, recalculations of certain categories, and improvement plans for each category within this sector.

5.1. General Overview (CRT Sector 3)

5.1.1. Sector Description

Agriculture, encompassing forestry and fisheries, is the second most significant economic activity following the manufacturing sector, contributing an average of 13.02% to Indonesia's GDP in 2022. Agriculture, in a narrow definition, accounts for 9.67% of GDP, derived from plantation crops (3.65%), food crops (2.70%), livestock (1.6%), horticulture (1.53%), and agricultural and hunting services (0.19%) (Ministry of Agriculture, 2023).

Category 3 encompasses emissions from the livestock sub-sector, specifically enteric fermentation (3.A) and manure management (3.B), as well as the agricultural management sub-sector, which includes emissions from rice cultivation (3.C), agricultural soils (3.D), savanna burning (3.E), agricultural residue burning (3.F), liming (3.G), and urea application (3.H). The greenhouse gas types produced from these activities include carbon dioxide (CO_2) , methane (CH_4) , and nitrous oxide (N_2O) .

5.1.2. Categories and Total Emissions

In 2022, greenhouse gas emissions from the agriculture sector totaled 6,206.43 kt CO₂, 3,078.48 kt CH₄, and 162.88 kt N₂O (Table 5- 1). Data indicate that CH₄ emissions represent the predominant GHG, comprising 63.58% of total emissions from the agricultural sector. Additional and comprehensive information regarding GHG emissions is available in the designated sections of each category.

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Table 5-1 Summary om GHG Emissions from Agriculture Sector in 2022

CO2	NO	Emissions (1) CO ₂ e (kt) 135,565.84 36,720.88 33,431.06 26,974.38 870.62 26,103.76 NA NA 1,781.05
Continue	NO	135,565.84 36,720.88 33,431.06 26,974.38 870.62 26,103.76 NA
3.A. Enteric fermentation 1,311.46 3.A.1. Cattle(3) 963.37 Option B (country-specific): 3.A.1.a. Other 963.37 3.A.1.a.i. Mature dairy cows 31.09 3.A.1.a.ii. Other mature cattle 932.28	NO	36,720.88 33,431.06 26,974.38 870.62 26,103.76 NA NA
3.A.1. Cattle ⁽³⁾ 963.37 Option B (country-specific): 963.37 3.A.1.a. Other 963.37 3.A.1.a.i. Mature dairy cows 31.09 3.A.1.a.ii. Other mature cattle 932.28		33,431.06 26,974.38 870.62 26,103.76 NA NA
Option B (country-specific):3.A.1.a. Other963.373.A.1.a.i. Mature dairy cows31.093.A.1.a.ii. Other mature cattle932.28		26,974.38 870.62 26,103.76 NA NA
3.A.1.a. Other 963.37 3.A.1.a.i. Mature dairy cows 31.09 3.A.1.a.ii. Other mature cattle 932.28		870.62 26,103.76 NA NA
3.A.1.a.i. Mature dairy cows 31.09 3.A.1.a.ii. Other mature cattle 932.28		870.62 26,103.76 NA NA
3.A.1.a.ii. Other mature cattle 932.28		26,103.76 NA NA
		NA NA
A La III (frowing cattle		NA
3.A.1.a.iv. Other (please specify) NA		1,/81.03
3.A.2. Sheep 63.61 3.A.3. Swine 85.06		2,381.62
3.A.4. Other livestock 199.42		5,583.83
3.B. Manure management 90.38 48.91 NO		15,492.83
3.B.1. Cattle ⁽³⁾ 29.42 24.36 NO		7,280.55
Option B (country-specific):	_	7,280.33
3.B.1.a. Other 29.42 24.36 NO		7,280.55
3.B.1.a.i. Mature dairy cows 0.62 NA NO		17.48
3.B.1.a.ii. Other mature cattle 28.80 24.36 NO		7,263.06
3.B.1.a.iii. Growing cattle NA NA NO		NA
3.B.1.a.iv. Other (please specify) NA NO		NA
3.B.2. Sheep 0.80 4.09 NO		1,105.75
3.B.3. Swine 43.68 1.65 NO		1,661.40
3.B.4. Other livestock 16.47 11.67 NO		3,554.64
3.B.5. Indirect N ₂ O emissions 7.13		,
3.C. Rice cultivation 1,672.91 NO		46,841.59
3.D. Agricultural soils ^(4,5) NA 113.76 NA NA NA		30,146.09
3.D.1. Direct N ₂ O emissions from managed soils 91.76		24,317.43
3.D.1.a. Inorganic N fertilizers 23.57		6,246.10
3.D.1.b. Organic N fertilizers 12.80		3,390.89
3.D.1.c. Urine and dung deposited by grazing animals		2,767.15
3.D.1.d. Crop residues 0.66		175.02
3.D.1.e. Mineralization/immobilization associated with loss/gain of soil organic NO matter		NO
3.D.1.f. Cultivation of organic soils (i.e. histosols) 44.30		11,738.28
3.D.1.g. Other NO		NO
3.D.2. Indirect N ₂ O Emissions from managed soils		5,828.66
3.E. Prescribed burning of savannas 3.69 0.20 3.70 61.68 NO	NO	156.19
3 F Field burning of agricultural		
residues 0.03 0.00 0.00 1.40 NO	NO	1.83
3.G. Liming 2,159.22		2,159.22
3.H. Urea application 4,047.21		4,047.21
3.I. Other carbon-containing fertilizers NO		NO
3.J. Other (please specify) NO NO NO NO NO NO	NO	NO

In 2022, the agriculture sector accounted for 9.80% of total national emissions, representing 12.66% of total emissions without LULUCF. In that year, emissions totaled 135,565.84 kt CO₂e, reflecting a 26.47% increase since 2000 and a 7.02% rise compared to 2019 (Table 5-2). Between 2000 and 2022, this sector exhibited fluctuating emissions, demonstrating an overall increasing trend since 2000, with the exception of 2022, when emissions decreased by

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3.29% compared to 2021 (Figure 5-1). This results from a decrease in nitrogen fertilizer and agricultural lime usage in 2022, alongside an increase in mitigation measures in rice cultivation during the same year compared to 2021. The emission trend indicates a continuous increase in emissions from the agriculture sector during the COVID-19 pandemic, spanning from 2019 to 2021. This suggests that the COVID-19 pandemic had no effect on the agriculture sector. Supriyanto (2020) indicates that the outbreak negatively affected the economic growth of all countries. Additionally, Muslim et al. (2020) report that Indonesia's economic growth declined by 4.19% in the second quarter of 2020, while the agriculture sector experienced an increase of 16.24% during the same period. The agriculture sector's contribution rose due to a 2.19% increase in its GDP growth. The rise in the agriculture sector's GDP can be attributed to a 9.23% growth in the food crop sub-sector, marking the highest growth rate observed in the past three years.

Table 5- 2 Agriculture sector emissions by sub-category (kt CO₂e)

GHG Source Categories	2000	2005	2010	2015	2019	2022
3.A. Enteric fermentation	25,480.92	24,980.06	30,014.99	32,458.09	34,757.63	36,720.88
3.B. Manure management	9,800.10	9,994.98	12,017.23	13,472.76	15,103.47	15,492.83
3.C. Rice cultivation	46,243.01	47,357.59	34,914.64	46,450.30	39,506.90	46,841.59
3.D. Agricultural soils	21,121.63	22,086.15	25,586.41	27,469.33	29,251.85	30,146.09
3.E. Prescribed burning of						
savannas	313.61	159.41	63.71	1,585.41	1,117.99	156.19
3.F. Field burning of						
agricultural residues	2.69	1,001.58	56.19	828.83	911.70	1.83
3.G. Liming	791.63	941.60	1,235.75	1,745.62	2,193.59	2,159.22
3.H. Urea application	3,435.33	3,610.19	4,192.84	4,034.92	3,832.03	4,047.21
Total	107,188.93	110,131.56	108,081.76	128,045.26	126,675.16	135,565.84

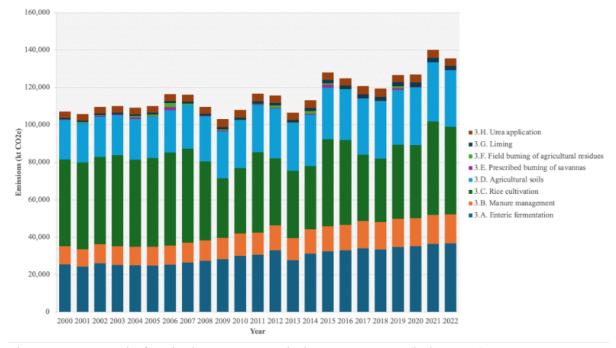


Figure 5-1 Trend of agriculture sector emissions 2000-2022 (in kt CO₂e)

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In 2022, the emissions from sub-categories ranked as follows: rice cultivation contributed 34.55%, enteric fermentation 27.09%, agricultural soils 22.24%, manure management 11.43%, and urea application 2.99%. Liming, prescribed burning of savannas, and field burning of agricultural residues account for less than 2% in this category (Figure 5-2). This information highlights the significance of CH₄ emissions from rice cultivation and enteric fermentation, as well as N₂O emissions from agricultural soils, for the GHG balance in Indonesia.

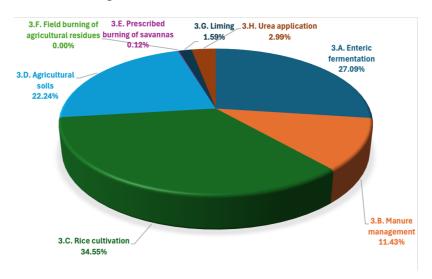
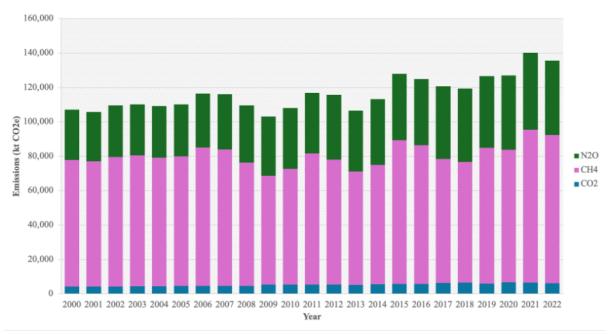


Figure 5-2 Contribution of agriculture sector sub-category emissions in 2022

In 2022, the agriculture sector's total emissions were primarily attributed to CH_4 emissions from rice cultivation, enteric fermentation, and manure management, accounting for 63.58%. This was followed by N_2O emissions from agricultural soils and manure management at 31.84%, and CO_2 emissions from urea application and liming at 4.58% (Table 5-3 and Figure 5-3).

Table 5- 3 Agriculture sector emissions by GHG type (in kt CO₂e)

GHG Source Categories	2000	2005	2010	2015	2020	2022
CO_2	4,226.97	4,551.79	5,428.60	5,780.54	6,025.62	6,206.43
CH ₄	73,584.31	75,349.05	67,189.16	83,521.89	78,819.41	86,197.38
N_2O	29,377.66	30,230.71	35,464.01	38,742.84	41,830.13	43,162.03
Total	107,188.93	110,131.56	108,081.76	128,045.26	126,675.16	135,565.84



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Figure 5- 3 Trend of agriculture sector emissions by gas type 2000-2022 (in kt CO₂e)

5.1.3. Methodological Issues

The estimation of GHG emissions from the agriculture sector for the period 2000 to 2022 employs the 2006 IPCC Guidelines and the 2019 IPCC Refinement. Table 5-4 presents the depth of the methods and EFs applied to each agricultural sector category and GHG type.

Table 5-4 Summary of methods and EFs in GHGI for agriculture sector from 2000 to 2022

		CO ₂	(CH4	N	I ₂ O
GHG Source Categories	Method	Emission	Method	Emission	Method	Emission
	applied	factor	applied	factor	applied	factor
3. Agriculture	T1	D	T1, T2	D, CS	T1	D
3.A. Enteric fermentation			T2	CS		
3.B. Manure management			T2	CS	T1	D
3.C. Rice cultivation			T2	CS		
3.D. Agricultural soils			NO	NO	T1	D
3.E. Prescribed burning of savannas			T1	D	T1	D
3.F. Field burning of agricultural residues			T1	D	T1	D
3.G. Liming	T1	D				
3.H. Urea application	T1	D				
3.I. Other carbon-containing fertilizers	NO	NO			•	
3.J. Other	NO	NO	NO	NO	NO	NO

T1 = Tier 1 IPCC, T2 = Tier 2 IPCC

Methane emissions from enteric fermentation and manure management, along with those from rice cultivation during the period 2000 to 2022, are estimated using Tier 2 methodologies. In contrast, other categories employ Tier 1, utilizing the default emission factors provided in the 2006 IPCC Guidelines and the 2019 IPCC Refinement.

D = IPCC default value, CS = Country-Specific

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The AD utilized for estimating GHG emissions primarily consist of statistical information sourced from BPS, the Ministry of Agriculture, and other organizations, including APPI (Association of Indonesian Fertilizer Producers). The AD types for the agriculture sector's GHGI include the number of livestock, harvested area, quantities of urea and nitrogen fertilizers, and land burning area. Table 5-5 presents the AD and data sources utilized for the inventory, with additional details available in each category.

Table 5-5 Sources of activity data for agriculture sector

GHG Source Categories	Sub-category Sub-category	Source of Data
3. Agriculture		
3.A. Enteric fermentation	3.A.1 (cattle); 3.A.2 (sheep); 3.A.3 (swine); 3.A.4 (other)	BPS, Agricultural Statistics
3.B. Manure management	3.B.1 (cattle); 3.B.2 (sheep); 3.B.3 (swine); 3.B.4 (other)	BPS, Agricultural Statistics
3.C. Rice cultivation	3.C.1 (irrigation); 3.C.2 (rainfed)	BPS, Agricultural Statistics
3.D. Agricultural soils	3.D.1 (direct N ₂ O emission); 3.D.2 (indirect N ₂ O emission)	APPI, BPS
3.E. Prescribed burning of savannahs	3.E.1 (savannas on forested land); 3.E.2 (savannas on grassland)	PKHL, KLHK
3.F. Field burning of agricultural residues	3.F.1.4 (rice field)	PKHL, KLHK
3.G. Liming	3.G.2 (Dolomite)	Assumptions (area of peatland plantations and acid sulfate soils) and APPI
3.H. Urea application	3.H (Urea)	APPI
3.I. Other carbon-containing fertilizers	NA	NA
3.J. Other	NA	NA

5.2. Enteric Fermentation (3.A)

5.2.1. Category Description

Methane is a by-product produced during the digestive process in the rumen of herbivores. Animal feed undergoes fermentation by bacteria in the digestive tract in anaerobic conditions, resulting in the production of simple fatty acids, carbon dioxide, and methane. Fatty acids are absorbed into the bloodstream, while gases are expelled through belching and respiration in animals. This category includes sub-categories such as dairy cows, beef cattle, buffaloes, sheep, goats, horses, donkeys, swine, and poultry. The production of methane (CH₄) is influenced by factors such as animal population, weight, age, and the quantity and quality of feed provided. Ruminant livestock generate greater quantities of CH₄ gas in comparison to non-ruminant livestock (IPCC 2006).

The national inventory categorizes animals into sub-groups, which consist of beef cattle, dairy cows, buffaloes, sheep, goats, swine, and horses, classified by age (Table 5-6). The calculation of CH₄ emissions from enteric fermentation facilitates the estimation of EFs specific to

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countries for cattle and other livestock. The equations outlined in Chapter 10, Volume 4 of the 2006 IPCC Guidelines and the 2019 IPCC Refinement are employed for the Tier 2 procedure.

Table 5- 6 Sub-categories of livestock

Livestock	Sub-category			
Beef Cattle	Weaning (0 – 1 year)			
	Yearling (1 – 2 year)			
	Young (2 – 4 year)			
	Mature (> 4 year)			
	Imported (fattening)			
Dairy Cows	Weaning (0 – 1 year)			
	Yearling (1 – 2 year)			
	Young (2 – 4 year)			
	Mature (> 4 year)			
Buffalo	Weaning $(0-1 \text{ year})$			
	Yearling $(1 - 2 \text{ year})$			
	Young (2 – 4 year)			
	Mature (> 4 year)			
Goats	Weaning			
	Yearling			
	Mature			
Sheep	Weaning			
	Yearling			
	Mature			
Swine	Weaning			
	Yearling			
	Mature			
Horses	Weaning			
	Yearling			
	Mature			

5.2.2. Trends in Greenhouse Gas Emissions by Category

Enteric fermentation is the second largest emitter in this sector, following rice cultivation, accounting for 27.09% of emissions. In 2022, emissions totaled 36,720.88 kt CO₂e, reflecting a 44.11% increase since 2000 and a 5.65% rise since 2019 (Table 5-7).

Table 5- 7 Enteric fermentation emissions by livestock sub-category (in kt CO₂e)

GHG Source Categories	2000	2005	2010	2015	2019	2022
3.A.1.a.i. Adult dairy cow	499.51	509.52	688.73	731.30	829.66	870.62
3.A.1.a.ii. Other adult cattle	15,207.36	14,601.30	18,762.67	21,302.02	23,747.11	26,103.76
3.A.2. Sheep	820.87	920.35	1,185.44	1,881.66	2,034.08	1,781.05
3.A.3. Swine	1,856.64	2,357.08	2,591.36	2,706.23	2,794.28	2,381.62
3.A.4.a. Buffalo	4,592.19	4,063.74	3,817.67	2,571.52	2,259.83	2,332.37
3.A.4.d. Goats	1,388.28	1,481.50	1,836.18	2,100.59	2,078.96	2,184.22
3.A.4.e. Horses	1,116.06	1,046.57	1,132.93	1,164.77	1,013.70	1,067.23
Total	25,480.92	24,980.06	30,014.99	32,458.09	34,757.63	36,720.88

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Figure 5-4 illustrates the trends in enteric fermentation emissions. Enteric fermentation emissions have exhibited a consistent upward trend from 2000 to 2022. The COVID-19 pandemic (2019-2022) did not impact the growth of the livestock sector in Indonesia. Initially, the pandemic posed challenges for the livestock sector, including difficulties in acquiring production facilities and feed, rising distribution costs, reduced marketing and sales attributed to social distancing (Darwis et al. 2020), and a decline in livestock production resulting from decreased consumer purchasing power. The impact of the COVID-19 pandemic on this sector was context-dependent, with not all entities experiencing negative effects. The production capacity of broiler chickens and sheep declined, whereas the capacity of layer hens exhibited relative stability. The capacity of beef cattle businesses remained stable due to the temporary suspension of buffalo meat imports from India (Ilhma and Haryanto 2020). The COVID-19 pandemic impacted farmers in NTB; however, it did not affect the performance of beef cattle breeders (Oktaviana and Mashur 2022).

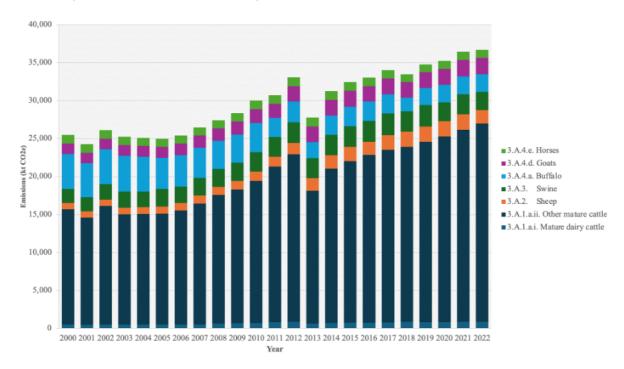


Figure 5-4 Trends in enteric fermentation emissions by livestock sub-category 2000-2022 (in kt CO₂e)

The highest percentage of emissions among livestock sub-categories was attributed to beef cattle at 71.09%, followed by swine at 6.49%, buffaloes at 6.35%, goats at 5.95%, sheep at 4.85%, horses at 2.91%, and dairy cows at 2.37% (Figure 5 - 5).

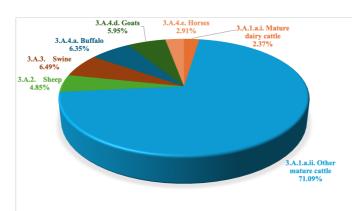


Figure 5- 5 Percentage of enteric fermentation emissions by livestock type in 2022

5.2.3. Methodological Issues

Methane emissions from enteric fermentation (3.A) are estimated utilizing the Tier 2 method specified in Chapter 10 of the 2006 IPCC Guidelines and the 2019 Refinement for six livestock categories: beef cattle, dairy cows, buffaloes, goats, sheep, swine, and horses. EFs vary by animal age class within specific countries. Age classes are established according to the proportion of the total population for each type of livestock. Table 5-8 below presents the methods and EFs categorized by sub-categories and GHG types.

Table 5-8 Enteric fermentation emission methods and factors for the period 2000-2022

GHG Source Categories	Method	Emission Factor
3.A.1.a.i. Adult dairy cows	T2	CS
3.A.1.a.ii. Other mature livestock	T2	CS
3.A.2. Sheep	T2	CS
3.A.3. Swine	T2	CS
3.A.4.a. Buffalo	T2	CS
3.A.4.d. Goats	T2	CS
3.A.4.e. Horses	T2	CS

T2 = Tier 2 IPCC

Emissions resulting from enteric fermentation are determined using Equation 10.19 found in Chapter 10, Volume 4 of the 2006 IPCC Guidelines, facilitating the estimation of EFs for each livestock sub-category. This inventory presents country-specific EF estimates for each sub-category of dairy cows and other livestock, utilizing population data sourced from national entities, including the BPS (Statistics Indonesia) and the agricultural statistics of the Ministry of Agriculture. Total emissions from enteric fermentation are calculated by aggregating the emissions produced for each type of livestock, as detailed in Equation 10.20 in Chapter 10, Volume 4 of the 2006 IPCC Guidelines.

The Tier 2 method is utilized for more detailed livestock population sub-categories to calculate country-specific EFs regarding emissions. The EFs for each livestock sub-category are

CS = Country-Specific



calculated using the gross energy (GE) intake and the methane conversion factor (Ym) specific to that sub-category, as illustrated in Equation 10.21.

The methane conversion factor (Ym) indicates the proportion of GE in the feed that is transformed into CH₄. This factor may differ by region, as it is influenced by various feed and animal factors that interact with one another. In the absence of a country-specific methane conversion factor, the 2006 IPCC Guidelines and the 2019 IPCC Refinement offer default ranges for the Ym value that may be utilized when a country lacks its own methane conversion factor. This factor depends on the digestibility and energy value of the feed. When the available feed is of high quality, characterized by high digestibility and energy value, the lowest Ym value is applied. In contrast, when the feed quality is lower, indicated by low digestibility and energy value, a higher Ym value is utilized. The methane conversion factor for young animals is considered to be zero, as their diet consists solely of milk (IPCC 2006).

GE denotes the data related to animal performance and diet utilized for estimating feed intake. The GE value denotes the daily energy requirement (MJ) for an animal, encompassing maintenance and activities like growth, lactation, and pregnancy. It can be computed using Equation 10.16, which considers the net energy requirements and the energy availability characteristics of the feed (IPCC 2006). The simplified Tier 2 method, as described in the 2006 IPCC Software, allows for the estimation of the GE value based on feed intake (DMI, in kg DM per day) and the energy density of the feed (FED, in MJ per kg DM) through the following equation:

$$GE = DMI x FED$$

Where:

GE = Gross energy, in MJ per day DMI = Daily feed intake, kg DM per day FED = Feed energy density, MJ per kg DM

The equation utilized for estimating country-specific enteric fermentation EFs is presented as Equation 10.21 in Chapter 10 of the 2006 IPCC Guidelines. Estimating these EFs requires the calculation of the GE and the methane conversion factor (Ym), which are derived from the previously outlined equations. Below is Equation 10.21:

$$EF = \left[\frac{GE \bullet \left(\frac{Ym}{100} \right) \bullet 365}{55.65} \right]$$

Where,

 $EF = Emission factor, in kg CH_4 per head per year$

GE = Gross energy intake, in MJ per head per day

Ym = Methane conversion factor, percentage of GE in feed converted to methane

The factor 55.65 (MJ/kg CH₄) is the energy content of methane

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Table 5-9 below presents a summary of country-specific EFs categorized by livestock subcategory and age class, derived from the equations above using the default parameters outlined in the 2006 IPCC Guidelines.

Table 5- 9 Age class proportions and specific EFs by age class for enteric fermentation CH₄ emissions

Livestock	Sub-category	Sex	Percentage (%)	EF CH ₄ Enteric Fermentation (kg CH ₄ /year/head)
	Weaning $(0-1 \text{ year})$	Female + Male	18.10	17.44
Beef Cattle	Yearling (1 – 2 year)	Female + Male	25.15	30.79
	Young (2 – 4 year)	Female + Male	19.14	56.73
	Mature (> 4 year)	Female + Male	28.26	72.96
	Imported (fattening)	Male	9.35	82.56
	Weaning $(0-1 \text{ year})$	Female + Male	18.68	10.85
D.: C	Yearling (1 – 2 year)	Female + Male	22.40	46.87
Dairy Cow	Young (2 – 4 year)	Female + Male	22.93	66.75
	Mature (> 4 year)	Female + Male	35.99	68.38
	Weaning $(0-1 \text{ year})$	Female + Male	13.53	23.60
D 00 1	Yearling $(1 - 2 \text{ year})$	Female + Male	21.47	47.19
Buffalo	Young (2 – 4 year)	Female + Male	14.81	70.79
	Mature (> 4 year)	Female + Male	50.19	94.39
	Weaning	Female + Male	25.84	1.31
Goats	Yearling	Female + Male	26.26	3.27
	Mature	Female + Male	47.90	5.90
	Weaning	Female + Male	24.46	1.31
Sheep	Yearling	Female + Male	26.69	3.27
_	Mature	Female + Male	48.85	5.90
	Weaning	Female + Male	37.54	3.54
Swine	Yearling	Female + Male	30.34	14.16
	Mature	Female + Male	32.09	18.88
	Weaning	Female + Male	18.82	47.19
Horses	Yearling	Female + Male	22.62	82.59
	Mature	Female + Male	58.56	117.99

5.2.4. Uncertainty Assessment and Time-Series Consistency

A quantitative evaluation of uncertainty utilizing Approach 1 for error propagation has been conducted. The uncertainty associated with the population (AD) sourced from statistics is around 20%, while the uncertainty associated with the EFs aligned with the 2006 IPCC Guidelines for the Tier 2 method is 20% (IPCC 2006). The combined uncertainty of the enteric fermentation emissions, derived from the uncertainty values of the AD and the EF, is estimated to be 28.28% for each livestock type. Additional information regarding this analysis can be found in Annex 2. The uncertainty for the enteric fermentation emissions based on Equation 3.2 in Volume 1, chapter 3, 2006 IPCC Guideline is approximately 20.41% (Table 5-10).

Table 5- 10 Uncertainty of enteric fermentation emissions

GHG Source Categories	GHG	Emission in 2022 (E), kt CO ₂ e	Uncertainty (U), %	$(E \times U)^2$	Combined Uncertainty, %
3.A.1.a.i. Mature dairy cattle	CH ₄	870.62	28.28	606,388,987	20.41

3.A.1.a.ii. Other mature cattle	CH ₄	26,103.76	28.28	545,124,934,282
3.A.2. Sheep	CH ₄	1,781.05	28.28	2,537,720,843
3.A.3. Swine	CH ₄	2,381.62	28.28	4,537,693,941
3.A.4.a. Buffalo	CH ₄	2,332.37	28.28	4,351,969,638
3.A.4.d. Goats	CH ₄	2,184.22	28.28	3,816,662,032
3.A.4.e. Horses	CH ₄	1,067.23	28.28	911,188,609
Total		36,720.88		561,886,558,331

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To maintain time-series consistency, the estimation of enteric fermentation GHG emissions is conducted using a method that aligns with the prior NGHGI. Recalculations are conducted in the event of methodological improvements or alterations in the AD. The methodology outlined in the 2006 IPCC Guidelines is consistently applied.

5.2.5. Category-Specific QA/QC and Verification

AD for this source category is sourced from BPS (Statistics Indonesia). This agency supplies data requirements for the government and the public, sourced from its own censuses or surveys, in addition to secondary data from other ministries or government agencies. The BPS, as the provider of fundamental statistical data, sectoral statistics, and specialized statistics, has established a series of QA and QC procedures concerning survey design, data entry, and consistency verification of survey outcomes and aggregate figures.

The evaluation of sampling errors in the surveys is conducted; however, there is a need for improved addressing and strengthening of these errors, particularly concerning the AD necessary for compiling the GHG emissions inventory. The anticipated improvements will enable accurate estimation of uncertainty values for the AD, facilitating access for compilers of national and sub-national GHG inventories.

Quality control activities for the 2022 inventory were conducted involving (1) participation from inventory compilers responsible for coordinating QC and verification activities, alongside the definition of roles and responsibilities in the inventory process; (2) an internal review of AD and EFs, as well as emission estimates; (3) uncertainty analysis and KCA; (4) a comparison of current and previous AD and emission estimates for the base year 2000 and the year 2019, along with an analysis of the changes in emissions between 2000 and 2022 in the current submission. Furthermore, this inventory includes technical documentation and archiving to guarantee transparency and traceability of the calculation methods and data sources. An external institution has not yet conducted QA for the GHGI compilers to re-evaluate the calculation worksheets.

5.2.6. Category-Specific Recalculations

The emission estimates for category 3.A in the prior GHGI Report have been recalculated for the years 2000 to 2019. This recalculation is attributed to the revision of EFs for all livestock

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types, adjustments in age class proportions for the years 2017 to 2019 by livestock type, the application of GWP from AR5, and the utilization of the 2006 IPCC software version 2.93. Modifications to the EF, AD, and associated parameters influence the estimation of methane emissions resulting from enteric fermentation. The adjustments to the EF and AD are detailed in Table 5-11 of the new NGHGI report.

Table 5-11 Recalculations and improvements to enteric fermentation emissions

Emission Source	Adjustment Category	Type of Recalculation
Category		
3.A Enteric Fermentation	Use of updated country-specific CH ₄ EFs based on the available (default) parameters in the 2016 IPCC Guidelines and the 2019 Refinement to the IPCC-2006 Guidelines	FE
	Adjustment of the livestock age class proportions for the period 2017 - 2019 using the 2018 Inter- Census Agricultural Survey	DA
	Use of AR5 GWP	Transparency

Table 5-12 indicates that emissions from the enteric fermentation category have consistently increased annually, showing a difference exceeding 87.48%. The observed difference arises from enhanced estimation of EFs for livestock sub-categories, achieved through the application of the Tier 2 method as outlined in the 2006 IPCC Guidelines and the 2019 IPCC 2006 Refinement, alongside the utilization of GWP parameters from AR5.

Table 5- 12 Comparison of enteric fermentation emissions between BUR3 and BTR1

NGHGI Report	2000	2005	2010	2015	2019
Submission 2021 BUR3, kt CO ₂ e	13,591.40	13,044.63	15,711.61	16,904.01	17,897.61
Submission 2024 BTR1, kt CO ₂ e	25,480.92	24,980.06	30,014.99	32,458.09	34,757.63
Difference, kt CO ₂ e	11,889.52	11,935.42	14,303.38	15,554.09	16,860.02
Difference, %	87.48	91.50	91.04	92.01	94.20

5.2.7. Plan of Improvements

To enhance the accuracy of enteric fermentation emission estimates in the future, the following aspects have been identified for review and/or revision (Table 5- 13).

Table 5- 13 Plan of improvements for enteric fermentation emission estimates

Plan of Improvements	Priority	Rationale
Grouping of livestock based on production systems	High	Currently, livestock grouping is only based on age class, without considering extensive, semi-intensive and intensive production systems
Improving the estimation of GE and methane conversion factor (Ym) for dairy cows, beef cattle, and buffalo according to production systems	High	Generally, the dominant livestock population is ruminants such as dairy cows, beef cattle and buffalo. Therefore, improving these parameters

Plan of Improvements	Priority	Rationale
		significantly affects the accuracy of methane emission estimates from enteric fermentation
Improving the proportion of livestock types by production system and age class based on the results of the latest surveys and other sources	High	The latest Inter-Census Agricultural Survey was in 2018
Study on imported beef cattle (number, age, feed, length of rearing)	Medium	Currently, the share of imported cattle is obtained from Sutas. Field information indicates that beef cattle information can be traced from BPS and the Ministry of Trade

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5.3. Manure Management (3.B)

5.3.1. Category Description

This category examines the direct and indirect emissions of CH₄ and N₂O arising from the storage, decomposition, and treatment of manure prior to its application on land or other enduse forms. Methane emissions arise from the decomposition of residual organic matter in livestock manure during storage and treatment, as well as from manure deposited on pastures. Methane emissions arise from the management of numerous animals in confined spaces, where manure is typically accumulated in substantial piles. Methane production takes place in anaerobic environments, with key determinants of CH₄ emissions being the quantity of manure generated and the fraction that undergoes anaerobic decomposition (IPCC 2006).

N₂O emissions can arise through two mechanisms. Direct N₂O emissions arise in the manure management system due to the nitrification and denitrification processes involving the ammonia nitrogen present in the manure. N₂O emissions are significantly influenced by nitrogen and carbon content during storage, which is further affected by the type of treatment applied. Secondly, indirect N₂O emissions arise from runoff and leaching, along with the deposition of volatilized nitrogen as ammonia and NO₂ resulting from the manure management system. The proportion of organic nitrogen excretion that is converted into ammonia nitrogen during storage and collection is significantly influenced by time and, to a lesser degree, by temperature (IPCC 2006). N₂O emissions resulting from manure deposited directly by animals on pastures and rangelands are categorized under agricultural soil (3D).

In the national context, the manure management category encompasses sub-categories for beef cattle, dairy cows, buffalo, sheep, goats, swine, and horses, which are further classified by age group, similar to the enteric fermentation emission estimates (Table 5-6). This category also includes emissions estimates from poultry, such as native chickens, grill chickens, layer chickens and ducks. In Indonesia, the prevalent manure management systems include:

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Daily distribution: dairy cows

• Dry lot: beef cattle, buffalo, sheep, goats, swine, horses

• Pasture: beef cattle

• Cage without litter: free-range, ducks

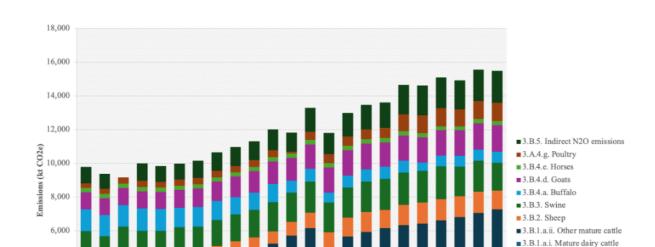
• Cage with litter: broiler and layer chickens

5.3.2. Trends in Greenhouse Gas Emissions by Category

In 2022, emissions from livestock manure management accounted for 11.43% of the agriculture sector. In the same year, total CH₄ and N₂O emissions amounted to 15,492.83 kt CO₂e, reflecting a 58.09% increase since 2000 and a 2.58% rise compared to 2019 (Table 5-14 dan Figure 5-6). The increase in demand for livestock products, including cattle, goats, sheep, swine, and poultry, is the primary factor contributing to this situation.

Table 5- 14 Manure management emissions by livestock sub-category (in kt CO₂e)

GHG Source Categories	2000	2005	2010	2015	2019	2022
3.B.1.a.i. Dairy cows (CH ₄)	10.03	10.23	13.83	14.68	16.66	17.48
3.B.1.a.i. Dairy cows (N ₂ O)	NO	NO	NO	NO	NO	NO
3.B.1.a.ii. Other cattle (CH ₄)	469.78	451.06	579.61	658.06	733.59	806.39
3.B.1.a.ii. Other cattle (N ₂ O)	3,761.49	3,611.58	4,640.88	5,268.98	5,873.77	6,456.68
3.B.2. Sheep (CH ₄)	10.22	11.46	14.76	23.43	25.51	22.33
3.B.2. Sheep (N ₂ O)	501.97	562.80	724.91	1,150.66	1,237.34	1,083.42
3.B.3. Swine (CH ₄)	899.95	1,142.52	1,256.08	1,311.76	1,435.02	1,223.09
3.B.3. Swine (N ₂ O)	341.69	433.79	476.91	498.05	514.25	438.31
3.B.4.a. Buffalo (CH ₄)	141.86	125.54	117.93	79.44	69.81	72.05
3.B.4.a. Buffalo (N ₂ O)	1,146.74	1,014.78	953.33	642.15	563.24	581.32
3.B.4.d. Goats (CH ₄)	9.61	10.25	12.71	14.54	14.15	14.87
3.B.4.d. Goats (N ₂ O)	996.64	1,063.56	1,318.18	1,508.00	1,483.60	1,558.72
3.B.4.e. Horses (CH ₄)	25.29	23.71	25.67	26.39	22.97	24.18
3.B.4.e. Horses (N ₂ O)	236.21	221.50	239.78	246.52	214.54	225.87
3.A.4.g. Poultry (CH ₄)	97.10	126.21	138.49	193.52	349.81	350.16
3.A.4.g. Poultry (N ₂ O)	173.22	235.08	265.90	383.79	727.11	727.48
3.B.5. Indirect N ₂ O emissions	978.31	950.91	1,238.26	1,452.81	1,822.11	1,890.49
Total	9,800.10	9,994.98	12,017.23	13,472.76	15,103.47	15,492.83



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Figure 5-6 Trend of manure management emissions by livestock sub-category (in kt CO₂e) The demand for livestock products significantly influences emissions from the sector. Statistical data indicates an increase in the number of beef cattle since 2000. The emission trend indicates that the pandemic did not affect livestock activities, as evidenced by the consistent production patterns of goats, sheep, swine, and poultry.

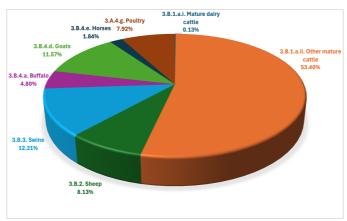
Direct N₂O emissions represent the largest share of emissions in this category, accounting for 71.46% of the total. In contrast, CH₄ and indirect N₂O emissions contribute 16.33% and 12.20%, respectively (Table 5- 15). The largest proportion of emissions among livestock categories is attributed to beef cattle, accounting for 53.40%. This is followed by swine at 12.21%, goats at 11.57%, sheep at 8.13%, poultry at 7.92%, and buffaloes at 4.80%. The other categories account for less than 2.0% (Figure 5-7).

Table 5- 15 Manure management emissions by gas sub-category (kt CO₂e)

4.000

2,000

GHG Source Categories	2000	2005	2010	2015	2019	2022
3.B CH ₄	1,663.83	1,900.98	2,159.09	2,321.82	2,667.51	2,530.56
3.B Direct N ₂ O	7,157.96	7,143.09	8,619.89	9,698.13	10,613.84	11,071.79
3.B Indirect N ₂ O	978.31	950.91	1,238.26	1,452.81	1,822.11	1,890.49
Total	9,800.10	9,994.98	12,017.23	13,472.76	15,103.47	15,492.83



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Figure 5-7 Percentage of manure management emissions by livestock sub-category in 2022

5.3.3. Methodological Issues

Category 3.B quantifies methane emissions resulting from manure storage and treatment, as well as from manure deposited on pasture. This category encompasses direct N₂O emissions from manure, indirect N₂O emissions resulting from runoff and leaching, and the deposition of volatilized N during the storage and treatment of manure.

Methane emissions from manure management (3.B.a) are estimated utilizing the Tier 2 method, incorporating country-specific EFs as outlined in Equation 10.23, Chapter 10 of the 2006 IPCC Guidelines and the 2019 IPCC Refinement. The Tier 2 method is utilized for six livestock categories: beef cattle, dairy cows, buffaloes, goats, sheep, swine, and horses, with country-specific EFs estimated according to animal age class. In contrast, the Tier 1 method is employed for poultry, including broilers, layer hens, and ducks. The data on livestock population is sourced from the BPS and the agricultural statistics provided by the Ministry of Agriculture. Direct and indirect N₂O emissions are calculated using the Tier 1 method, employing default EFs that are modified based on country-specific animal weights. The table below presents the methods and EFs categorized by sub-categories and GHG types.

Table 5- 16 Methane emission methods and emission factors for manure management

	1	CH ₄		N_2O		
GHG Source Categories		Emission		Emission		
	Method	Factor	Method	Factor		
3.B.1.a.i. Dairy Cows	T2	CS	T1	D		
3.B.1.a.ii. Other adult cattle	T2	CS	T1	D		
3.A.2. Sheep	T2	CS	T1	D		
3.A.3. Swine	T2	CS	T1	D		
3.A.4.a. Buffalo	T2	CS	T1	D		
3.A.4.d. Goats	T2	CS	T1	D		
3.A.4.e. Horses	T2	CS	T1	D		
3.A.4.g. Poultry	T2	CS	T1	D		

T2 = Tier 2 IPCC

CS = Country-Specific

5.3.3.1 Methane (CH₄) emissions from manure management

The methane emissions from manure management for beef cattle, dairy cows, buffaloes, goats, sheep, swine, and horses are determined using the Tier 2 method as outlined in Equation 10.22 of the 2006 IPCC Guidelines. Emissions are calculated by multiplying the population of livestock by the corresponding EF for that population. The EFs for enteric fermentation CH₄ emissions utilize country-specific values derived from Equation 10.23.

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The equation for calculating methane emissions from livestock manure is as follows:

$$CH_{4Mature} = \sum_{(T)} \frac{\left(EF_{(T)} \bullet N_{(T)}\right)}{10^6}$$

Where:

 $CH_{4Manur} = CH_4$ emissions from manure management, for a defined livestock population, Gg CH_4 per year

EF_(T) = Emission factor for the livestock population T, kg CH₄ per head per year

 $N_{(T)}$ = Number of head of livestock species/category T

T = Livestock species/category

The formula for determining methane emissions from livestock manure is presented below:

$$EF_{(T)} = \left(VS_{(T)} \bullet 365\right) \bullet \left[B_{0(T)} \bullet 0.67 \ kg/m^3 \bullet \sum_{S,k} \frac{MCF_{S,k}}{100} \bullet MS_{(T,S,k)}\right]$$

Where:

EF_(T) = Annual CH₄ emission factor for livestock T, kg CH₄ animal-1 yr-1

 $VS_{(T)}$ = Daily volatile solid excreted for livestock category T, kg dry matter per animal per day

Basis for calculating annual VS production, days per year

B0_(T) = Maximum methane producing capacity for manure produced by livestock category T, m³ CH₄ per kg of VS

kg of v S

0.67 = Conversion factor of m³ CH₄ to kilograms CH₄

 $MCF_{(S,k)}$ = Methane conversion factor for each manure management system S by climate region k, %

 $MS_{(T,S,k)}$ = Fraction of manure from livestock category T managed in manure management system S in climate region k, dimensionless

The methane EF for manure is a function of volatile solids (VS), methane producing capacity (Bo), and methane conversion factors (MCF). The VS excretion for dairy cows, other cattle, buffaloes, goats, sheep, swine, and horses is calculated using Equation 10.24 from the 2006 IPCC Guidelines.

$$VS = \left[GE \bullet \left(1 - \frac{DE\%}{100} \right) + \left(UE \bullet GE \right) \right] \bullet \left[\left(\frac{1 - ASH}{18.45} \right) \right]$$

Where:

VS = Volatile solids excreted per day on a dry-organic matter basis, kg VS per day

GE = Gross energy intake, MJ per day



DE% = Digestibility of the feed in percent (e.g., 60%)

(UE • GE) = Urinary energy expressed as a fraction of GE. Usually, 0.04 GE can be considered the urinary energy excretion for most ruminants (reduce to 0.02 for ruminants fed with 85% or more grain in the diet or for swine).

18.45 = Conversion factor for dietary GE to kg of dry matter fed, MJ per kg. This factor is relatively constant across a wide range of forage and grain-based feeds commonly consumed by livestock.

The data required for calculating VS in livestock consist of GE intake, feed digestibility (DE), urinary energy (UE), and manure ash content.

Table 5- 17 presents the methane EFs for various sub-categories, including cattle, other cattle, buffalo, sheep, goats, swine, and horses, as derived from Equation 10.23 of the 2006 IPCC Guidelines.

Table 5- 17 Age distribution and specific emission factors by age class for CH₄ emissions from manure management

Livestock	Sub-Category	Sex	Percentage (%)	EF CH ₄ Enteric Fermentation (Kg CH ₄ /year/head)
	Weaning $(0-1 \text{ year})$	Female + Male	18.10	0.54
Beef Cattle	Yearling (1 – 2 year)	Female + Male	25.15	0.95
	Young (2 – 4 year)	Female + Male	19.14	1.75
	Mature (> 4 year)	Female + Male	28.26	2.25
	Imported (fattening)	Male	9.35	2.55
	Weaning $(0-1 \text{ year})$	Female + Male	18.68	0.22
Daimy Carro	Yearling (1 – 2 year)	Female + Male	22.40	0.94
Dairy Cows	Young (2 – 4 year)	Female + Male	22.93	1.34
	Mature (> 4 year)	Female + Male	35.99	1.37
	Weaning $(0-1 \text{ year})$	Female + Male	13.53	0.73
Buffalo	Yearling (1 – 2 year)	Female + Male	21.47	1.46
Dullalo	Young (2 – 4 year)	Female + Male	14.81	2.19
	Mature (> 4 year)	Female + Male	50.19	2.92
	Weaning	Female + Male	25.84	0.03
Goats	Yearling	Female + Male	26.26	0.03
	Mature	Female + Male	47.90	0.03
	Weaning	Female + Male	24.46	0.01
Sheep	Yearling	Female + Male	26.69	0.05
	Mature	Female + Male	48.85	0.08
	Weaning	Female + Male	37.54	6.00
Swine	Yearling	Female + Male	30.34	6.00
	Mature	Female + Male	32.09	6.00
	Weaning	Female + Male	18.82	2.19
Horses	Yearling	Female + Male	22.62	2.19
	Mature	Female + Male	58.56	2.19

5.3.3.2 N₂O Emission Manure Management

N₂O emissions from manure management arise from various systems, including dry lot systems for beef cattle, buffalo, sheep, goats, swine, and horses; pasture systems for beef cattle; daily spreading practices for dairy cows; and poultry management involving both litter (layer and broiler chickens) and non-litter systems (native chickens and ducks), occurring directly and

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indirectly from agricultural soils. N_2O emissions linked to the pasture management system are categorized under agricultural soils (3.D).

Direct N₂O emissions from manure management are estimated using the Tier 1 method outlined in the 2006 IPCC Guidelines, specifically employing Equation 10.25. Indirect emissions are calculated using Equation 10.27, which accounts for volatilization, and Equation 10.29, which addresses leaching from manure management. This method entails calculating the total nitrogen (N) excretion from all livestock species and categories for each manure management system type and multiplying it by the corresponding EF for that system type. The Tier 1 method utilizes default IPCC N₂O EFs alongside standard nitrogen excretion data. Additionally, the weight of each livestock type employs country-specific weights categorized by age class (Table 5- 18).

Table 5- 18 Livestock-specific weights by age class

Livestock	Sub-category	Sex	Percentage (%)	Animal mass (Kg/ head)
	Weaning $(0-1 \text{ year})$	Female + Male	18.10	63
Beef Cattle	Yearling $(1-2 \text{ year})$	Female + Male	25.15	134
	Young (2 – 4 year)	Female + Male	19.14	286
	Mature (> 4 year)	Female + Male	28.26	400
	Imported (fattening)	Male	9.35	500
	Weaning $(0-1 \text{ year})$	Female + Male	18.68	46
D.: C	Yearling $(1-2 \text{ year})$	Female + Male	22.40	199
Dairy Cows	Young (2 – 4 year)	Female + Male	22.93	275
	Mature (> 4 year)	Female + Male	35.99	403
	Weaning $(0-1 \text{ year})$	Female + Male	13.53	46
D.,, CC, 1.	Yearling (1 – 2 year)	Female + Male	21.47	199
Buffalo	Young (2 – 4 year)	Female + Male	14.81	275
	Mature (> 4 year)	Female + Male	50.19	403
	Weaning	Female + Male	25.84	8
Goats	Yearling	Female + Male	26.26	20
	Mature	Female + Male	47.90	25
	Weaning	Female + Male	24.46	8
Sheep	Yearling	Female + Male	26.69	20
•	Mature	Female + Male	48.85	25
	Weaning	Female + Male	37.54	15
Swine	Yearling	Female + Male	30.34	60
	Mature	Female + Male	32.09	80
	Weaning	Female + Male	18.82	200
Horses	Yearling	Female + Male	22.62	350
	Mature	Female + Male	58.56	500
Free-range chicken				2
Broiler chicken				1
Layer chicken				2
Duck				2

5.3.4. Uncertainty Assessment and Time-Series Consistency

The uncertainty of AD sourced from statistics is applied at a value of 20%, while the uncertainty of Tier 2 EFs for CH₄ emissions from manure management is used at a value of 20% (IPCC 2006). Based on the uncertainty from these 2 sources, the combined uncertainty of

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 CH_4 emissions for each livestock type is 28.28%. Meanwhile, the uncertainty of N_2O EFs for manure management is estimated using the IPCC 2006 default values as presented in Table 5-19. The combined uncertainty of the direct N_2O and the indirect N_2O emissions, derived from the uncertainty values of the AD and the EF, are estimated to be 81.55 % and 141,09% respectively. Additional information regarding this analysis can be found in Annex 2.

Table 5 - 19 Default value of the uncertainty N₂O of emission factors for manur management

Emission Factor / Parameter	Source	Uncertainty
Direct N ₂ O:		
a. Nrate(T) = default N excretion rate	2006 IPCC GL default values	50.00%
b. TAM(T) = typical animal mass for livestock	2006 IPCC GL default values	25.00%
c. MS(T,S) = fraction of total annual nitrogen excretion	2006 IPCC GL default values	25.00%
d. EF3 = Emission factor for direct N_2O emission	2006 IPCC GL default values	50.00%
Combined uncertainty		79.06%
Indirect N ₂ O:		
a. $Nrate(T) = default N excretion rate$	2006 IPCC GL default values	50.00%
b. TAM(T) = typical animal mass for livestock	2006 IPCC GL default values	25.00%
c. MS(T,S) = fraction of total annual nitrogen excretion	2006 IPCC GL default values	25.00%
d. EF4 = N volatilization and redeposition	2006 IPCC GL default values	96.00%
e. EF5 = leaching/runoff	2006 IPCC GL default values	65.33%
Combined uncertainty	2006 IPCC GL default values	140.48%

The uncertainty for the manure management based on Equation 3.2 in Volume 1, chapter 3, 2006 IPCC Guideline is approximately 16.86% for CH₄ emission and 47.59% for N₂O emission (Table 5-20).

Table 5 - 20 Uncertainty of manure management emissions

GHG Source Categories	GHG	Emission in 2022 (E), kt CO ₂ e	Uncertainty (U), %	(E x U) ²	Combined Uncertainty, %
3.B.1.a.i. Mature dairy cattle	CH ₄	17.48	28.28	244,490	-
3.B.1.a.ii. Other mature cattle	CH ₄	806.39	28.28	520,211,204	_
3.A.2. Sheep	CH ₄	22.33	28.28	399,008	_
3.A.3. Swine	CH ₄	1,223.09	28.28	1,196,763,060	16.86
3.A.4.a. Buffalo	CH ₄	72.05	28.28	4,153,072	
3.A.4.d. Goats	CH ₄	14.87	28.28	176,846	_
3.A.4.e. Horses	CH ₄	24.18	28.28	467,776	_
3.A.4.g. Poultry	$\mathrm{CH_{4}}$	350.16	28.28	98,089,039	

GHG Source Categories	GHG	Emission in 2022 (E), kt CO ₂ e	Uncertainty (U), %	(E x U) ²	Combined Uncertainty, %
Total		2,530.56		1,820,504,496	
3.B.1.a.ii. Other mature cattle	N_2O	6,456.68	81.55	277,249,740,090	_
3.A.2. Sheep	N_2O	1,083.42	81.55	7,806,326,497	_
3.A.3. Swine	N_2O	438.31	81.55	1,277,649,599	_
3.A.4.a. Buffalo	N_2O	581.32	81.55	2,247,386,020	_
3.A.4.d. Goats	N_2O	1,558.72	81.55	16,157,969,669	47.59
3.A.4.e. Horses	N_2O	225.87	81.55	339,297,395	_
3.A.4.g. Poultry	N ₂ O	727.48	81.55	3,519,609,777	_
3.B.5. Indirect N ₂ O emissions	N ₂ O	1,890.49	141.90	71,960,389,503	
Total		12,962.28		380,558,368,551	

The time-series of emissions for Category 3B is consistent, as it employs a uniform methodology across all years in the reporting period, and the AD is also consistent and comprehensive. Changes in the AD necessitate revisions for all pertinent years, conducted in collaboration with institutions supplying information pertinent to this sector and the Ministry of Agriculture, along with agricultural sector experts.

5.3.5. Category-Specific QA/QC and Verification

The AD utilized to estimate emissions for Category 4B is the livestock population categorized by animal type from the Basic Payment Scheme, consistent with the data type and source employed in Category 4A. QC has been implemented during the compilation process for this inventory category, adhering to the procedures outlined in Section 1.6 and specifically in 5.2.5.

5.3.6. Category-Specific Recalculations

This inventory reflects recalculated emissions from manure management based on the revision of EFs utilizing the Tier 2 method, adjustments to the proportion of livestock age classes for 2017-2019 across all livestock types, the application of GWP from AR5, and the implementation of IPCC 2006 software version 2.93, as reported in the GHGI Report in BUR2. The series of adjustments has influenced the calculation of livestock numbers by age and the estimation of emissions from manure management. Adjustments of EFs and ADs for Category 3.B are presented in Table 5-21.

Table 5 - 21 Recalculations and improvements to the emissions from the manure management category

Emission Source	Adjustment Category	Type of Recalculation
Category		
3.B Manure	Use of updated country-specific CH ₄ EFs for	EF
management	category 3.B based on available (default) parameters	

' 1 2000 IDGG G '11' 14 2010 IDGG	
in the 2006 IPCC Guidelines and the 2019 IPCC	
Refinement	
Adjustment of the proportion of livestock age	AD
classes for the period 2017-2019 using the 2018	
Inter-Census Agricultural Survey	
Use of AR5 GWP	Transparency

Table 5- 22 illustrates that emissions from the manure category have consistently increased annually, with the disparity between emissions from BUR3 and BTR1 varying from 12.52% to 37.17%. The observed difference arises from enhanced estimation of EFs for livestock subcategories, achieved through the application of the Tier 2 method as outlined in the 2006 IPCC Guidelines and the 2019 IPCC Refinement, alongside the utilization of GWP parameters from AR5.

Table 5- 22 Comparison of emissions from enteric fermentation category between BUR3 and BTR1

NGHGI Report	2000	2005	2010	2015	2019
Submission 2021 BUR3, kt CO ₂ e	7,144.42	7,481.45	8,975.40	10,584.79	13,423.09
Submission 2024 BTR1, kt CO ₂ e	9,800.10	9,994.98	12,017.23	13,472.76	15,103.47
Difference, kt CO ₂ e	2,655.68	2,513.53	3,041.83	2,887.97	1,680.38
Difference, %	37.17	33.60	33.89	27.28	12.52

5.3.7. Plan of Improvements

To enhance future estimates of manure management emissions, the following aspects have been identified for review and/or revision (Table 5 - 23)

Table 5-23 Plan of improvements for the estimation of manure management emissions

Plan of Improvements	Priority	Rationale
Improve the estimation of VS for dairy cows, beef cattle, buffalo, layer chickens, and broiler chickens	High	Methane emissions are highly influenced by VS, which is a function of maximum methane producing capacity (Bo) and MCF
Improve the estimation of N excretion for dairy cows, beef cattle, layer chickens, and broiler chickens	High	N ₂ O emissions from manure management are highly influenced by N excretion, which is a function of milk yield, milk-protein content, milk-fat content, animal weight, weight gain, and feed characteristics
Improve the assumptions on manure management systems (dry lot, pasture, daily spread, poultry with litter and without litter)	High	The assumptions used in manure management in the GHGI, such as dairy cows (daily spread), beef cattle (30% pasture; 70% dry lot), buffalo, sheep, goats, swine, horses (dry lot), are considered for evaluation



5.4. Rice Cultivation (3.C)

5.4.1. Category Description

Emissions from rice cultivation in Indonesia represent a significant category. Rice fields cultivated under diverse irrigation systems produce varying levels of methane emissions, influenced by the flooded soil conditions and agricultural practices employed. Emissions result from the decomposition of organic matter via complex biochemical reactions conducted by methanogenic microbes in anaerobic or flooded environments. The quantity of methane gas emitted into the atmosphere is influenced by the total area of rice cultivation under various irrigation systems, including irrigated, rainfed, and tidal. Factors such as water management practices implemented before and during cultivation, the duration of the crop, the use of organic amendments, as well as soil type and variety, also play significant roles (IPCC 2006).

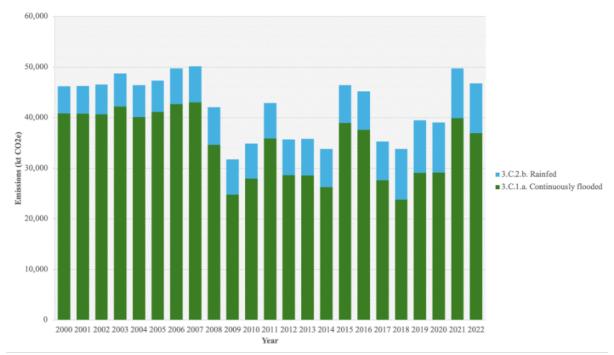
Methane emissions in the national context from the 3C category arise from rice cultivation utilizing continuous flooding irrigation systems, encompassing both low-emission and non-low-emission varieties, as well as intermittent and rainfed practices. Planting is typically conducted through the manual transplantation of seedlings from nurseries. The transplanted seedlings exhibit fully developed leaves. Crop management is conducted through three primary methods: weeding, irrigation, and fertilization.

5.4.2. Trends in Greehouse Gas Emissions by Category

In 2022, methane emissions from rice cultivation constituted the primary source, contributing 46,841.59 kt CO₂e, or 34.55%, to agricultural emissions. This represents an increase of 1.29% since 2000 and 18.57% since 2019 (Table 5-24 and Figure 5 - 8). The emission status of this category exhibits a fluctuating trend, particularly during the 2008-2017 period. This may be caused by production processes such as land-use change, climate variability (especially El Niño), and pests and diseases. Rice production is contingent upon the area harvested and the level of productivity. Data from BPS for the period 2000-2019 indicate that the harvested area of rice exhibited variability and a general decline (BPS 2020). Following 2019, emissions rose by 22.0%, and it seems that the COVID-19 pandemic had no impact on rice production, which was even greater than prior to the pandemic.

Table 5- 24 Rice cultivation emissions by sub-category (in kt CO₂e)

GHG Source Categories	2000	2005	2010	2015	2019	2022
3.C.1.a. Continuous						
flooded	40,845.02	41,125.20	28,003.08	38,958.97	29,118.31	36,942.72
3.C.2.b. Rainfed	5,398.99	6,232.28	6,911.56	7,491.32	10,388.59	9,898.87
Total	46,243.01	47,357.59	34,914.64	46,450.30	39,506.90	46,841.59



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Figure 5-8 Emission trends of rice cultivation based on sub-categories (in kt CO₂e)

In the rice ecosystem, rice production is significantly greater in irrigated regions compared to rainfed areas. Data from BPS 2017 (Kementan 2020) indicates that approximately 58% of rice fields are irrigated, while the remaining 44% consists of non-irrigated rice fields, including rainfed and tidal varieties. Irrigated rice fields account for 78.87% of total CH₄ emissions from rice cultivation, whereas rainfed sources contribute 21.13%.

5.4.3. Methodological Issues

The Tier 2 methodology estimates CH₄ emissions from rice cultivation (3.C) using Equation 5.1 from the 2006 IPCC Guidelines and the 2019 IPCC Refinement. Emission estimates for category 3.C incorporate scaling factors related to soil and rice varieties, alongside country-specific EFs. Parameters concerning water regime and organic amendments are derived from IPCC defaults. Table 5-25 delineates the methods and EFs utilized according to sub-categories and greenhouse gas types.

Table 5- 25 Methane emission methods and factors for rice cultivation

Irrigation Type	Method	Emission Factor
Irrigation		
Continuous flooding	T2	CS
SLPTT (Sekolah Lapang Pengelolaan Tanaman Terpadu / Integrated Crop Management Field School)	T2	CS
• Intermittent	T2	CS
Low-emission variety	T2	CS

Non-irrigated (rainfed)	T2	CS

T2 = Tier 2 IPCC

CS = Country-Specific

The scaling factors for the specific rice variety were sourced from the Agricultural Environment Instrument Standard Testing Center, Ministry of Agriculture, Pati, Central Java. Soil type scaling factors at the order level of soil taxonomy were sourced from the Ministry of Agriculture and subsequently adjusted using weights based on the distribution of soil types in Indonesia, due to the unavailability of data on harvested rice areas by soil type.

In the national context, the soil scaling factor applied is 0.98. The organic amendment consists of manure at a variable application rate of 0.34 tons per hectare and rice straw at a rate of 1.16 tons per hectare. The country-specific methane EF is 1.61 kg CH₄ per hectare. The soil type scaling factor of 0.98 represents the weighted average value. The scaling factors for rice varieties range from a minimum of 0.34 to a maximum of 2.46, as indicated in the table (Kementan 2020) below.

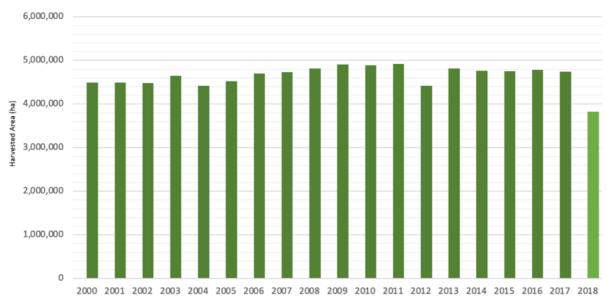
Table 5- 26 Rice variety scaling factors

Variety	Age (day)	Scaling Factor
Aromatik	115	1.35
Batang Anai	110	0.76
BP 205	110	0.97
BP 360	110	1.06
Ciherang	115	0.57
Cisadane	135	1.01
Cisanggarung	110	0.57
Cisantana	115	0.92
Dodokan	115	0.72
Fatmawati	110	1.81
Gilirang	120	2.46
Hipa 4	116	0.98
Hipa 5 Ceva	110	1.60
Hipa 6	110	1.08
Inpari	108	1.34
Inpari 13	99	0.89
Inpari 18	102	0.90
Inpari 31	119	1.05
Inpari 32	120	1.22
Inpari 33	107	0.95
Inpari 6 Jete	116	1.34
Inpari 9 Elo	125	1.77
IPB 3S	110	0.95
IR 36	115	0.73
IR 42	140	1.33
IR 64	110	1.00

Variety	Age (day)	Scaling Factor
IR 72	120	1.10
Limboto	110	0.49
Margasari	120	0.93
Maros	118	0.37
Mekongga	120	1.16
Memberamo	110	0.72
Mendawak	110	1.26
Muncul	125	0.63
Rokan	110	1.52
Tukad Balian	110	0.57
Tukad Petanu	110	0.78
Tukad Unda	110	1.21
WayApoburu	105	0.72
Wayarem	110	0.45

The data regarding the harvested area of rice fields, categorized by irrigated and non-irrigated conditions, was sourced from BPS for the period 2000 to 2017. Post-2017, the BPS data on harvested area ceased to distinguish between irrigated and non-irrigated rice field areas. The 2018-2019 inventory calculations for these two harvested areas were based on the area of irrigated and non-irrigated rice fields, as well as the planting index. The national harvested area has been estimated by the government using the KSA (*Kerangka Sample Area* / Area Sample Framework) approach since 2018, which differs from the methodology employed prior to that year. This approach indicates that the harvested area in 2018 is lower than that of previous years (Figure 5-9). Consequently, the harvested area from prior years must be aligned with the KSA approach, as utilizing the 2018 data for emissions estimation will yield a lower value than that of 2017. This may result in a misunderstanding that the reduction in emissions in 2018 relative to 2017 is attributable to mitigation efforts.

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Figure 5- 9 Comparison of harvested area using Non-KSA method (2000 - 2017) and KSA method (2018)

5.4.4. Uncertainty Assessment and Time-Series Consistency

The annual harvested area used to estimate CH₄ emissions from rice cultivation is derived from statistics and the uncertainty of this AD is assumed to be equal to 20% (IPCC 2006). The annual harvested area used to estimate CH₄ emissions from rice cultivation is derived from statistics and the uncertainty of this AD is assumed to be equal to 20% (IPCC 2006). The uncertainty of the EF and other parameters uses the default values from the 2006 IPCC Guidelines (Table 5-27). A quantitative assessment of uncertainty utilizing the 1 error propagation method has been conducted, estimating the combined uncertainty (AD and EF) in rice cultivation to be approximately 44.20% for irrigated rice fields and 45.36 rainfed rice fields.

Table 5-27 Default value of the uncertainty CH₄ of emission factors for rice cultivation

Emission Factor / Parameter	Source	Uncertainty
Irrigated rice fields		
a. EF _c = baseline emission factor for continuously flooded fields	2006 IPCC GL default values	21.54%
b. SF _w = scaling factor in water regime during the cultivation period	2006 IPCC GL default values	9.40%
c. SF _p = scaling factor to account for the differences in water regime in the preseason before the cultivation	2006 IPCC GL default values	5.20%
d. SF _o = scaling factor of organic amendment for compost	2006 IPCC GL default values	28.00%
e. SF _o = scaling factor of organic amendment for straw	2006 IPCC GL default values	13.79%
Combined uncertainty		39.42%

Rainfed rice fields	
a. EF _c = baseline emission factor for continuously flooded fields 2006 IPCC GL default values	21.54%
b. SF _w = scaling factor in water regime during the cultivation period 2006 IPCC GL default values	11.43%
c. SF _p = scaling factor to account for the differences in water regime in the preseason before the cultivation 2006 IPCC GL default values	5.20%
d. SF _o = scaling factor of organic amendment for compost 2006 IPCC GL default values	28.00%
e. SF _o = scaling factor of organic amendment for straw 2006 IPCC GL default values	13.79%
Combined uncertainty	40.71%

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The uncertainty for the rice cultivation emissions based on Equation 3.2 in Volume 1, chapter 3, 2006 IPCC Guideline is approximately 36.16% (Table 5-28).

Table 5- 28 Uncertainty of rice cultivation emissions

GHG Source Categories	GHG	Emission in 2022 (E), kt CO ₂ e	Uncertainty (U), %	(E x U) ²	Combined Uncertainty, %
3.C.1.a. Continuously flooded	CH ₄	36,942.72	44.20	2,666,663,038,882	
3.C.2.b. Rainfed	CH ₄	9,898.87	45.36	201,590,208,499	36.16
Total		46,841.59		2,868,253,247,381	

The time-series of emissions for category 3C demonstrates consistency, as it is derived using a uniform methodology across all years within the reporting period, coupled with consistent and complete AD. Data revisions are conducted for all pertinent years when changes occur in the AD utilized, in collaboration with institutions supplying information pertinent to this sector and the Ministry of Agriculture, along with agricultural sector experts.

5.4.5. Category-Specific QA/QC and Verification

The factors for estimating emissions from rice cultivation include the harvested area, irrigation management regime, and the varieties utilized. The data on harvested areas is obtained from BPS, whereas the planting area data for various varieties and crop ages is sourced from the Ministry of Agriculture, specifically from the Technical Directorate General responsible for food crops. The data is derived from seed assistance provided by the Ministry of Agriculture, while the planting and harvesting areas for each rice variety are sourced from the district Agriculture Office. Normative QA/QC procedures are implemented by performing random field surveys as part of monitoring and evaluation activities.

The evaluation of sampling errors in the survey data is conducted; however, there is a necessity to enhance and reinforce these errors, particularly concerning the AD needed for the

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compilation of the GHGI. The improvements aim to enable a reliable estimation of the uncertainty value of the AD, ensuring its availability and accessibility to both national and subnational inventory compilers.

QC activities for the inventory were conducted through (1) involvement of inventory compilers responsible for coordinating QA/QC and verification activities, as well as defining roles and responsibilities; (2) internal review of activity data and EFs, alongside emission estimates; (3) uncertainty and key category analyses; and (4) comparison of current and previous AD and emission estimates for the base years 2000 and 2019, including an analysis of the changes in emissions from 2000 to 2022 in the current submission. Furthermore, technical documentation and archiving have been established in this inventory to guarantee transparency and traceability of the calculation methods and data sources. QA by entities external to the inventory compilers has not been conducted to re-verify the calculation worksheets.

5.4.6. Category-Specific Recalculations

Emissions from the rice cultivation category for the GHGI BUR3 have been recalculated for the years 2000 to 2019, reflecting updates in AD, harvested area aggregation, application of AR5 GWP, and utilization of IPCC software. The use of these updated data and parameters has affected the emission calculations for this category, and information on the updates to the AD and parameters can be seen in Table 5-29.

Table 5 - 29 Recalculation and improvements to rice cultivation emissions

Emission Source Category	Category Adjustment	Type of Recalculation
3.C Rice Cultivation	Change in the amount of manure applied to rice fields based on Equation 11.4, Chapter 11, Volume 4, 2006 IPCC Guidelines, proportional to the area of rice fields and upland agriculture	AD
	Change in the amount of crop residues returned to rice fields	AD
	Aggregation of provincial-level harvested area to the national level	Soil type FS
	Use of AR5 GWP	Transparency

Table 5-30 presents a comparison of emissions from the rice cultivation category as reported in the GHGI for BTR1 and BUR3. The table indicates that emission patterns from this category in both GHGIs exhibit similarities and a consistent annual increase. However, methane emissions from rice cultivation in BTR1 are notably higher, ranging from 56.55% to 98.17%. The emissions differential in 2019 is less pronounced than in 2015, attributable to mitigation strategies involving intermittent irrigation systems and low-emission crop varieties.

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Table 5-30 Comparison of rice cultivation emissions between BUR3 and BTR1

NGHGI Report	2000	2005	2010	2015	2019
Submission 2021 BUR3, kt CO ₂ e	23,335.16	24,008.49	24,847.74	25,236.93	25,235.20
Submission 2024 BTR1, kt CO ₂ e	46,243.01	47,357.59	34,914.64	46,450.30	39,506.90
Difference, kt CO ₂ e	22,907.85	23,349.10	10,066.90	21,213.37	14,271.70
Difference, %	98.17	97.25	40.51	84.06	56.55

5.4.7. Plan of Improvements

To enhance the accuracy of future rice cultivation emissions estimates, the subsequent aspects have been identified for evaluation and potential modification (Table 5-31).

Table 5-31 Plan of improvements for estimating rice cultivation emissions

Plan of Improvements Priority Rationale	Plan of Improvements Priority Rationale	Plan of Improvements Priority Rationale
Validation and improvement of Tier 2 EFs based on rainfall patterns	High	Validation of Tier 2 EFs needs to be done in the field with different climate regime characteristics. Rice cultivation emissions are determined by the irrigation ecosystem, and the Tier 2 emission EFs currently applied do not yet consider rainfall patterns: monsoon, equatorial, local
Field study on organic amendment (straw)	Medium	Currently, the amendment of fresh straw to rice fields is estimated based on expert judgment (around 30% of residue biomass) and considered for further study to determine the correct application rate

5.5. Agricultural Soils (3.D)

5.5.1. Category Description

The agricultural soil source category represents a significant contributor to N_2O emissions in Indonesia. The application of nitrogen fertilizers to agricultural soils results in N_2O emissions from the soil, attributed to the microbial transformation of nitrogen compounds through

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nitrification and denitrification processes. Emission sources are categorized into direct and indirect N_2O emissions.

The direct N₂O emissions in sector 3.D encompass emissions resulting from the use of inorganic fertilizers, manure application, composting, grazing, and crop residues. Category 3.D encompasses indirect N₂O emissions resulting from nitrogen deposition, leaching, and surface runoff.

5.5.2. Trends in Greenhouse Gas Emissions by Category

In 2022, agricultural soils accounted for 22.24% of total agricultural emissions. The emission trend exhibited a consistent increase from 2000 to 2000. In 2022, emissions from this sector totaled 30,146.09 kt CO_2e , reflecting a 42.73% increase since 2000 and a 3.06% rise since 2019 (Table 5-32 and Figure 5 - 10). Emissions in this category are affected by the heightened application of nitrogen fertilizers for food crops and plantations, alongside the quantity of livestock manure utilized as organic fertilizer and the augmented nitrogen deposition in soils due to grazing livestock. This category encompasses emissions resulting from the decomposition of managed peatland soils utilized for agricultural activities.

Table 5- 32 Emissions from agricultural soils by sub-category (in kt CO₂e)

GHG Source Categories	2000	2005	2010	2015	2019	2022
3.D.1. Direct N ₂ O emission	16,686.40	17,505.67	20,574.44	22,032.05	23,659.24	24,317.43
3.D.2. Indirect N ₂ O emission	4,435.23	4,580.48	5,011.97	5,437.29	5,592.60	5,828.66
Total	21,121.63	22,086.15	25,586.41	27,469.33	29,251.85	30,146.09

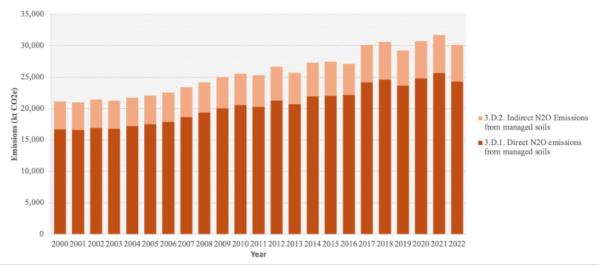


Figure 5- 10 Emission trends of agricultural soils by sub-category (in kt CO₂e)

The sub-category of agricultural soils is primarily characterized by direct N₂O emissions, which account for 80.67%, whereas indirect N₂O emissions contribute the remaining 19.33%.



5.5.3. Methodological Issues

Direct N₂O emissions resulting from the application of nitrogen-containing inorganic fertilizers (urea, ammonium sulfate, and NPK), manure, compost, and crop residues are estimated using the Tier 1 method, employing default EFs as outlined in the 2006 IPCC Guidelines, specifically through Equations 11.1 and 11.2 in Chapter 11, Volume 4. The quantity of inorganic nitrogen applied to agricultural soils is determined by multiplying the nitrogen content by the annual application rates of urea, ammonium sulfate, and NPK fertilizers, as sourced from APPI. The nitrogen content for various inorganic and organic fertilizers frequently utilized in Indonesia is detailed in the Table 5-33 below (Ministry of Agriculture, 2020). The calculation of manure addition employs the Tier 1 approach as outlined in Equation 11.4, Chapter 11, Volume 4 of the 2006 IPCC Guidelines. This calculation is differentiated for upland and wetland (paddy) agriculture according to the respective proportions of upland and paddy land area. The estimation of urine and dung deposited on pastures is conducted using the Tier 1 approach as outlined in Equation 11.5, Chapter 11, Volume 4 of the 2006 IPCC Guidelines. The livestock count in this sub-category is estimated to represent 30% of the total beef cattle population.

Table 5-33 N content of fertilizer substrates

No.	Substrate	N Content (%)
1	Urea	46
2	NPK	25
3	Ammonium sulfate	21
4	Manure	16
5	Compost	0.5
6	Crop residues	0.5

The annual nitrogen contribution from crop residues is estimated to originate from rice, which is returned to paddy fields. This report assumes that 25% of paddy rice residues are utilized as green manure, with the nitrogen amount estimated using Equation 11.6 from Chapter 11, Volume 4 of the 2006 IPCC Guidelines.

Indirect N₂O emissions resulting from the application of inorganic fertilizers, manure, and compost are calculated independently. The emissions are estimated utilizing Equations 11.9 and 11.10 from Chapter 11 of Volume 4 of the 2006 IPCC Guidelines. Default EFs are utilized for the estimation of emissions.

5.5.4. Uncertainty Assessment and Time-Series Consistency

The AD for estimating emissions from agricultural soils are amount of synthetic fertilizer N; amount of animal manure, and compost; amount of N in crop residues; area of managed/drained organic soils; and amount of urine and dung N deposited by grazing animals on pasture. Except for area of managed/drained organic soils, other AD are derived from statistics and therefore the uncertainty applied is 20%. Area of managed/drained organic soils is derived from the land cover maps used to estimate emissions and removals in the LULUCF sector and the uncertainty used is the same, which is 12%.

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The uncertainty of the EF and other parameters uses the default values from the 2006 IPCC Guidelines (Table 5-34). A quantitative assessment of uncertainty utilizing the 1 error propagation method has been conducted, estimating the combined uncertainty (AD and EF) in direct N_2O emissions from agricultural soil to be approximately 70.11% for inorganic N fertilizer, organic N, and crop residue fertilizer; 78.26% for the urine and dung deposited by grazing animals; 55.07% for cultivation of organic soils (i.e. histosols). Meanwhile, the combined uncertainty of N_2O emissions from agricultural soils is 144.92%.

Table 5-34 Default value of the uncertainty N₂O of emission factors in agricultural soils

Emission Factor / Parameter	Source	Uncertainty
Direct N ₂ O emissions		
Inorganic/organic N fertilizers and crop residue:		
a. EF ₁ = emission factor for N ₂ O emissions from N inputs	2006 IPCC GL default values	54.00%
b. EF _{1FR} is the emission factor for N ₂ O emissions from N inputs to flooded rice	2006 IPCC GL default values	40.00%
Combined uncertainty		67.20%
•		
Managed/drained organic soils		
a. EF2 = emission factor for N ₂ O emissions from drained/managed organic soils	2006 IPCC GL default values	53.75%
Urine and dung N deposited on pasture		
a. EF _{3PRP, CPP} for cattle (dairy, non-dairy and buffalo), poultry and pig	2006 IPCC GL default values	53.00%
b. EF _{3PRP, SO} for sheep and 'other animals'	2006 IPCC GL default values	54.00%
Combined uncertainty		75.66%
Direct N ₂ O emissions		
a. EF ₄ = emission factor for N ₂ O emissions from atmospheric deposition of N	2006 IPCC GL default values	96.00%
b. EF ₅ = emission factor for N ₂ O emissions from N leaching and runoff	2006 IPCC GL default values	65.33%
c. Frac _{GASM} = fraction of applied organic N fertilizer	2006 IPCC GL default values	45.00%
d. Frac _{GASF} = fraction of synthetic fertilizer N that volatilizes	2006 IPCC GL default values	54.00%
e. Frac _{LEACH-(H)} = fraction of all that leaching/runoff	2006 IPCC GL default values	46.67%
Combined uncertainty		143.54%

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The uncertainty for the agricultural soils based on Equation 3.2 in Volume 1, chapter 3, 2006 IPCC Guideline is approximately 36.16% (Table 5-35).

Table 5- 35 Uncertainty of agricultural soils emissions

GHG Source Categories	GHG	Emission in 2022 (E), kt CO ₂ e	Uncertain ty (U), %	(E x U) ²	Combined Uncertainty, %
3.D.1.a. Inorganic N fertilizers	N ₂ O	6,246.10	70.11	191,791,473,145	
3.D.1.b. Organic N fertilizers	N_2O	3,390.89	70.11	56,524,718,255	
3.D.1.c. Urine and dung deposited by grazing animals	N_2O	2,767.15	78.26	46,899,740,885	
3.D.1.d. Crop residues	N_2O	175.02	70.11	150,590,778	39.62
3.D.1.f. Cultivation of organic soils (i.e. histosols)	N ₂ O	11,738.28	55.07	417,917,410,587	
3.D.2. Indirect N ₂ O Emissions from managed soils	N ₂ O	5,828.66	144.92	713,547,643,522	
Total		30,146.09		1,426,831,577,172	

The time-series of emissions for category 3C demonstrates consistency, as it is derived using a uniform methodology across all years within the reporting period, coupled with consistent and complete AD. Data revisions are conducted for all pertinent years when changes occur in the AD utilized, in collaboration with institutions supplying information pertinent to this sector and the Ministry of Agriculture, along with agricultural sector experts.

5.5.5. Category-Specific QA/QC and Verification

The data for this source category, specifically concerning upland crops (including secondary crops and horticulture) and rice fields, is sourced from the Central Statistics Agency (BPS). Data regarding nitrogen-containing fertilizer consumption is sourced from APPI, the Indonesian Fertilizer Producers Association, which represents all fertilizer producers in Indonesia. The data is categorized into production, consumption, and export segments. The data utilized conforms to the consumption data as outlined by IPCC Guidelines. APPI, as a significant organization authorized to publish domestic fertilizer production and consumption data, has implemented a series of QA and QC procedures on the released data via a comprehensive data input process.

QC activities for the inventory have been conducted through (1) the involvement of inventory compilers responsible for coordinating QA/QC and verification activities, along with defining roles and responsibilities; (2) an internal review of AD and EFs, as well as emission estimates; (3) uncertainty analysis and KCA; and (4) a comparison of current and previous AD and emission estimates for the base year 2000 and the year 2019, alongside an analysis of the changes in emissions between 2000 and 2022 in the current submission. Furthermore, this inventory includes technical documentation and archiving to guarantee transparency and

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traceability of the calculation methods and data sources. External QA by entities not affiliated with the inventory compilers has yet to be conducted to re-evaluate the calculation worksheets.

5.5.6. Category-Specific Recalculations

The emission estimates for category 3.D in the previous NGHGI report have been recalculated for the years 2000 to 2019. This recalculation is attributed to updates in AD, revisions of EFs across all livestock types, adjustments in the age class distribution of livestock for the period 2017 to 2019 by livestock type, and the application of the Global Warming Potential from the AR5, alongside the utilization of the IPCC 2006 software version 2.93. Modifications to EF, AD, and associated parameters have influenced the estimation of methane emissions resulting from enteric fermentation. The adjustments to EF and AD are detailed in Table 5-36 of the new NGHGI report.

Table 5-36 Recalculations and improvements to agricultural soil emissions

Emission Source Category	Adjustment Category	Type of Recalculation
3.D Agricultural Soils	Updates to the amount of N from inorganic fertilizers (urea, ammonium sulfate, NPK) for large plantations	AD
	Changes in the assumption of the amount of N from organic fertilizers (manure) using Equation 11.4, Chapter 11, Volume 4, 2006 IPCC Guidelines for agricultural soils	AD
	New emission source for leaching	AD
	Changes in the assumption of the amount of crop residues returned to agricultural soils	AD
	New emission sources from urine and dung New emission source from agricultural management on peatlands	
	Use of GWP from AR5	Transparency

Table 5-37 indicates a year-on-year increase in emissions from the agricultural soil category, with N_2O emissions in the BUR3 being 25.62 - 37.67% lower than those in the BTR1. The observed difference primarily arises from the reduced quantity of organic nitrogen fertilizer derived from manure in the new inventory relative to the BUR3 inventory, alongside the variation in the GWP utilized, with the N_2O GWP value from AR5 being lower than that from AR2.

Table 5 - 37 Comparison of agricultural soil emissions between BUR3 and BTR1

NGHGI Report	2000	2005	2010	2015	2019
Submission 2021 BUR3, kt CO ₂ e	33,423.94	35,433.58	39,022.99	39,024.89	39,326.26
Submission 2024 BTR1, kt CO ₂ e	21,121.63	22,086.15	25,586.41	27,469.33	29,251.85
Difference, kt CO ₂ e	-12,302.31	-13,347.43	-13,436.58	-11,555.55	-10,074.42
Difference, %	-36.81	-37.67	-34.43	-29.61	-25.62



5.5.7. Plan of Improvements

To enhance the accuracy of agricultural soil emission estimates in the future, the following aspects have been identified for review and/or revision (Table 5 - 38).

Table 5-38 Plan of improvements for agricultural soil emission estimates

Plan of Improvements	Priority	Rationale
Development of FE N ₂ O	High	This category is classified as a key
		source in the agricultural and
		national sectors, and based on IPCC
		Guidelines, key sources need to be
		estimated using a higher Tier
		approach
Study of the dung and urine	Medium	Currently not considered in the
fraction from manure		BTR1 inventory due to the lack of
		available dung/urine fractions
Crop residue fraction according	Medium	Currently, the crop residue fraction
to the type of food crop applied		as green manure is estimated based
as green manure		on expert judgment (around 30% of
		residue biomass) and is being
		considered for review to obtain the
		correct fraction
Study of organic amendment	Medium	Currently, the compost fertilizer
(compost) application on		application rate is estimated based
vegetables		on expert judgment at around 10
		tons per hectare for all vegetable
		land, and is being considered for
		review to obtain the correct
		application rate

5.6. Prescribed Burning of Savannahs (3.E)

5.6.1. Category Description

Savanna is characterized by continuous grass vegetation, with occasional trees and shrubs present. Savannas are subjected to controlled burns to regulate vegetation growth, manage pest and weed populations, enhance nutrient cycling, and facilitate the growth of new grasses for grazing animals. The combustion of savannas leads to the release of carbon dioxide emissions. As vegetation regrows between burning cycles, the carbon dioxide released into the atmosphere is reabsorbed during the subsequent growth period. Consequently, CO₂ emissions resulting from savanna burning are excluded from the overall inventory, as they are considered to have net zero emissions.

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Alongside CO₂, savanna burning emits non-CO₂ gases such as methane, carbon monoxide, nitrous oxide, and nitrogen oxides. These emissions are of human origin and should be included in the inventory.

This section addresses emissions resulting from the combustion of grassland vegetation within the national context. This category includes non-CO₂ emissions resulting from savanna burning.

5.6.2. Trends in Greenhouse Gas Emissions by Category

In 2022, emissions from controlled savanna burning amounted to 156.19 kt CO₂e (Table 5-39), with the emission trend illustrated in Figure 5-11. Methane constitutes 66.19% of this category, whereas nitrous oxide represents 33.81%. The emission trend in this category exhibits significant fluctuations due to climatic conditions, yet it has shown a decreasing pattern over time, suggesting effective fire control measures in practice. In 2022, emissions were reduced by 55.44% relative to 2000 and by 56.82% relative to 2019. The data indicate that peak emissions were recorded in 2015, reaching 1,585.41 kt CO₂e, which coincided with an extended El Niño event.

Table 5- 39 Emissions from prescribed burning of savannahs (in kt CO₂e)

GHG Source Categories	2000	2005	2010	2015	2019	2022
Prescribed burning of savannahs (CH ₄)	195.10	122.01	44.77	1,481.77	995.70	103.38
Prescribed burning of savannahs (N ₂ O)	118.51	37.41	18.93	103.64	122.29	52.81
Total	313.61	159.41	63.71	1,585.41	1,117.99	156.19

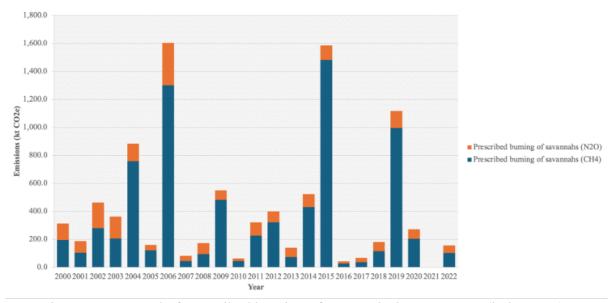


Figure 5- 11 Trend of prescribed burning of savannahs by GHG type (in kt CO₂e)



5.6.3. Methodological Issues

Savanna burning is generally conducted during the dry season or its early to mid-stages, facilitating nutrient recycling and promoting the growth of young savanna vegetation. The combustion of savanna ecosystems results in the release of carbon dioxide as well as other compounds, such as carbon monoxide, methane, nitrous oxide, and nitrogen oxides.

The non-CO₂ emissions for this category are estimated utilizing Tier 1 and the default EFs provided in the 2006 IPCC Guidelines, as outlined in Equation 2.27, Chapter 2, Volume 4. This report assumes that the area of savanna burned is equivalent to the area of grassland fire as determined through land use interpretation. The burned area of grassland is obtained through the visual interpretation of Landsat satellite data, as compiled by the Ministry of Environment and Forestry for the period from 2000 to 2022. The biomass burned can be determined by multiplying the burned area by the default grassland biomass value. This AD differs from the prior NGHGI report, which utilized the area of burned upland rice fields in the BUR3.

5.6.4. Uncertainty Assessment and Time-Series Consistency

The uncertainty of AD applied to the emission estimation for this category is 12%. This uncertainty value is used because the data source comes from forest and land fire maps, while the uncertainty of EFs uses the default IPCC 2006 value, which is 39% for CH₄ EF and 48% for N₂O EF, and 46% for biomass stocks. The uncertainty for the prescribed burning of savannahs emissions based on Equation 3.2 in Volume 1, chapter 3, 2006 IPCC Guideline is approximately 46.62% (Table 5-40).

Table 5-40 Uncertainty of prescribed burning of savannahs emissions

GHG Source Categories	GHG	Emission in 2022 (E), kt CO ₂ e	Uncertainty (U), %	$(E \times U)^2$	Combined Uncertainty, %
3.E.1. Prescribed burning of savannahs	CH ₄	103.38	61.50	40,418,129	
3.E-2. Prescribed burning of	0114	103.30	01.00	10,110,125	46.62
savannahs	N_2O	52.81	67.22	12,601,155	
Total		156.19		53,019,284	

Time-series consistency is maintained by employing uniform methodologies and performing recalculations in response to methodological enhancements or alterations in AD.

5.6.5. Category-Specific QA/QC and Verification

he data regarding the burned area of savanna is sourced from the Ministry of Environment and Forestry, with general QA/QC procedures applied as outlined in Section 1.6. The assessment of burned areas, applicable to both forested and non-forested regions, is derived from an analysis of Landsat 8 OLI/TIRS satellite imagery. This analysis incorporates hotspot distribution data and is supplemented by ground verification reports of hotspots and fire

suppression activities conducted by Manggala Agni, the forest and land fire control brigade under the Ministry of Environment and Forestry at the local level. The fire detection procedure adheres to the Technical Guidelines for Estimating the Area of Forest and Land Fires as outlined in the Regulation of the Director General of Climate Change No. P.11/PPI/PKHL/KUM.1/12/2018. The detection and estimation of burned areas are typically conducted visually on imagery that has been geometrically and radiometrically/ atmospherically corrected. Hotspot locations and fire suppression data constitute essential components of the fire detection process, providing initial verification of fire sites. The accuracy of fire locations and the calculation of fire area and location have been validated through field visits employing a purposive sampling method.

5.6.6. Category-Specific Recalculations

The emissions from savannah burning in the NGHGI report from BUR3 have been recalculated using updated activity data for the years 2000 to 2019, following the update of the AD on burned area, the application of GWP from AR5, and the utilization of the IPCC software. Table 5 - 41 provides the updated AD utilized for estimating emissions in category 3.E.

Table 5-41 Recalculation and improvement of prescribed burning of savannahs emissions

Emission Source	Adjustment Category	Type of Deceloulation
Category	Adjustifient Category	Type of Recalculation
3.E Prescribed burning of savannas	Use of actual grassland burned area data from visual interpretation of Landsat satellite imagery, which was previously estimated from the area of shifting cultivation burned for land preparation	AD
	Aggregation of emission estimates from the previous provincial level to the national level;	AD
	Use of GWP from AR5	Transparency

Table 5-42, indicates that emissions from category 3.D in the BTR1 exhibit fluctuations. The emissions from controlled savanna burning in the new inventory are lower than those in the same emission category in BUR3. The observed difference arises from the seasonal patterns of savanna burned area data in the BTR1 such as in 2015 and 2019, which typically exhibit elevated levels during extended dry seasons, such as those associated with El Niño, compared to normal years.

Table 5 - 42 Comparison of prescribed burning of savannas emissions between BUR3 and BTR1

NGHGI Report	2000	2005	2010	2015	2019
Submission 2021 BUR3, kt CO ₂ e	1,232.33	1,163.22	1,114.05	1,015.88	821.64
Submission 2024 BTR1, kt CO ₂ e	313.61	159.41	63.71	1,585.41	1,117.99
Difference, kt CO ₂ e	-918.71	-1,003.80	-1,050.34	569.53	296.36
Difference, %	-74.55	-86.30	-94.28	56.06	36.07



5.6.7. Plan of Improvements

To enhance savanna emission estimates, the subsequent aspects have been identified for review and/or revision (Table 5 - 43).

Table 5 - 43 Plan of improvements for improving estimates of prescribed burning of savannahs emissions

Plan of Improvements	Priority	Rationale
Improving the estimation of burned area by land use in years where land cover maps are not available	Medium	Currently, land cover maps for the years 2001, 2002, 2004, 2005, 2007, 2008, and 2010 are unavailable

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

5.7.1. Category Description

This category details the emissions of CH₄, N₂O, CO, NOx, and NMVOC resulting from the combustion of agricultural crop residues in the field, including rice, maize, and sugarcane, with biomass as the primary impacted carbon stock. CO₂ emissions resulting from the burning of agricultural residues are excluded from the total inventory, based on the assumption that the CO₂ released is equivalent to the CO₂ absorbed during plant growth.

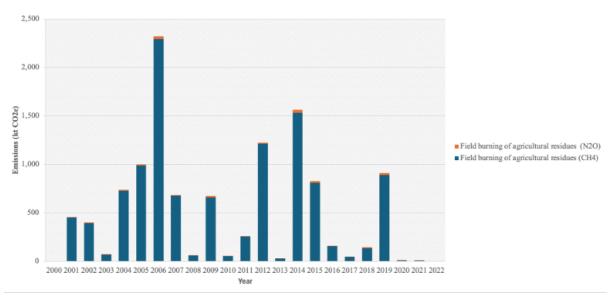
This category encompasses emissions resulting from the combustion of crop residues in paddy fields, dryland agriculture, mixed dryland agriculture, and transmigration areas within the national context. Emissions resulting from the combustion of maize, sugarcane, legumes, tubers, and other crop residues are not explicitly quantified, as they are expected to arise within the mixed dryland agriculture and transmigration land use classifications.

5.7.2. Trends in Greenhouse Gas Emissions by Category

In 2022, emissions resulting from the field burning of agricultural residues were minimal, totaling only 1.83 kt CO₂e (Table 5 - 44). Emissions have declined by 32.19% since 2000 and by 95.77% since 2019. The emission trend for this category exhibits significant fluctuations influenced by climatic conditions. El Niño events corresponded with increased emissions in the years 2006, 2012, 2015, and 2019, resulting in emissions of 2,321.80 kt CO₂e, 1,224.49 kt CO₂e, 828.83 kt CO₂e, and 911.70 kt CO₂e, respectively. Under typical climatic conditions, emissions remain comparatively low.

Table 5 - 44 Emissions from the field burning of agricultural residues (in kt CO₂e)

GHG Source Categories	2000	2005	2010	2015	2019	2022
Field burning of agricultural residues (CH ₄)	1.45	988.42	55.67	809.90	891.67	0.98
Field burning of agricultural residues (N ₂ O)	1.25	13.15	0.52	18.93	20.04	0.85
Total	2.69	1,001.58	56.19	828.83	911.70	1.83



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Figure 5- 12 Trend of the field burning of agricultural residues by GHG type (in kt CO₂e)

5.7.3. Methodological Issues

The practice of field burning of crop residues is prevalent in agricultural systems, especially in developing nations. The quantity of crop residues during burning is typically lower than at harvest, as a portion of these residues is extracted from the land for use as composting material.

The estimation of non-CO₂ emissions in this category employs Tier 1 methodology, utilizing the default EFs provided in the 2006 IPCC Guidelines, specifically referenced in Equation 2.27, Chapter 2, Volume 4 of the guidelines. This report assumes that the quantity of crop residues burned corresponds to the area of agricultural land, specifically paddy rice cultivation, that is burned. The AD source is the MoEF, derived from visual interpretation of Landsat satellite data spanning the years 2000 to 2022. The burned biomass can be calculated by multiplying the burned area by the biomass value associated with that land use. This AD, as noted in category 3.E, differs from earlier GHGI reports, wherein BUR3 utilized the area of burned paddy fields. The biomass burned in prior GHGI reports was estimated to range from 10% to 70% of the land area, contingent upon the provincial administrative region.

5.7.4. Uncertainty Assessment and Time-Series Consistency

The source of AD applied to estimate emissions in the category is the forest and land fire map. The uncertainty of this data is estimated at 12%, while the uncertainty of the EF uses the default value of IPCC 2006, which is 50% for the CH₄ EF, 50% for the N₂O EF and 50% for biomass stock. The uncertainty for the field burning of agricultural residues emissions based on Equation 3.2 in Volume 1, Chapter 3, 2006 IPCC Guideline is approximately 50.85% (Table 5-45).

Table 5-45 Uncertainty of field burning of agricultural residues emissions

GHG Source Categories	GHG	Emission in 2022 (E), kt CO ₂ e	Uncertainty (U), %	(E x U) ²	Combined Uncertainty %
3.F.1. Field burning of agricultural					
residues	$\mathrm{CH_{4}}$	0.98	71.72	4,940	
3.F.2. Field burning of agricultural					50.85
residues	N_2O	0.85	71.72	3,689	
Total		1.83		8,629	

Time-series consistency is maintained by employing uniform methodologies and conducting recalculations in response to methodological enhancements or alterations in AD.

5.7.5. Category-Specific Quality Assurance / Quality Control and Verification

The data regarding agricultural residue burning in the field is sourced from the Ministry of Environment and Forestry, with general QA/QC procedures detailed in Section 1.6. The AD regarding agricultural residue burning is presumed to pertain to the burning conducted in paddy fields. The burn area data is obtained from visually interpreted Landsat data, in accordance with the Technical Guidelines for Estimating Forest and Land Burn Area outlined in the Regulation of the Director General of Climate Change No. P.11/PPI/PKHL/KUM.1/12/2018.

5.7.6. Category-Specific Recalculations

Emissions from agricultural residue burning in the GHGI and BUR3 reports have been recalculated for the years 2000-2019, reflecting updates in burn area AD, the application of GWP from AR5, and the utilization of IPCC software. Table 5 - 46 provides the AD updates utilized for estimating emissions in category 3.F.

Table 5 - 46 Recalculation and improvement of the field burning of agricultural residues emissions

Emission Source Category	Adjustment Category	Type of Recalculation
3.F Field burning of agricultural residues	Use of actual agricultural residue burn area data from paddy fields based on visual interpretation of Landsat satellite imagery, previously estimated from the area of shifting cultivation burned for land preparation	AD
	Aggregation of emission estimates from the previous provincial level to the national level Use of GWP from AR5	AD Transparency

Table 5 - 47, illustrates the variability in emissions from category 3.F in the BTR1. The emissions from agricultural residue burning in the new inventory are lower than those reported in the BUR3 for the same category. The discrepancy arises from the seasonal patterns of

savanna burn area data in the BTR1, which typically increases during extended dry seasons, such as those associated with El Niño, compared to normal years.

Table 5 - 47 Comparison of field burning of agricultural residues between BUR3 and BTR1

NGHGI Report	2000	2005	2010	2015	2019
Submission 2021 BUR3, kt CO ₂ e	1,100.07	1,122.17	1,312.25	1,454.80	1,254.56
Submission 2024 BTR1, kt CO ₂ e	2.69	1,001.58	56.19	828.83	911.70
Difference, kt CO ₂ e	-1,097.38	-120.59	-1,256.07	-625.97	-342.85
Difference, %	-99.76	-10.75	-95.72	-43.03	-27.33

5.8. Liming (3.G)

5.8.1. Category Description

his category examines the CO₂ emissions associated with the application of agricultural lime. Liming agricultural soils reduces soil acidity, enhances the availability of certain nutrients, and promotes plant growth. In managed agricultural and forest lands, the carbonate from lime (limestone or dolomite) added to the soil dissolves, releasing bicarbonate, which subsequently converts to CO₂ gas and water.

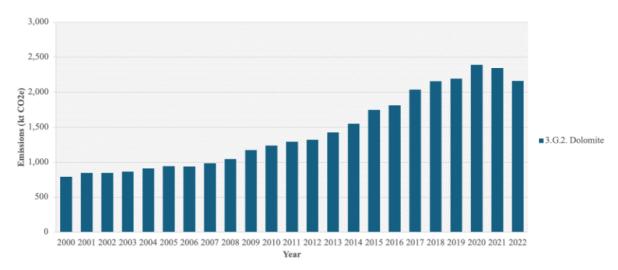
Category 3G encompasses the emissions produced from the application of lime on agricultural land, specifically limestone and dolomite. This inventory reports emissions from agricultural dolomite lime, which is the commonly utilized type.

5.8.2. Trends in Greenhouse Gas Emissions by Category

In 2022, the emissions associated with the application of dolomite lime on agricultural soils amounted to 2,159.22 kt CO₂, representing 1.59% of the total agricultural emissions (Table 5 - 48). In that year, emissions rose by 172.76% relative to 2000 and decline by 1.57% in comparison to 2019 emissions. Figure 5-13 illustrates a consistent rise in emissions associated with the use of dolomite lime since the year 2000.

Table 5- 48 Liming emissions (in kt CO₂)

GHG Source Category	2000	2005	2010	2015	2019	2022
3.G.2. Dolomite	791.63	941.60	1,235.75	1,745.62	2,193.59	2,159.22
Total	791.63	941.60	1,235.75	1,745.62	2,193.59	2,159.22



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Figure 5- 13 Trend of liming emissions (in kt CO₂)

5.8.3. Methodological Issues

The Tier 1 method outlined in the 2006 IPCC Guidelines is utilized to estimate emissions resulting from the application of agricultural lime, employing Equation 11.2 from Chapter 11, Volume 4. The EFs utilized are based on default values.

The utilization of agricultural lime in Indonesia is contingent upon governmental programs and the state of agricultural soils. Data regarding the utilization of agricultural lime is not consistently accessible. In prior submissions for NC and BUR, estimates were derived from the area of agricultural land, specifically acid sulfate soils and peatlands, multiplied by a lime application rate of 2 tons per hectare. The lime consumption data in this BTR1 Report continues to employ the same methodology as in prior reports, due to the limited and inconsistent availability of lime usage data from the Ministry of Agriculture and the Indonesian Fertilizer Producers Association (APPI).

5.8.4. Uncertainty Assessment and Time-Series Consistency

The source of AD applied to estimate emissions in the category is statistic data. The uncertainty of this data is estimated at 20%, while the uncertainty of the EF uses the default value of IPCC 2006, which is 50%. The Tier 1 error propagation approach has been employed for quantitative assessment in estimating the combined uncertainty from the liming, which is 53.85%.

Time-series consistency is maintained by employing uniform methodologies and performing recalculations in response to methodological enhancements or alterations in AD.

5.8.5. Category-Specific QA/QC and Verification

Liming is a prevalent method employed on acidic soils to enhance soil fertility. AD on agricultural lime use is unavailable; therefore, this inventory estimates it by multiplying the area of agricultural land (acid soils and peatlands) by the rate of agricultural lime application. The difficulty in estimating this AD arises from the uncertainty inherent in the data or

estimation factors, which may contain errors. In the future, if data on agricultural lime usage is unavailable and this method continues to be utilized, it is essential to accurately assess the area of agricultural land with acid or peat soils and the rate of agricultural lime application in accordance with field conditions.

At present, verification is absent; however, future implementation of a verification process concerning the application rate of agricultural lime is necessary, particularly for the primary food crops and plantations utilizing this substance.

5.8.6. Category-Specific Recalculations

Emissions from agricultural lime use in the GHGI of the BUR3 have been recalculated utilizing the 2006 IPCC software for the years 2000 to 2019, revealing no significant differences in the emission values relative to prior estimates. The discrepancy in emissions between BUR3 and BTR1 arises from the rounding of the agricultural lime application amount (Table 5- 49).

Table 5 - 49 Comparison of liming emissions between BUR3 and BTR1

NGHGI Report	2000	2005	2010	2015	2019
Submission 2021 BUR3, kt CO ₂ e	809.84	947.05	1,261.77	1,717.06	2,160.21
Submission 2024 BTR1, kt CO ₂ e	791.63	941.60	1,235.75	1,745.62	2,193.59
Difference, kt CO ₂ e	-18.21	-5.45	-26.02	28.56	33.38
Difference, %	-2.25	-0.58	-2.06	1.66	1.55

5.8.7. Plan of Improvements

To enhance emission estimates in the future, the following aspects have been identified for review and/or revision (Table 5 - 50).

Table 5- 50 Plan of improvements for liming emission estimates

Plan of Improvements	Priority	Rationale
Identification of data sources on	Medium	The current AD on agricultural lime
agricultural lime use from		use is estimated based on the need
government programs and APPI		for agricultural lime to improve soil
		pH on acid sulfate soils and
		peatlands, which is estimated from
		the area multiplied by the lime
		application rate

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5.9. Urea Application (3.H)

5.9.1. Category Description

Nitrogen is essential for optimal plant growth and production. Plants can acquire the necessary nitrogen through the application of urea fertilizer. Category 3.H details the CO₂ emissions produced from the application of urea fertilizer. Nitrogen fertilization using urea leads to CO₂ emissions via a reaction that involves urease and water.

5.9.2. Trends in Greenhouse Gas Emissions by Category

In 2022, emissions in this category totaled 4,047.21 kt CO₂, accounting for 2.99% of agricultural emissions (Table 5 - 51). Emissions have risen by 17.81% since 2000 and by 5.62% relative to 2019. Figure 5-14 illustrates the trend of urea use emissions, indicating a rise since the year 2000. The COVID-19 pandemic did not impact the production and distribution of fertilizers. Swastika et al. (2020) indicate that fertilizer consumption rose during the COVID-19 pandemic compared to the pre-pandemic period (2017-2019), aligning with government initiatives aimed at enhancing food crop production and ensuring food security. The increase in the production of all types of fertilizers under the APPI, coupled with the smooth and controlled distribution, supports this assertion.

Table 5- 51 Urea application emissions (in kt CO₂)

GHG Source Category	2000	2005	2010	2015	2019	2022
3.H. Urea application	3,435.33	3,610.19	4,192.84	4,034.92	3,832.03	4,047.21
Total	3,435.33	3,610.19	4,192.84	4,034.92	3,832.03	4,047.21

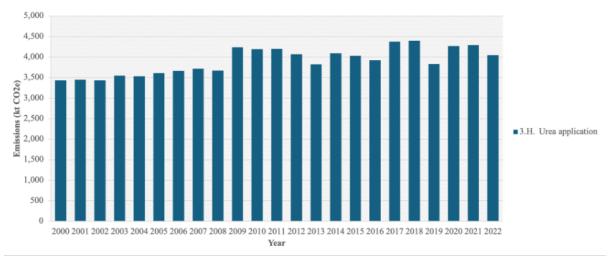


Figure 5- 14 Urea application emissions (in kt CO₂)



5.9.3. Methodological Issues

The Tier 1 method is utilized to calculate emissions from Urea Application, as outlined in Equation 11.13, Chapter 11, Volume 4 of the 2006 IPCC Guidelines. The IPCC's default EF utilized is 0.2 tons of carbon per ton of urea.

The information regarding urea utilization for food crops and plantations in this BTR1 Report is derived from the Indonesian Fertilizer Producers Association (APPI). In earlier NC and BUR reports, urea consumption data were estimated by multiplying the plantation area by the application rate of urea fertilizer, in addition to subsidized urea fertilizer for food crops, which was obtained from APPI. This estimate was generated due to the incomplete availability of urea use data, which was not provided in a time-series format corresponding to the reporting period of the previous inventory compilation. Since 2020, APPI has provided data on urea fertilizer consumption for food crops and plantations. The available data is incomplete, covering only the period from 2006 to 2022, with data for 2000-2005 currently unavailable. In this BTR1 Report, urea usage data from 2000 to 2005 was estimated using a proxy derived from the area of food crops and large plantations.

5.9.4. Uncertainty Assessment and Time-Series Consistency

The source of AD applied to estimate emissions in the category is statistic data. The uncertainty of this data is estimated at 20%, while the uncertainty of the EF uses the default value of IPCC 2006, which is 50%. The Tier 1 error propagation approach has been employed for quantitative assessment in estimating the combined uncertainty from the urea application, which is 53.85%.

Time-series consistency is maintained by employing uniform methodologies and performing recalculations when methodological enhancements or alterations in AD occur.

5.9.5. Category-Specific QA/QC and Verification

The data on urea fertilizer production is sourced from the APPI (Indonesian Fertilizer Producers Association), the organization representing all fertilizer producers in Indonesia. The data is categorized into production, consumption, and export segments. The data utilized conforms to the IPCC Guidelines, specifically pertaining to urea production. APPI, as a large organization authorized to release domestic fertilizer production and consumption data, has implemented a series of QA and QC procedures on the published data. This process includes a detailed data input methodology and the involvement of third parties in the audit process.

5.9.6. Category-Specific Recalculations

Emissions resulting from urea application in the GHGI BUR3 Report have been recalculated utilizing urea consumption data from the new source, APPI, for the years 2000 to 2019. The updated AD has influenced the emission calculations (Table 5 - 52).

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Table 5 - 52 Recalculation and improvement of urea application emissions

Emission Source Category	Adjustment Category	Type of Recalculation
3.H Urea application	Update of urea amount for large plantations, sourced from APPI	AD

Table 5 - 53 indicates a consistent annual increase in emissions from the urea category, with CO₂ emissions in BTR1 being 10.97-26.06% lower than those in BUR3. The observed difference primarily results from a lower quantity of urea fertilizer in the new inventory compared to the BUR3 inventory. The urea quantity in the GHGI BUR3 Report includes urea utilized for food crops obtained from APPI, in addition to urea usage from large plantations, estimated by multiplying the plantation area by the urea application rate. The urea usage data for food crops and plantations in BTR1 is derived from APPI, indicating that urea application for plantations is less than the estimate provided in BUR3.

Table 5 - 53 Comparison of urea application emissions between BUR3 and BTR1

NGHGI Report	2000	2005	2010	2015	2019
Submission 2021 BUR3, kt CO ₂ e	3,900.30	4,209.99	4,709.24	4,746.32	5,182.29
Submission 2024 BTR1, kt CO ₂ e	3,435.33	3,610.19	4,192.84	4,034.92	3,832.03
Difference, kt CO ₂ e	-464.97	-599.79	-516.40	-711.40	-1,350.26
Difference, %	-11.92	-14.25	-10.97	-14.99	-26.06

5.9.7. Plan of Improvements

To enhance emission estimates in the future, the subsequent aspects have been identified for review and/or revision (Table 5 - 54).

Table 5-54 Plan of Improvements for urea application emission estimates

Plan of Improvements	Priority	Rationale
Identification of additional data sources on urea fertilizer consumption besides APPI	Medium	The current AD on urea use is limited to APPI. Additional data sources need to be explored, such as the Ministry of Trade regarding urea or N fertilizer imports



VI. LAND USE, LAND-USE CHANGE AND FORESTRY (CRT SECTOR

4)

6.1. General Overview (CRT Sector 4)

The LULUCF sector encompasses GHG emissions and removals resulting from land management practices, influencing alterations in carbon stocks within vegetation and soils. This sector possesses the ability to act as a carbon sink, with vegetation capable of absorbing carbon dioxide emissions from the atmosphere.

6.1.1. Sector Description

The LULUCF sector encompasses CO₂ emissions and removals associated with alterations in carbon stocks within living biomass, dead organic matter, and soil carbon across all managed lands, in addition to CO₂ emissions arising from peat fires and decomposition of organic soils.

In Indonesia, land is categorized as managed, with a distinction made between mineral soils and organic soils. The NGHGI categorizes this sector as encompassing the emissions or removals of CO₂ resulting from activities that affect changes in biomass (both above-ground and below-ground), dead organic matter (including dead wood and litter), and soil carbon (soil organic matter). The alterations in biomass are analyzed within the framework of six land-use categories established by the IPCC: Forest Land (FL), Cropland (CL), Grassland (GL), Wetlands (WL), Settlements (SL), and OL. Furthermore, within these six land-use categories, the sub-categories of CO₂ emissions resulting from peat fires and peat decomposition are incorporated, with separate reporting in the inventory under biomass loss due to disturbance and soil organic carbon emissions, respectively. Emissions and removals associated with harvested wood products are excluded from the GHGI because of insufficient information and data necessary for the implementation of this sub-category.

During the reporting period for GHG emissions and removals across land-use categories, a distinction is made between two areas:

- Areas that have not experienced land-use change and, therefore, remain within the same land-use category. The following areas are classified under the "remaining" categories: FL-FL, CL-CL, GL-GL, WL-WL, SL-SL, and OL-OL;
- These include regions that have experienced land-use change. The areas are classified according to their respective categories. The following are categorized under "conversion": L-FL, L-CL, L-GL, L-WL, L-SL, and L-OL.

6.1.2. Categories and Total Emissions

The LULUCF sector accounts for 22.58% of total national emissions. In the LULUCF sector inventory for the year 2022, GHG emissions and removals were documented as 297,895.78 kt CO₂, 323.37 kt CH₄, and 20.23 kt N₂O (Table 6 - 1). Certain sub-categories of the LULUCF

sector, including FL-FL, L-FL, L-GL demonstrated net CO₂ removals, thereby establishing their significance as CO₂ sink sub-categories within LULUCF. Additional information and details on GHG emissions and removals are available in the designated sections for each sector category.

Table 6 - 1 GHG emissions and removals from LULUCF sector by sub-category in 2022

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO ₂ emissions/ removals	CH ₄ ⁽²⁾	$N_2O^{(2)}$	NO _x	СО	NMVOC	Total GHG emissions/ removals (3)
			(kt)				CO ₂ e (kt) (4)
4. Total LULUCF	297,895.78	323.37	20.23	26.86	813.13	NA,NE	312,311.57
4.A. Forest Land	-266,741.53	84.69	18.94	3.12	202.99	NE	-259,351.80
4.A.1. Forest land remaining forest land	-262,231.05	84.69	18.94	3.12	202.99	NE	-254,841.31
4.A.2. Land converted to forest land	-4,510.48	NE	NA,NE	NE	NE	NE	-4,510.48
4.B. Crop Land	412,258.89	199.48	0.59	10.65	392.02	NE	418,000.87
4.B.1. Cropland remaining cropland	364,677.31	199.48	0.59	10.65	392.02	NE	370,419.28
4.B.2. Land converted to cropland	47,581.58	NE	IE,NA,NE	NE	NE	NE	47,581.58
4.C. Grassland	86,099.06	38.49	0.70	13.09	218.12	NE	87,363.54
4.C.1. Grassland remaining grassland	91,638.95	38.49	0.70	13.09	218.12	NE	92,903.43
4.C.2. Land converted to grassland	-5,539.89	NE	IE,NA,NE	NE	NE	NE	-5,539.89
4.D. Wetlands (5)	1.66	0.70	NA,NE	NE	NE	NE	21.26
4.D.1. Wetlands remaining wetlands	IE,NA,NE	0.70	NA,NE	NE	NE	NE	19.60
4.D.2. Land converted to wetlands	1.66	NE	NA,NE	NE	NE	NE	1.66
4.E. Settlement	1,994.71	NE	NA,NE	NE	NE	NE	1,994.71
4.E.1. Settlements remaining settlements	IE,NE	NE	NA,NE	NE	NE	NE	IE,NA,NE
4.E.2. Land converted to settlements	1,994.71	NE	NA,NE	NE	NE	NE	1,994.71
4.F. Other ⁽⁶⁾	64,283.00	NE,NO	NE,NO	NE	NE	NE	64,283.00
4.F.1. Other land use remaining other land use							
4.F.2. Land converted to other land use	64,283.00	NE,NO	NE,NO	NE	NE	NE	64,283.00
4.G. Harvested wood product (7)							
4.H. Other (please specify)	NO	NO	NA,NO	NA,NE	NA,NE	NA,NE	NA,NO
N ₂ O emission from aquaculture [IPCC Software 3.C.12]	NO	NO	NO	NA	NA	NA	NO
Other emissions from LULUCF [IPCC Software 3.D.2]	NO	NO	NO	NE	NE	NE	NO
Memo item:							
Emissions and removals from natural disturbances on managed land	NE	NE	NE	NE	NE	NE	NE

In 2022, this sector emitted 312,311.57 kt CO₂e, reflecting an 8.94% reduction since 2000 and a 61.85% decrease since 2019 (Table 6 - 2). The increase in removals since 2019 can be attributed primarily to a reduction in deforestation, a decline in forest and land fires, and an expansion of planted forest cover, all of which have enhanced carbon stocks through biomass growth.

Table 6 - 2 GHG emissions and removals from LULUCF sector in 2022

GHG Source and Sink Categories	2000	2005	2010	2015	2019	2022
4.A.1. Forest land remaining		-	-		-	-
forest land	-201,863.63	227,188.77	250,704.70	-177,125.49	239,443.20	254,841.31
4.A.2. Land converted to						
forest land	-6,866.96	-30,750.78	-67,896.40	-27,611.39	-708.08	-4,510.48
4.B.1. Cropland remaining						
cropland	357,646.89	503,067.78	476,700.61	718,992.13	484,991.55	370,419.28
4.B.2. Land converted to						
cropland	65,282.48	86,377.72	42,268.40	213,437.69	47,275.28	47,581.58
4.C.1. Grasslands remaining						
grasslands	62,112.64	164,194.77	131,248.32	308,260.52	240,606.23	92,903.43
4.C.2. Land converted to						
savanna	50,434.52	120,240.62	68,119.13	7,350.82	-30,583.05	-5,539.89
4.D.1. Wetlands remaining						
wetlands	0.98	1,136.57	18.42	1,868.33	3,853.67	19.60
4.D.2. Land converted to						
wetlands	-0.04	483.04	590.22	1,374.33	1.71	1.66
4.E.1. Settlement remaining						
settlement	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE	IE,NA,NE
4.E.2. Land converted to						
settlements	746.07	2,731.73	3,540.32	44,407.68	1,602.26	1,994.71
4.F.1. Other land use						
remaining other land use						
4.F.2. Land converted to						
other land use	15,498.35	89,388.39	125,637.85	639,321.29	311,057.62	64,283.00
Total	342,991.31	709,681.07	529,522.17	1,730,275.90	818,653.99	312,311.57

Figure 6-1 presents an overview of LULUCF emissions for the BTR1 submission, illustrating the trend of GHG emissions over time. The x-axis displays the years included in the report, whereas the y-axis illustrates emissions (positive values) and removals (negative values), measured in kt CO₂e.

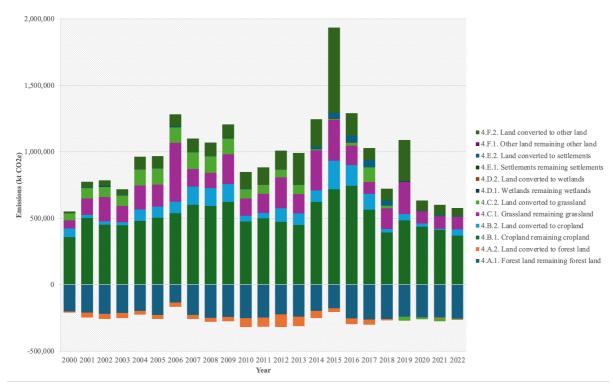


Figure 6- 1 GHG emissions and removals in LULUCF sector for the period 2000 – 2022 (in kt CO₂e)

During the period from 2000 to 2022, the average emissions and removals for this category amounted to 704,391.26 kt CO₂e annually. In 2022, FL removals were documented at 259,351.80 kt CO₂e, reflecting a 24.25% increase since 2000 and an 8.00% increase since 2019. In the same year, the CL emissions/removals were documented at 418,000.87 kt CO₂, reflecting a 1.17% decrease since 2000 and 21.47% since 2019; the GL emissions and removals were documented at 87,363.54 kt CO₂, reflecting a reduction of 22.38% since 2000 and 58.40% since 2019; the WL emissions and removals were documented at 21.26 kt CO₂, reflecting an increase of 2,156.24% since 2000 and a reduction of 99.45% since 2019, the SL emissions and removals were documented at 1,994.71 kt CO₂, reflecting a 167.36% increase since 2000 and 24.49% since 2019; and the OL emissions and removals were documented at 64,283.00 kt CO₂, reflecting an increase of 314.77% from 2000 and a decrease of 79.33% from 2019.

In 2022, CO_2 emissions and removals were predominant, accounting for 95.38% of total LULUCF emissions, while CH_4 and N_2O contributed 2.90% and 1.72%, respectively (Table 6 – 3).

Table 6 - 3 LULUCF emissions and removals by gas (in kt CO₂₎

Gas	2000	2005	2010	2015	2019	2022
CO_2	331,569.65	675,639.63	512,040.46	1,655,383.61	761,324.83	297,895.78
CH ₄	4,785.22	25,759.11	11,640.82	63,538.96	47,662.58	9,054.25
N_2O	6,636.43	8,282.33	5,840.88	11,353.34	9,666.58	5,361.54
Total	342,991.31	709,681.07	529,522.17	1,730,275.90	818,653.99	312,311.57

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6.1.3. Methodological Issues

Emissions and removals in the LULUCF sector are determined through biomass changes utilizing the Tier 1 method, employing carbon stock (CS) and default EFs as outlined in the 2006 IPCC Guidelines, the 2013 IPCC Supplement, and the 2019 IPCC 2006 Refinement. The alterations in CSs are calculated by aggregating the biomass changes across the six land-use categories, following the 2006 IPCC Guidelines and the 2019 IPCC 2006 Refinement, as outlined in Equation 2.1, Chapter 2, Volume 4.

The estimation of changes in CSs across six land uses is conducted for all strata or land surface subdivisions (e.g., species, climate zones, ecotypes, management regimes, etc.) as per Equation 2.2, Chapter 2, Volume 4, 2006 IPCC Guidelines. This report distinguishes stratification solely by soil type (mineral and peat) and land cover type.

Additionally, the alterations in the CS of a land use within a specific stratum are assessed by analyzing the carbon cycle processes across the five carbon pools, as outlined in Equation 2.3 of the 2006 IPCC Guidelines. The estimation of harvested wood products remains unachieved due to insufficient information and data.

The annual variations in carbon stocks across each pool are assessed through a process-based methodology known as the gain and loss method, as outlined in Equation 2.4 of Chapter 2, Volume 4 of the 2006 IPCC Guidelines. This method incorporates gains from biomass increment and carbon transfers among pools, such as from live biomass to dead organic matter, while accounting for losses resulting from wood harvesting and disturbances caused by disease or fire.

Non-CO₂ emissions from the LULUCF sector, resulting from biomass burning, peat decomposition, or other sources, are estimated alongside emissions/removals from biomass changes in land use, utilizing Equation 2.6 from Chapter 2, Volume 4 of the 2006 IPCC Guidelines. Table 6-4 below presents the methodologies and EFs utilized in the GHGI.

Table 6 - 4 Summary of LULUCF sector methodologies and emission factors

	CO_2		CH ₄		N ₂ O	
GHG Source and Sink Categories	Method applied	EF	Method applied	EF	Method applied	EF
4.A.1 Forest land remaining forest land	T1	D, CS	T1	D	T1	D
4.A.2 Land converted to forest land	T1	D, CS	T1	D	T1	D
4.B.1 Cropland remaining cropland	T1	D, CS	T1	D	T1	D
4.B.2 Land converted to cropland	T1	D, CS	T1	D	T1	D
4.C.1 Grasslands remaining grasslands	T1	D, CS	T1	D	T1	D
4.C.2 Land converted to grasslands	T1	D, CS	T1	D	T1	D
4.D.1 Wetlands remaining wetlands	T1	D, CS	T1	D	T1	D
4.D.2 Land converted to wetlands	T1	D, CS	T1	D	T1	D
4.E.1 Settlement remaining settlement	T1	D, CS	T1	D	T1	D
4.E.2 Land converted to settlements	T1	D, CS	T1	D	T1	D
4.F.1 Other land use remaining other land use	T1	D, CS	T1	D	T1	D
4.F.2 Land converted to other land use	T1	D, CS	T1	D	T1	D
Biomass burning (fire)	T1	CS	T1	D	T1	D
Peat decomposition	T1	CS	T1	D	T1	D
Peat fire	T1	CS	T1	D	T1	D

T1 = Tier 1 IPCC

D = Default IPCC, CS = Country-Specific

National AD has been utilized to estimate GHG emissions and removals in this sector, incorporating spatial land use data, forest and land fire area, roundwood, spatial peatland data, and fuelwood. This table summarizes the primary sources of AD for the LULUCF sector.

Table 6-5 Source of activity data

Category	Sub-category	Source of AD
Forest land	Forest land remaining forest	IPSDH, KLHK
	land	
	Land converted to forest land	IPSDH, KLHK
Cropland	Cropland remaining cropland	IPSDH, KLHK
	Land converted to cropland	IPSDH, KLHK
Grasslands	Grasslands remaining	IPSDH, KLHK
	grasslands	
	Land converted to grasslands	IPSDH, KLHK
Wetland	Wetlands remaining wetlands	IPSDH, KLHK
	Land converted to wetlands	IPSDH, KLHK
Settlement	Settlement remaining	IPSDH, KLHK
	settlement	
	Land converted to settlements	IPSDH, KLHK
Other Land Use	Other land use remaining other	IPSDH, KLHK
	land use	
	Land converted to other land	IPSDH, KLHK
	use	
Total of forest and land fire	Fire area in FL, CL, GL, SL,	PKHL, KLHK
	WL, OL	
Roundwood	Roundwood from FL and	PHL, KLHK
	Plantation Forests	
Fuel wood	Fuel Wood	FAO
Peatland Map	1:50,000 scale Peatland Map,	Kementan
	2019	

6.2. Land Use Definitions and Land Use Classification System

6.2.1. Forests

Indonesia is an archipelago state with a land area of 1,922,570 km² and a water area of 6,315,222 km² (BIG 2018). The 2nd FREL submission defines forests as land areas greater than 0.25 hectares, characterized by trees that attain a height exceeding 5 meters at maturity and possess a canopy cover exceeding 30 percent (Kemenhut 2004). This definition is consistent with those provided by the FAO and IPCC.

6.2.2. Land Use Classification

The Indonesian territory encompasses 23 land cover classes, comprising 6 natural forest classes, 1 plantation forest class, 15 non-forest classes, and 1 class designated for cloud-no data. The descriptions of the 23 classes are detailed in SNI 7645-2010 and Margono et al. (2016), summarized in Table 6-6. The inventory utilizes 23 land cover classes to account for

biomass changes over two time periods (tn - tn-1), based on land cover maps from 2000 to 2022, which include estimates of non-CO₂ emissions.

Table 6 - 6 Description of the 23 land cover classes

No	Class	Description
Forest		
1	Primary dryland forest	Natural tropical forests growing on non-wet habitat including lowland, upland, and montane forests. The class includes heath forest and forest on ultramafic and limestone, as well as coniferous, deciduous and mist or cloud forest, which is not (or low) influenced by human activities or logging
2	Secondary dryland forest	Natural tropical forest growing on non-wet habitat including lowland, upland, and montane forests that exhibit signs of logging activities indicated by patterns and spotting of logging (appearance of roads and logged-over patches). The class includes heath forest and forest on ultramafic and limestone, as well as coniferous, deciduous and mist or cloud forest
3	Primary swamp forest	Natural tropical forest growing on wet habitat in swamp form, including brackish swamp, marshes, sago and peat swamp, which is not or low influenced by human activities or logging
4	Secondary swamp forest	Natural tropical forest growing on wet habitat in swamp form, including brackish swamp, marshes, sago and peat swamp that exhibit signs of logging activities indicated by patterns and patches of logging (appearance of roads and logged-over patches)
5	Primary mangrove forest	Wetland forests in coastal areas such as plains that are still influenced by the tides, muddy and brackish water and dominated by species of mangrove and Nipa (<i>Nipa frutescens</i>), which is not or low influenced by human activities or logging
6	Secondary mangrove forest	Wetland forests in coastal areas such as plains that are still influenced by the tides, muddy and brackish water and dominated by species of mangrove and Nipa (<i>Nipa frutescens</i>), and exhibit signs of logging activities, indicated by patterns and patches of logging activities
7	Plantation forest	The appearance of the structural composition of the forest vegetation in large areas, dominated by homogeneous trees species, and planted for specific purposes. Planted forest include areas of reforestation, industrial plantation forest and community plantation forest
Non-for	est	
8	Dry shrub	Highly degraded logged-over areas on non-wet habitat that are in an ongoing process of succession but have not yet reached a stable forest ecosystem, with naturally scattered trees or shrubs
9	Wet shrub	Highly degraded logged-over areas on wet habitat that are in an ongoing process of succession but have not yet reached a stable forest ecosystem, with naturally scattered trees or shrubs

No	Class	Description
10	Savanna and Grasses	Areas with grasses and scattered natural trees and shrubs.
10	Savanna and Grasses	This is typical of natural ecosystem and appearance on
		Sulawesi Tenggara, East Nusa Tenggara, and the southern
		part of Papua Island. This type of cover could be on wet or
		non-wet habitat.
11	Pure dry agriculture	All land covers associated with agricultural activities on
		dry/non-wet land, such as tegalan (moor), mixed garden
		and ladang (agriculture fields)
12	Mixed dry agriculture	All land covers associated with agricultural activities on
		dry/non-wet land mixed with shrubs, thickets, and logged-
		over forest. This type of cover often results from shifting
		cultivation and its rotation, including on karst
13	Estate crop	Estate areas that have been planted, mostly with perennials
	D 11 (C 11	crops or other agricultural trees commodities
14	Paddy field	Agriculture areas on wet habitat, especially for paddy, that
		typically exhibit dike patterns (pola pematang). This cover
		type includes rainfed, seasonal paddy field, and irrigated
1.5		paddy fields
15	Transmigration areas	Kind of unique settlement areas that exhibit association of
1.6	F: 1	houses and agroforestry and/or garden at surrounding
16	Fish pond/aquaculture	Areas exhibit aquaculture activities including fish ponds,
17	Bare ground	Shrimp ponds or salt ponds Bare grounds and areas with no vegetation cover,
1 /	Bare ground	including open exposure areas, craters, sandbanks,
		sediments, and areas post-fire areas that have not shown
		sign of regrowth
18	Mining area	Mining areas exhibit open mining activities such as open-
10	wining area	pit mining including tailing ground
19	Settlement areas	Settlement areas include rural, urban, industrial and other
		built-up areas with typical appearance
20	Port and harbor	Sighting of port and harbor that is big enough to be
		delineated as independent object
21	Open water	Water bodies including ocean, rivers, lakes, and ponds
22	Open swamps	Wetland area with few vegetation
23	Cloud and no data	Clouds, cloud shadows or data gaps with a size of more
		than 4 cm ² at a 100.000 scale display

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According to the primary land-use categories outlined in the 2006 IPCC Guidelines—forest land, cropland, grassland, wetlands, settlements, and other land uses—the 23 land cover classes can be categorized into 6 classes, as shown in Table 6-7 below.

Table 6 - 7 Correspondence of MoEF land cover types with IPCC land-use categories

No	IPCC Land Use	Land Cover
1	Forest land	Primary dryland forest
2	Forest land	Secondary dryland forest
3	Forest land	Primary swamp forest
4	Forest land	Secondary swamp forest
5	Forest land	Primary mangrove forest
6	Forest land	Secondary mangrove forest
7	Forest land	Plantation forest
8	Cropland	Pure dry agriculture

No	IPCC Land Use	Land Cover
9	Cropland	Mixed dry agriculture
10	Cropland	Estate crop
11	Cropland	Paddy field
12	Cropland	Transmigration areas
13	Grasslands	Dry shrub
14	Grasslands	Wet shrub
15	Grasslands	Savanna and Grasses
16	Wetlands	Fish pond/aquaculture
17	Wetlands	Open water
18	Wetlands	Open swamps
19	Settlement	Settlement
20	Other land use	Bare ground
21	Other land use	Mining area
22	Other land use	Port and harbor
23	No data	Cloud and no data

6.2.3. Peatland

In estimating CO₂ and non-CO₂ emissions, land is stratified not only by land cover types but also by mineral soil and organic soil (peatland) types. The sources and sinks of GHG emissions vary between the two, making this distinction significant. Indonesia possesses a significant expanse of peatland that has been utilized for agricultural and other purposes for an extended period.

Peatland is a wetland ecosystem characterized by the accumulation of decomposed organic material, water saturation, a minimum organic matter content of 12%, and a cumulative depth of at least 50 cm. This definition adheres to the global peat soil classification established by the USDA Soil Taxonomy. Indonesian peatlands cover an area of 13.43 million hectares, distributed across four major islands: Sumatra, Kalimantan, Papua, and Sulawesi (Anda et al. 2021).

6.3. Forest Land (4.A)

6.3.1. Category Description

This category encompasses CO₂ and non-CO₂ emissions and removals from both remaining FL (4.A.1) and land that has been converted to FL (4.A.2). CO₂ emissions and removals, in relation to emission levels and trends, arise from alterations in biomass, dead wood, mineral soil, and peat carbon, along with fire occurrences on managed FL.

In the national context, CO₂ emissions and removals on mineral and peat soils result from increased biomass in both natural and planted forests, as well as land-use changes from other uses to FL. CO₂ emissions arise from activities related to the use of roundwood from both natural and planted forests, the harvesting of fuelwood, and the occurrence of forest fires.

Emissions encompass nitrous oxide from forest fires and the drainage of organic soils, as well as methane from these same sources.

6.3.2. Trends in Greenhouse Gas Emissions by Category

In 2022, total emissions and removals from forestry and land use reached 254,841.31 kt CO₂e, representing a 24.25% increase since 2000 and a 8.00% increase since 2019 (Table 6 - 8). Figure 6 - 2 illustrates the emission trends from 2000 to 2022. The trend in FL-FL emission and removal indicates an upward trajectory in removals. The rise in removals can be attributed to a reduction in deforestation, an expansion of forest cover in planted forests, a decline in forest fires, and limitations on the development of peatland areas. In the final year of LULUCF sector GHG reporting (2022), the FL-FL sub-category accounted for nearly 98.26% of total removals, whereas the L-FL sub-category contributed less than 1.74%.

Table 6 - 8 Emissions from forest land category (in kt CO₂e)

GHG Source and Sink Categories	2000	2005	2010	2015	2019	2022
4.A.1. Forest land						
remaining forest land	-201,863.63	-227,188.77	-250,704.70	-177,125.49	-239,443.20	-254,841.31
4.A.2. Land converted						
to forest land	-6,866.96	-30,750.78	-67,896.40	-27,611.39	-708.08	-4,510.48
Total	-208,730.59	-257,939.55	-318,601.11	-204,736.87	-240,151.28	-259,351.80

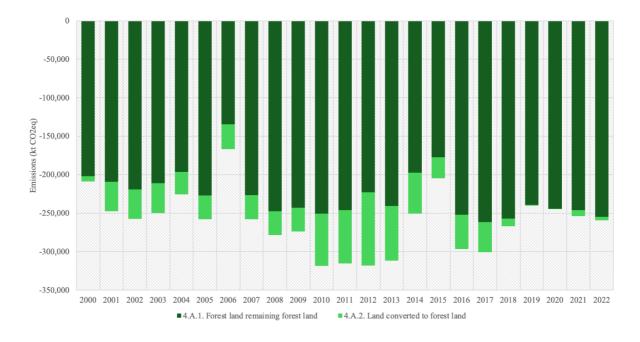


Figure 6- 2 Emission trends of the forest land category for the period 2000 – 2022 (in kt CO₂e)

Based on sources and sinks, in 2022, the primary emissions and removals were attributed to biomass changes within the FL sub-category, accounting for 97.30%. Emissions from drained peatlands and fires contributed 2.49% and 0.20%, respectively. The CO₂ is the predominant gas, accounting for 97.30%, followed by N₂O at 1.83% and CH₄ at 0.87%. The highest fire

emissions were recorded in 2006, followed by 2015, with values of 28,257.06 kt CO₂e and 23,377.41 kt CO₂e, respectively, attributed to extended El Niño dry seasons (Table 6 - 9).

Table 6 - 9 Forest land emissions by gas type (in kt CO₂e)

GHG Source and Sink Categories	2000	2005	2010	2015	2019	2022
CO ₂ emissions/						
removals	-216,378.54	-267,180.92	-326,410.90	-233,826.47	-251,399.64	-266,741.53
Organic soil CH ₄	865.13	945.52	1,163.74	1,306.76	1,763.09	1,917.58
Organic soil N ₂ O	5,965.46	5,642.44	4,973.48	4,405.44	4,615.14	4,914.90
Biomass burning CH ₄	661.39	2,403.77	1,468.07	20,589.79	4,121.12	453.81
Biomass burning N ₂ O	155.97	249.64	204.51	2,787.62	749.01	103.45
Total	-208,730.59	-257,939.55	-318,601.11	-204,736.87	-240,151.28	-259,351.80

6.3.3. Methodological Issues

The Tier 1 method outlined in the 2006 IPCC Guidelines is utilized across all sub-categories, employing biomass values derived from forest inventories alongside country-specific peatland EFs. The table below outlines the methods and EFs utilized according to sub-category and GHG type.

Table 6 - 10 Methods and emission factors for forest land

Codo	GHG Source and Sink	CO_2		$\mathrm{CH_4}$		N_2O	
Code	Categories	Method	EF	Method	EF	Method	EF
4.A.1	FL-FL	T1	CS, D	T2, T1	CS, D	T1	D
4.A.2	L-FL	T1	CS, D	T2, T1	CS, D	T1	D
4.A.2.a	CL-FL	T1	CS, D	T2, T1	CS, D	T1	D
4.A.2.b	GL-FL	T1	CS, D	T2, T1	CS, D	T1	D
4.A.2.c	WL-FL	T1	CS, D	T2, T1	CS, D	T1	D
4.A.2.d	SL-FL	T1	CS, D	T2, T1	CS, D	T1	D
4.A.2.e	OL-FL	T1	CS, D	T2, T1	CS, D	T1	D

T1 = Tier 1 IPCC

6.3.3.1. Biomass

6.3.3.1.1. Forest land remaining forest land

The estimation of changes in CS in biomass is derived from the "gain and loss" approach outlined in the 2006 IPCC Guidelines, employing country-specific EFs and Tier defaults. This method calculates the variation in CS by determining the difference between the annual biomass increase and the annual biomass losses (Equation 2.7). Emissions are assessed for forest land at two distinct time intervals (FL-FL).

The annual increase in CS in biomass from the growth of living biomass is estimated using Equation 2.9. Conversely, the annual decrease in CS in biomass resulting from the harvesting of roundwood, fuelwood logging, and forest fire disturbances is estimated using Equations 2.12, 2.13, and 2.14, respectively, as outlined in Chapter 2, Volume 4 of the 2006 IPCC

D = Default IPCC, CS = Country-Specific

Guidelines. Table 6 - 11 presents the EFs and additional parameters utilized for estimating the increase in CS. The default T1 EFs provided in the 2006 IPCC Guidelines are utilized for estimating biomass losses.

Table 6 - 11 Emission factors for estimating addition of biomass CS in forest land

Land-Use Categories	Stock Carbon Above-Ground (ton/ha)	Ratio of below- ground biomass to above-ground biomass (R)	Above-ground biomass growth (Gw, ton/dm/ha)	Carbon fraction (CF)
Primary dryland forest	291.24	0.29	0.7	0.47
Secondary dryland forest	204.10	0.29	3.4	0.47
Primary swamp forest	248.80	0.22	0.7	0.47
Secondary swamp forest	204.61	0.22	3.4	0.47
Primary mangrove forest	236.17	0.31	0.7	0.47
Secondary mangrove forest	118.02	0.11	3.4	0.47
Plantation forest	161.23	0.33	9.60	0.47

Alongside the CO_2 emissions resulting from harvesting and fire disturbances, this subcategory's inventory estimates CH_4 and N_2O emissions from forest fires utilizing Equation 2.27 from Chapter 2, Volume 4 of the 2006 IPCC Guidelines.

6.3.3.2. Land converted to forest land

The estimation of carbon emissions and removals from the conversion of land use to FL is detailed in Equation 2.15, Chapter 2, Volume 4 of the 2006 IPCC Guidelines. This equation determines the variation in biomass CS by aggregating the increase in biomass CS from biomass growth and the alteration in biomass CS resulting from land conversion to forest, while deducting biomass losses. The alteration in biomass CS resulting from the conversion of land to FL is determined using Equation 2.16 from Chapter 2 of Volume 4 of the 2006 IPCC Guidelines.

The alteration in biomass CS resulting from the conversion of land to FL is determined using Equation 2.16 from Chapter 2, Volume 4 of the 2006 IPCC Guidelines.

6.3.3.3. Dead wood and litter

6.3.3.3.1. Forest land remaining forest land

The annual variation in the CS of dead wood and litter is assessed through the stock-difference method employing a Tier 1 approach, as outlined in Equation 2.23, Chapter 2, Volume 4 of the 2006 IPCC Guidelines.

6.3.3.3.2. Land converted to forest land

The yearly variation in the CS of dead wood and litter for areas converted to FL is calculated using Equation 2.23 from Chapter 2, Volume 4 of the 2006 IPCC Guidelines. This equation is identical to the one utilized for calculating the change in dead wood and litter CS in FL that

remains classified as FL. The standard time period value of 20 years is applied across all subcategories.

6.3.3.4. Soil organic carbon

6.3.3.4.1. *Mineral soil*

This section presents data on CO₂ emissions resulting from alterations in soil carbon stocks on forested land.

Forest land remaining forest land

The annual variation in the CS of mineral soils within FL that remains classified as FL is considered to be zero, as specified in the Tier 1 method of the 2006 IPCC Guidelines. Consequently, no annual change is documented for this carbon pool.

Land converted to forest land

The annual variation in CS within mineral soils on land transitioned to FL is estimated employing the Tier 1 method, as outlined in Equation 2.25, Chapter 2, Volume 4 of the 2006 IPCC Guidelines. The reference values for soil organic carbon (SOC) before and after, along with other parameters, utilize default values corresponding to different land-use types.

6.3.3.4.2. Organic soil

This section examines CO₂ and non-CO₂ emissions from organic soils resulting from FL management practices.

Forest land remaining forest land

CO₂ emissions from drained peatlands are estimated using Equation 2.3 from Chapter 2 of the 2013 Wetlands Supplement, employing CS EFs. In contrast, non-CO₂ emissions from drained peatlands are estimated using Equation 2.6 from the same chapter, utilizing CS EFs for CH₄ and default values for N₂O. GHG emissions from organic soils are documented across all landuse categories.

Land converted to forest land

The estimation of CO₂ and non-CO₂ emissions for land converted to FL employs Equations 2.3 and 2.6 from Chapter 2 of the 2013 Wetlands Supplement. The equations correspond to those utilized for the FL remaining FL sub-category. Annual emissions are documented for each year within the conversion category.

6.3.3.5. Activity data

The area of each land use for FL, remaining FL, and land converted to FL is presented in Tables 6-12 and 6-13 below. Additional information is provided in the CRTs appended to this document as an Annex.

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Table 6 - 12 Land-use area and land-use change from forest land category on mineral soils 2000 - 2022 (ha)

Year	FL-FL	CL-FL	GL-FL	SL-FL	WL-FL	OL-FL
1996/2000	95,161,354	186,070	153,291	396	1,313	38,996
2000/2003	94,339,008	24,834	153,360	4	1,285	32,281
2003/2006	92,486,401	11,044	195,905	207	1,022	47,862
2006/2009	90,490,034	18,931	153,114	117	770	61,604
2009/2011	89,881,299	14,742	61,371	27	5,238	79,843
2011/2012	89,359,291	45,657	215,846	359	340	13,821
2012/2013	88,877,862	19,759	102,287	8	89	36,687
2013/2014	88,699,116	7,780	17,323	4	537	81,496
2014/2015	88,087,323	1,332	21,481	0	130	24,720
2015/2016	87,448,166	44,246	84,060	346	3,849	39,963
2016/2017	87,015,634	52,574	89,486	302	923	14,663
2017/2018	84,464,856	787,067	1,564,749	6,742	48,656	424,387
2018/2019	86,991,058		2,680			
2019/2020	87,964,477	720	335	38		169
2020/2021	87,110,711	112	2,212	85		16,408
2021/2022	88,807,362	315	2,544	801	_	7,753

Table 6 - 13 Land-use area and land-use change from the forest land category on peat soils 2000 - 2022 (Ha)

_							
	Year	FL-FL	CL-FL	GL-FL	SL-FL	WL-FL	OL-FL
	1996/2000	8,747,325	1,915	4,307			4,024
	2000/2003	8,522,246	3,735	139,678	288		29,817
	2003/2006	8,142,849	2,859	68,833		1	61,447
	2006/2009	7,531,534	695	54,280		272	87,879
_	2009/2011	7,322,712	4,622	212,522		14,657	110,135
	2011/2012	7,494,552	301	17,851			87,336
	2012/2013	7,365,767	5,127	42,278		67	69,209
_	2013/2014	7,259,436		3,195			53,761
_	2014/2015	6,826,347	2,079	12,765			36,445
	2015/2016	6,746,397	2,775	9,809	32	742	6,393
	2016/2017	6,684,466	4,795	10,760		22	9,330
	2017/2018	6,555,688	39,050	105,181	67	3,598	406,061
	2018/2019	6,949,082		135			254
	2019/2020	7,215,826		2,343			30
	2020/2021	7,126,237		1,499			1,480
	2021/2022	7,268,931	-	2,155		-	1,926

The table below presents timber harvesting data from natural forests and plantations. Data on roundwood harvesting were obtained from Forestry Statistics and augmented with information from the Directorate General of Sustainable Production Forest Management and Perum Perhutani (State-Owned Enterprise).

Table 6 - 14 Volume of roundwood harvesting from natural forests and industrial timber plantations for the period 2000 - 2022

Year	Natural Forest (m ³)	$HTI(m^3)$	Total (m ³)
2000	4,132,714	8,125,004	12,257,718
2001	4,132,714	5,918,767	10,051,481
2002	3,202,547	4,933,756	8,136,303
2003	5,061,386	6,362,116	11,423,502
2004	5,142,637	8,406,300	13,548,937
2005	9,334,862	14,887,776	24,222,638
2006	9,020,903	12,771,241	21,792,144
2007	9,501,292	21,990,293	31,491,585
2008	7,393,032	24,607,753	32,000,785
2009	11,476,397	22,844,139	34,320,536
2010	19,739,728	22,375,042	42,114,770
2011	5,689,293	41,740,042	47,429,335
2012	5,890,177	43,368,050	49,258,227
2013	5,780,849	40,005,428	45,786,277
2014	11,841,582	39,233,472	51,075,055
2015	6,260,416	40,341,628	46,602,044
2016	5,867,785	38,931,742	44,799,527
2017	5,165,796	44,792,174	49,957,970
2018	5,429,082	44,174,416	49,603,498
2019	5,429,979	42,812,196	48,242,175
2020	4,651,465	48,027,721	52,679,186
2021	4,665,071	50,281,542	54,946,613
2022	4,560,605	50,492,519	55,053,124

The annual fuelwood consumption is sourced from FAO data. The annual total value is presumed to derive from branches or stumps. The subsequent table displays fuelwood harvesting measured in cubic meters (m³).

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Table 6-15 Volume of fuelwood harvesting from natural forests

Year	Fuel Wood (m ³)
2000	88,981,100
2001	85,712,100
2002	82,555,800
2003	79,507,700
2004	76,563,800
2005	73,719,900
2006	70,719,200
2007	67,825,400
2008	65,034,200
2009	62,341,400
2010	59,743,200
2011	57,288,100
2012	54,917,000
2013	52,626,800
2014	50,414,400
2015	48,276,700
2016	46,209,100
2017	44,210,600
2018	42,278,700
2019	40,410,700

Year	Fuel Wood (m ³)
2020	38,604,400
2021	38,604,400
2022	36.877.800

Information on forest fires was sourced from the Directorate General of Climate Change and Forest and Land Fires, Ministry of Environment and Forestry, based on the interpretation of remote sensing satellite imagery. The extent of forest fires is illustrated in the subsequent table.

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Table 6 - 16 Extent of fire in FL (in ha)

Year	Primary Mangrove Forest (Hmp)	Secondary Mangrove Forest (Hms)	Primary Dryland Forest (Hp)	Primary Swamp Forest (Hrp)	Secondary Swamp Forest (Hrs)	Secondary Dryland Forest (Hs)	Plantation Forest (Ht)
2000	179	418	871	33	1,565	10,427	6,659
2001	727	2,994		421	12,596		12,259
2002	1,886	3,793		2,210	31,468		4,194
2003	1,910	6,174	4,102	2,396	35,797	71,958	40,621
2004	241	2,857		15,084	81,552		11,237
2205	439	617		8,545	12,306		11,826
2006	1,962	2,217	4,740	22,126	264,506	98,794	66,239
2007	356	255		3,438	52,172		9,959
2008	99	140		57	1,504		6,801
2009	103	175	911	40	26,577	18,380	10,371
2010	61	206		40	14,647		1,655
2011	88	94	174	127	6,310	12,081	12,204
2012	2	537	832	1,087	35,736	37,980	44,567
2013	21	20	3,809	70	7,561	17,841	13,524
2014	628	1,248	1,105	1,971	53,176	39,513	96,302
2015	245	2,722	11,683	4,667	83,537	78,425	110,435
2016	125	1,297	5,413	1,841	20,811	14,922	22,965
2017	2	94	221	29	1,506	9,846	4,354
2018	20	121	861	599	7,313	10,602	2,327
2019	47	1,005	2,942	2,439	27,021	41,590	22,511
2020	16	109	2,969	557	3,525	18,077	8,497
2021	73	42	1,865	7	1,620	14,479	8,082
2022	109	26	904	56	1,964	5,168	1,718

6.3.4. Uncertainty Assessment and Time-Series Consistency

The uncertainty in AD from FL arises from the variability in spatial data processing. In contrast, the uncertainty regarding growth and above-ground biomass CS within the FL category is mainly attributed to the standard error associated with the national forest inventory, as documented in Indonesia's FREL.

The combined uncertainty for the FL remaining FL and land converted to FL categories are estimated 48.64 and 13.62% respectively. Additional details can be found in Annex 2. Time-series consistency is maintained by employing uniform methods and performing recalculations in response to methodological enhancements or alterations in AD.



6.3.5. Category-Specific QA/QC and Verification

QC for the LULUCF sector has been implemented in accordance with specific QC procedures outlined in Chapter 8 of the 2006 IPCC Guidelines. The Directorate of GHGI and MRV of the Ministry of Environment and Forestry conducted general checks during the preparation of the GHGI, focusing on procedures for processing, handling, documenting, archiving, and reporting for all emission source categories.

The primary sources of data for LULUCF activities include the land cover map matrix, soil maps (both mineral and peat), and the forest and land fire area map. The land-use matrix is generated from the land cover map created by IPSDH. The data utilized consist of satellite images, predominantly from Landsat, SPOT Vegetation, and MODIS. Mapping is conducted visually in accordance with the land cover classification system, utilizing progressively refined mapping procedures. The mapping system was established in 2000, with notable enhancements occurring in 2009 through the consolidation of land cover data layers from the years 1990, 1996, 2000, 2003, 2006, 2009, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, and 2022 into a unified geodatabase. Revision processes and accuracy assessments have been conducted as components of QC.

The GHGI for the LULUCF sector is compiled by the GHGI Sub-Directorate utilizing the land-use matrix supplied by IPSDH of the Ministry of Environment and Forestry. Initially, the land-use matrix, mineral and peat soil matrix, and forest fire data are obtained from data custodians, subjected to quality checks, and subsequently approved for emission calculations. Emission calculations for annual land-use changes are conducted using data matrixes, implemented in stages and presented in tabular form, utilizing area data and EFs. Following this, the Directorate of GHGI and MRV, in collaboration with Expert Teams, evaluates the worksheets and CRTs developed by the GHG Inventory Sub-Directorate. This evaluation involves reviewing input data, assessing calculation accuracy, ensuring time-series consistency, and verifying alignment with calculations from previous years.

The QA process for reviewing and documenting the results of GHG Inventory for the LULUCF sector in accordance with QA guidelines has not been implemented. Moving forward, this will be a primary focus within the plan of improvements.

The inventory for the LULUCF sector is primarily developed utilizing IPSDH land cover maps, spatial data on forest fires, soil maps (peat/mineral), and forest inventory data. The AD serve as the primary sources, and there are no available comparative data for verification purposes. Land cover mapping, forest inventory, and soil mapping (peat/mineral) implement specific QC measures to ensure data quality.

6.3.6. Category-Specific Recalculations

Emission estimates for category 4.A have been revised for the years 2000 to 2019, reflecting updates in AD, adjustments to EFs, the application of GWP values from AR5, and the

utilization of IPCC 2006 software version 2.93. The modifications to EFs, AD, and parameters, influence the emission and removal estimates for FL. The table below illustrates the variations in AD and EFs utilized between BUR3 and BTR1.

Table 6 - 17 Changes in activity data and emission factors for calculating categories 4.A.1 and 4.A.2 FL

Type of Recalculation	Category	BUR3	BTR1	Adjustment
	Primary Forest	2.15	0.7	Improvement of EF data (Gw) from
	Secondary Forest	2.15	3.4	natural forests for primary and secondary forests
	Primary Forest	0	0	EE from most decommonition (drained
	Secondary Forest	5.18	8.84	EF from peat decomposition (drained peat) where BUR3 used IPCC default values, BTR uses country-specific
	Plantation Forest	19.91	19.90	values (Novita et al. 2021)
	Primary Forest	0.37	0.290	
	Secondary Forest	0.37	0.290	
EF	Secondary Swamp Forest	0.37	0.220	
	Primary Swamp Forest	0.37	0.220	- EF from ratio of below-ground
	Primary Mangrove Forest	0.37	0.311	biomass to above-ground biomass
	Secondary Mangrove Forest	0.37	0.115	
	Plantation Forest	0.37	0.325	•
AD	Peatland (Million Hectares)	6.9-9.3	6.7-8.7	The peatland area has changed between that used in BUR3 and BTR1. This change is due to updated data (reference)
AD	Mineral Soil (Million Hectares)	86.4- 100.9	86.9- 95.5	The mineral soil area data used in BUR3 differs from BTR1. This difference is due to changes in administrative boundaries each year that were not recalculated backward. Meanwhile, the data in BTR already uses the latest administrative boundaries applied to all land use
Category	Peat decomposition and fires	Separate categories	Part of Forest Soil Carbon	Emissions from peat decomposition and peat fires in FL become part of emissions from the FL category
Metric		AR2	AR5	Use of GWP

Table 6-18 presents a comparison of emissions from category 4.A between BUR3 and BTR1, indicating a notable difference of 18.63% to 54.35% for emissions in BUR3. The observed

difference arises from the utilization of an updated version of land-use area data for GHG emission calculations in BTR1.

Table 6 - 18 Comparison of forest land category emissions between BUR3 and BTR1

NGHGI Report	2000	2005	2010	2015	2019
Submission 2021 BUR3,	2000	2003	2010	2013	2017
kt CO ₂ e	-457,235.04	-457 254 28	-391,525.77	-370 033 01	-355,211.44
Submission 2024 BTR1,	-437,233.04	-437,234.20	-371,323.77	-370,033.01	-333,211.44
· · · · · · · · · · · · · · · · · · ·	209 720 50	-257,939.55	-318,601.11	204 726 97	240 151 29
kt CO ₂ e	-208,730.59				-240,151.28
Difference, CO ₂ e		-199,314.73		-165,296.14	-115,060.16
Difference, %	54.35	43.59	18.63	44.67	32.39

6.3.7. Plan of Improvements

Several aspects have been identified concerning future plans for enhancing emission estimates within the LULUCF category. (i) Evaluating emission estimates from inundated areas in accordance with the 2019 updates to the 2006 IPCC Guidelines; (ii) employing suitable methodologies and assumptions for estimating emissions and removals associated with peat decomposition, taking into account peat water table levels; (iii) applying relevant EFs and advanced tiers for significant categories; and (iv) recognizing forestry sector activities with potential for GHG emission reduction, followed by the formulation of methods for quantifying GHG emission reductions.

6.4. Cropland (4.B)

6.4.1. Category Description

This category encompasses CO₂ and non-CO₂ emissions from both cropland remaining cropland (4.B.1) and land that has been converted to cropland (4.B.2). CO₂ emissions, in terms of levels and trends, arise from alterations in biomass, dead wood, litter, variations in mineral and peat soil carbon, and fires occurring on cropland.

In the national context, CO₂ emissions from this category arise on mineral and peat soils as a result of alterations in living biomass, dead biomass, and soil carbon on cropland that remains cropland and land that has been converted to cropland (including both annual and perennial crops). Cropland comprises both annual and perennial crops. This category utilizes land cover data as its source. The inventory includes annual crops, specifically paddy fields and dryland agriculture, while perennial crops encompass plantations, mixed dryland farming, and transmigration areas. Emissions from agricultural land remaining agricultural land (including paddy fields and dryland agriculture) are not included in this inventory, as emissions and removals on annual agricultural land are balanced; emissions released during the harvest cycle are absorbed in the following period. Emissions may arise from the burning of agricultural residues, particularly from annual crops, as well as from the drainage of organic soils in

cropland. Alongside CO_2 emissions, these two sources generate CH_4 and N_2O emissions on cropland.

6.4.2. Trends in Greenhouse Gas Emissions by Category

In 2022, total emissions and removals from cropland amounted to 418,000.87 kt CO₂e, reflecting a 1.17% decrease in the emission trend since 2000, while showing a 21.47% decrease since 2019. Table 6 – 19 presents emissions data for the cropland category, categorized by groups and gases, whereas Figure 6 - 3 illustrates emission trends from 2000 to 2022. The trend of emission and removal in this category exhibits fluctuations. Increased emissions result from the expansion of cropland, the use of peatlands for agriculture, and land fires. Conversely, the declining emission trend is attributed to reduced land clearing, enhanced vegetation cover on perennial cropland, and limitations on peatland clearing permits. In 2022, the CL-CL subcategory accounted for 86.62%, whereas the L-CL sub-category represented only 11.38%.

Table 6 - 19 Emissions from crop land category

GHG Source and Sink Categories	2000	2005	2010	2015	2019	2022
4.B.1. Cropland remaining						
cropland	357,646.89	503,067.78	476,700.61	718,992.13	484,991.55	370,419.28
4.B.2. Land converted to						
cropland	65,282.48	86,377.72	42,268.40	213,437.69	47,275.28	47,581.58
Total	422,929.37	589,445.49	518,969.01	932,429.81	532,266.83	418,000.87

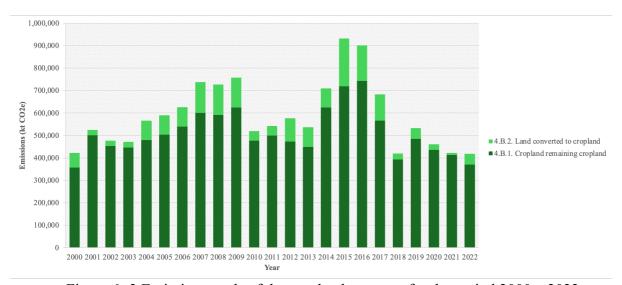


Figure 6- 3 Emission trends of the cropland category for the period 2000 – 2022

Dominant emissions and removals are primarily attributed to biomass changes within the cropland sub-category, accounting for 98.63%. In contrast, emissions from drained peatlands and fires represent only 1.02% and 0.35%, respectively. The CO₂ is the predominant gas, accounting for 98.63%, followed by CH₄ at 1.34% and N₂O at 0.04% (Table 6 - 20).

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Table 6 - 20 Cropland emissions by gas type (in kt CO₂e)

GHG Source and Sink Categories	2000	2005	2010	2015	2019	2022
Emissions/Removals of						
CO_2	420,580.14	576,679.04	513,239.11	920,209.28	513,934.96	412,258.89
Soil organic CH ₄	1,426.32	2,039.06	2,519.80	2,807.11	3,819.48	4,275.43
Soil organic N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00
Biomass burning CH ₄	773.34	9,612.49	2,929.20	8,324.01	13,044.22	1,310.10
Biomass burning N ₂ O	149.56	1,114.91	280.89	1,089.42	1,468.18	156.45
Total	422,929.37	589,445.49	518,969.01	932,429.81	532,266.83	418,000.87

6.4.3. Methodological Issues

The 2006 IPCC Guidelines employ Tier 1 and Tier 2 methods across all sub-categories, utilizing biomass values and EFs specific to peatlands. Table 6 - 21 details the methods and EFs utilized according to sub-categories and GHG types.

Table 6 - 21 Method and emission factors for crop land

Code	GHG Source and Sink	CO	CO_2		CH ₄		N_2O	
Code	Categories	Method	EF	Method	EF	Method	EF	
4.B.1	CL-CL	T1	D	T2, T1	CS, D	T1	D	
4.B.2	L-CL	T1	D	T2, T1	CS, D	T1	D	
4.B.2.a	FL-CL	T1	D	T2, T1	CS, D	T1	D	
4.B.2.b	GL-CL	T1	D	T2, T1	CS, D	T1	D	
4.B.2.c	WL-CL	T1	D	T2, T1	CS, D	T1	D	
4.B.2.d	SL-CL	T1	D	T2, T1	CS, D	T1	D	
4.B.2.e	OL-CL	T1	D	T2, T1	CS, D	T1	D	

T1 = Tier 1 IPCC, T2 = Tier 2 IPCC

D = Default IPCC, CS = Country-Specific

6.4.3.1.Biomass

6.4.3.1.1. Cropland remaining cropland

Carbon stock changes in biomass on cropland remaining cropland are estimated using Equation 2.7 from Chapter 2 of Volume IV of the 2006 IPCC Guidelines. This method quantifies changes in CS by calculating the difference between annual biomass increases from perennial crops and annual biomass losses resulting from removals. Biomass carbon changes are calculated using country-specific and default EFs from the 2006 IPCC Guidelines and the 2019 Refinement, along with cropland matrixes as AD.

Emissions from cropland with annual crops in this category are assumed to be zero, as the extraction of annual biomass is regarded as equivalent to biomass growth within the same year. The 2006 IPCC Guidelines indicate that biomass changes are projected to occur solely in perennial woody crops. This estimate utilizes land-use area data for plantations, dryland agriculture, and transmigration areas.

Table 6-22 below presents EFs and other parameters utilized for estimating increases in biomass CSs. Default T1 EFs from the 2006 IPCC Guidelines are utilized to estimate biomass losses.

Table 6 - 22 Emission factors for estimating biomass CS additions in crop land

	Stock Carbon	Ratio of below-	Above-ground	
Land-Use Categories	Above-Ground	ground biomass to above-ground	biomass growth (Gw,	Carbon fraction (CF)
	(ton/ha)	biomass (R)	ton/dm/ha)	. ,
Pure dry agriculture	30	0.20	0.40	0.47
Paddy field	21	0.24	0.00	0.47
Estate crop	102	0.32	5.04	0.47
Mixed dry agriculture	138	0.20	1.20	0.47
Transmigration areas	30	0.20	2.64	0.47

Besides CO₂ emissions, emissions of CH₄ and N₂O from cropland fires are also estimated in this sub-category inventory using Equation 2.27 from Chapter 2, Volume 4 of the 2006 IPCC Guidelines, employing default T1 EFs.

6.4.3.1.2. Land converted to cropland

Emissions estimates from land-use conversion to cropland are derived using Equation 2.16, Chapter 2, Volume 4 of the 2006 IPCC Guidelines. This equation quantifies changes in biomass CS resulting from land conversion by assessing the difference between the initial CS prior to conversion and the CS of the cropland post-conversion. It is assumed that the annual cropland biomass and the initial biomass CS are zero. Non-CO₂ emissions resulting from the conversion of land to cropland arise from fires and are estimated utilizing Equation 2.27 from Chapter 2 of Volume 4 of the 2006 IPCC Guidelines.

6.4.3.2. Dead wood and litter

6.4.3.2.1. Cropland remaining cropland

According to the 2006 IPCC Guidelines, dead wood and litter in cropland that remains cropland are regarded as being in equilibrium, thus assumed to be zero.

6.4.3.2.2. Land converted to cropland

Annual variations in carbon stocks within dead wood and litter for land transitioned to cropland are estimated using Equation 2.23 from Chapter 2, Volume 4 of the 2006 IPCC Guidelines.

6.4.3.3. Soil organic carbon

6.4.3.3.1. *Mineral soils*

This section details CO₂ emissions resulting from changes in soil CSs on cropland.

Cropland remaining cropland

According to the Tier 1 method outlined in the 2006 IPCC Guidelines, annual changes in CSs in mineral soils on cropland remaining cropland are assumed to be nonexistent; therefore, no annual changes are reported for this carbon pool.



Land converted to cropland

The Tier 1 method, as outlined in Equation 2.25 of Chapter 2, Volume 4 of the 2006 IPCC Guidelines, is employed to estimate annual changes in mineral soil carbon stocks on land converted to cropland. Utilize available default values for reference measurements of SOC and other parameters both pre- and post-assessment.

6.4.3.3.2. Organic soil

This section examines CO₂ and non-CO₂ emissions from organic soils resulting from cropland management practices.

Cropland remaining cropland

Estimates of CO₂ emissions from drained peatlands are derived using Equation 2.3 from Chapter 2 of the 2013 Wetlands Supplement, employing carbon stock emission factors (CS EFs). In contrast, non-CO₂ emissions from drained peatlands are calculated using Equation 2.6 from the same chapter, utilizing CS EFs for methane (CH₄) and default values for nitrous oxide (N₂O). GHG emissions from organic soils are documented across all land-use categories.

Land converted to cropland

Estimates of CO₂ and non-CO₂ emissions for land converted to cropland are derived using Equations 2.3 and 2.6 from Chapter 2 of the 2013 Wetlands Supplement. The equations utilized are identical to those applied in the cropland remaining cropland sub-category. Annual emissions are documented for each year within the conversion category.

6.4.3.4. Activity data

The area designated for cropland remaining cropland and for land converted to cropland is presented in Tables 6-23 and 6-24 below. Additional information is provided in the CRTs that accompany this document, located in the CRTs Annex.

Table 6 - 23 Land use and land-use change area for cropland category on mineral soils from 2000 - 2022 (ha)

Year	CL-CL	FL-CL	GL-CL	SL-CL	WL-CL	OL-CL
1996/2000	41,518,097	3,114,139	3,255,103	24,775	37,936	103,101
2000/2003	47,875,638	175,237	289,690	1,255	3,481	32,940
2003/2006	48,174,301	626,331	553,011	604	14,525	85,872
2006/2009	49,128,665	761,288	1,570,847	1,778	21,710	229,659
2009/2011	51,543,891	187,968	127,959	28,586	5,570	132,189
2011/2012	51,948,914	186,102	366,864	2,986	464	31,199
2012/2013	51,873,159	179,834	793,317	846	445	81,309
2013/2014	52,298,009	42,422	1,047,810	76,709	20,201	210,375
2014/2015	52,548,748	92,299	1,981,361	56,295	74,819	382,789
2015/2016	53,345,563	169,902	1,435,519	123,931	62,410	474,228
2016/2017	52,326,840	244,864	1,683,222	124,815	37,564	379,446
2017/2018	51,963,220	1,551,142	3,405,381	50,319	36,403	395,839
2018/2019	56,960,765	24,685	610,947	1,313	1,856	323,150
2019/2020	58,551,063	31,973	292,690		1,081	150,708
2020/2021	59,957,626	10,973	273,378		896	76,857

Year	CL-CL	FL-CL	GL-CL	SL-CL	WL-CL	OL-CL
2021/2022	58,847,889	16,774	299,869	14	2,473	84,298

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Table 6 - 24 Land use and land-use change area for cropland category on peat soils from 2000 -2022 (ha)

Year	CL-CL	FL-CL	GL-CL	SL-CL	WL-CL	OL-CL
1996/2000	1,074,384	398,865	64,637	88	154	9,251
2000/2003	1,529,506	10,165	9,401			17,822
2003/2006	1,561,805	46,841	19,811		12	37,100
2006/2009	1,660,044	173,896	84,705		2,052	107,639
2009/2011	2,017,005	31,321	52,080	67	5,421	18,596
2011/2012	2,123,979	21,959	9,739			15,493
2012/2013	2,159,084	34,599	164,993			24,359
2013/2014	2,370,265	6,955	54,359	2,717	783	72,791
2014/2015	2,425,276	36,005	208,708	972	3,444	84,212
2015/2016	2,735,787	32,406	117,124	397	272	80,156
2016/2017	2,863,334	44,331	192,015	1,883	2,887	89,416
2017/2018	3,105,920	50,225	202,339	1,078	153	149,651
2018/2019	3,437,225	1,140	48,805	55	43	34,947
2019/2020	3,532,102	972	13,753			48,279
2020/2021	3,567,363	54	2,694			7,953
2021/2022	3,496,931	2,416	71,080			14,817

The extent of fires on agricultural land is sourced from the Directorate General of PKHL MoEF, based on the interpretation of remote sensing satellite imagery (Table 6 - 25).

Table 6 - 25 Extent of fire in cropland (in ha)

Year	Estata Cran	Dryland	Mixed Dryland	Transmigration Area
i cai	Estate Crop	Agriculture	Agriculture	Transmigration Area
2000	27,493	22,905	23,567	70
2001	52,065	55,673	42,036	1,552
2002	56,183	94,424	98,489	15,207
2003	68,936	104,210	98,626	9,530
2004	94,415	84,510	125,549	6,577
2005	127,602	55,586	88,070	988
2006	320,001	168,899	237,242	17,343
2007	61,592	29,100	51,586	2,150
2008	32,629	15,984	24,107	428
2009	75,451	115,932	87,353	2,527
2010	32,628	5,734	23,015	171
2011	33,615	66,158	33,364	472
2012	72,975	54,124	65,909	685
2013	28,923	11,517	21,405	22
2014	134,230	72,016	133,707	1,127
2015	222,676	159,167	169,197	3,579
2016	20,831	12,062	17,413	2,017
2017	5,225	11,708	14,203	10
2018	55,348	47,728	36,445	55
2019	159,678	134,163	145,288	314
2020	12,100	29,884	30,230	37
2021	15,794	72,545	28,364	15

Year	Estate Crop	Dryland Agriculture	Mixed Dryland Agriculture	Transmigration Area
2022	15,305	29,295	19.111	24

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6.4.4. Uncertainty Assessment and Time-Series Consistency

The uncertainty in AD from cropland arises from the variability in spatial data processing, whereas the uncertainty in above-ground biomass growth and carbon stocks in non-forest categories primarily originates from the standard error reported in the national forest inventory, as documented in Indonesia's FREL. The combined uncertainty in the cropland remaining cropland and land converted to cropland categories are estimated 3.94% and 76.81% respectively. Additional details can be found in Annex 2. Time-series consistency is maintained by employing uniform methods and conducting recalculations in response to methodological advancements or alterations in AD.

6.4.5. Category-Specific QA/QC and Verification

The rationale for this section is detailed in sub-section 6.3.5.

6.4.6. Category-Specific Recalculations

The GHGI for cropland categories 4.B.1 and 4.B.2 has been recalculated for the years 2000 to 2019, reflecting updates in AD, adjustments to EFs, the application of GWP from AR5, and the utilization of IPCC 2006 software version 2.93. The modifications to EFs, AD, and parameters influence the estimates of cropland emissions. Table 6 - 26 illustrates the variations in AD and EFs utilized between BUR3 and BTR1.

Table 6 - 26 Changes in AD and emission factors for calculating categories 4.B.1 and 4.B.2 CL

Type of Recalculation	Category	BUR3	BTR1	Adjustments
	Estate crop	2.15	0	In DI ID2 steelt less values
	Mixed dryland agriculture	2.15	0.07	In BUR3, stock loss values were used, while BTR1
	Pure dry agriculture	2.15	0,5	employs the fraction of
	Paddy field	2.15	0,5	biomass loss (fd) approach
	Transmigration area	2.15	0	biolilass loss (Id) approach
	Estate crop	10.91	9.99	EFs for drained peat
EF	Mixed dryland agriculture	13.91	14.91	decomposition: BUR3
	Dryland agriculture	13.91	12.39	used IPCC default values,
	Paddy field	9.55	9.19	whereas BTR1 uses
	Transmigration area	13.91	14.91	country-specific values (Novita et al. 2021)
	Estate crop	0.37	0.325	EEs for the metic of heless
	Mixed dryland agriculture	0.37	0.200	EFs for the ratio of below- ground biomass to above-
	Dryland agriculture	0.37	0.200	ground biomass has been
	Paddy field	0.37	0.236	updated
	Transmigration area	0.37	0.200	updated
AD	Peatland (Million Hectare)	2.0-4.3	1.5-3.6	The peatland area has changed between BUR3 and BTR1. This change is

Type of Recalculation	Category	BUR3	BTR1	Adjustments
				due to updated data (reference)
AD	Mineral Land (Million Hectare)	47.7- 59.5	48.0- 60.3	The mineral soil area data used in BUR3 differs from BTR1. This difference is due to annual changes in administrative boundaries that were not retrospectively recalculated. BTR data now uses the most recent administrative boundaries, which have been applied consistently across all land-use categories
Category	Peatland decomposition and fire	Separate category	Part of Forest Soil Carbon	CO ₂ emissions from peat decomposition and peat fires on cropland are now included as emissions from the cropland category
Metric		AR2	AR5	Use of GWP

Table 6-27 presents a comparison of emissions from category 4.B between BUR3 and BTR1, indicating a significant difference exceeding 100%. The observed difference can be attributed to variations in EFs and parameters utilized, as indicated in the preceding table, as well as the incorporation of emission sources from peat decomposition and fires, which were documented separately as additional emission sources in BUR3.

Table 6 - 27 Comparison of cropland category emissions between BUR3 and BTR1

NGHGI Report	2000	2005	2010	2015	2019
Submission 2021 BUR3, kt CO ₂ e	351,518.92	40,028.22	7,141.96	268,922.93	83,146.36
Submission 2024 BTR1, kt CO ₂ e	422,929.37	589,445.49	518,969.01	932,429.81	532,266.83
		-	-	_	-
Difference, kt CO ₂ e	-71,410.45	549,417.27	511,827.05	663,506.88	449,120.47
Difference, %	-20.31	-1,372.57	-7,166.48	-246.73	-540.16

6.4.7. Plan of Improvements

Plans for improvement for this sub-category are detailed in sub-section 6.3.7.

6.5. Grasslands (4.C)

6.5.1. Category Description

This category encompasses CO₂ and non-CO₂ emissions from grasslands that remain as grassland (4.C.1) and from land that has been converted to grassland (4.C.2). In the national context, emissions from this category arise from mineral and peat soils as a result of alterations in living biomass, dead biomass, and soil carbon associated with land conversion to grassland.

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In savanna grasslands, emissions originate exclusively from alterations in soil CSs in both mineral and peat soils. This category encompasses the calculations of CH₄ and N₂O emissions resulting from grassland fires.

6.5.2. Trends in Greenhouse Gas Emissions by Category

In 2022, grassland emissions (4.C) were measured at 87,366.54 kt CO₂e, reflecting a 22.38% reduction since 2000 and a 58.40% decrease since 2019 (see Table 6-28 and Figure 6-4). In 2022, GL-GL contributed 94.37% by sub-category, whereas L-GL represented only 5.63%.

Table 6 - 28	Emissions	from	grassland	category
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GHG Source and Sink Categories	2000	2005	2010	2015	2019	2022
4.C.1. Grassland remaining						
grassland	62,112.64	164,194.77	131,248.32	308,260.52	240,606.23	92,903.43
4.C.2. Land converted to						
savanna	50,434.52	120,240.62	68,119.13	7,350.82	-30,583.05	-5,539.89
Total	112,547.16	284,435.38	199,367.45	315,611.34	210,023.19	87,363.54

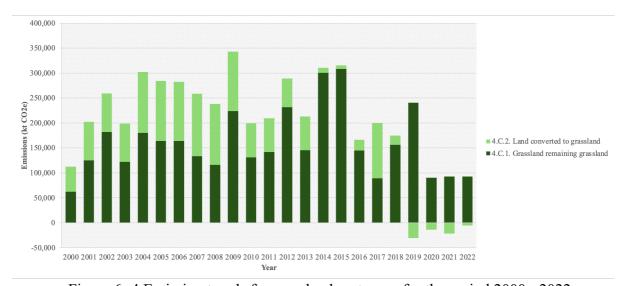


Figure 6- 4 Emission trends for grasslands category for the period 2000 - 2022

Dominant emissions and removals are primarily attributed to biomass changes within the grassland sub-category, accounting for 98.55%. In contrast, emissions from drained peatlands and fires represent only 0.47% and 0.97%, respectively. CO₂ is the predominant gas, accounting for 98.7%, followed by CH₄ at 1.23% and N₂O at 0.21% (Table 6 - 29).

Table 6 - 29 Grassland emissions by gas type (in kt CO₂e)

GHG Source and Sink Categories	2000	2005	2010	2015	2019	2022
CO ₂	111 100 -		105 110 06	•••	10410=00	0.6.000.06
Emissions/Removals	111,123.67	273,538.34	195,443.86	283,897.51	186,127.93	86,099.06
Organic Soil CH ₄	306.13	489.59	561.22	446.03	438.62	413.51
Organic Soil N2O	0.00	0.00	0.00	0.00	0.00	0.00
Biomass Burning CH ₄	751.93	9,132.11	2,980.37	28,196.94	20,622.39	664.23

Biomass Burning N ₂ O	365.44	1,275.34	382.01	3,070.86	2,834.25	186.74
Total	112,547.16	284,435.38	199,367.45	315,611.34	210,023.19	87,363.54

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6.5.3. Methodological Issues

Tier 1 methods from the 2006 IPCC Guidelines are utilized for all sub-categories, employing default biomass values and EFs for peat soils. Table 6-30 outlines the methods and EFs utilized by sub-category and GHG type.

Table 6 - 30 Methods and emission factors for grasslands

- C 1	GHG Source and Sink	CO	O_2	CI	H_4	N ₂ O)
Code	Categories	Method	EF	Method	EF	Method	EF
4.C.1	GL-GL	T1	D	T1	D	T1	D
4.C.2	L-GL	T1	D	T1	D	T1	D
4.C.2.a	FL-GL	T1	D	T1	D	T1	D
4.C.2.b	CL-GL	T1	D	T1	D	T1	D
4.C.2.c	WL-GL	T1	D	T1	D	T1	D
4.C.2.d	SL-GL	T1	D	T1	D	T1	D
4.C.2.e	OL-GL	T1	D	T1	D	T1	D

T1 = Tier 1 IPCC

D = Default IPCC, CS = Country-Specific

6.5.3.1.Biomass

6.5.3.1.1. Grassland remaining grassland

In the grassland remaining grassland sub-category, biomass changes within a single growth cycle are assumed to be negligible, as annual biomass loss is regarded as equivalent to biomass growth within the same year. In woody grasslands, including shrubland and swamp shrubland, biomass alterations resulting from growth are accounted for in the assessment of living biomass change (Table 6 - 31).

Table 6 - 31 Emission factors for estimating biomass CS additions in grassland

	Stock Carbon	Ratio of below-	Above-ground	
Land-Use Categories	Above-	ground biomass	biomass	Carbon
Land-Ose Categories	Ground	to above-ground	growth (Gw,	fraction (CF)
	(ton/ha)	biomass (R)	ton/dm/yr)	
Dry shrub	128.49	0.236	0.40	0.47
Grassland	8.64	0.236	0.40	0.47
Wet shrub	41.15	0.236	1.20	0.47

In this sub-category inventory, emissions of CH_4 and N_2O resulting from grassland fires are estimated using Equation 2.27 from Chapter 2, Volume 4 of the 2006 IPCC Guidelines, employing default Tier 1 EFs.



6.5.3.1.2. Land converted to grassland

Estimates of emissions resulting from the conversion of land to grassland use Equation 2.16 from Chapter 2 of Volume 4 of the 2006 IPCC Guidelines. This equation determines changes in biomass CS resulting from land conversion by assessing the difference between initial carbon stocks prior to conversion and carbon stocks in grassland post-conversion. It is assumed that annual grassland biomass and initial biomass carbon stocks are zero. Non-CO₂ emissions resulting from land conversion to grassland arise from fires and are estimated using Equation 2.27 from Chapter 2 of Volume 4 of the 2006 IPCC Guidelines.

6.5.3.2. Dead wood and litter

6.5.3.2.1. Grassland remaining grassland

This sub-category assumes no carbon change from dead organic matter, which is regarded as being in equilibrium; consequently, this emission source is considered to be zero.

6.5.3.2.2. Land converted to grassland

Annual variations in carbon stocks within dead organic matter for land transitioned to grassland are assessed using Equation 2.23 from Chapter 2, Volume 4 of the 2006 IPCC Guidelines.

6.5.3.3. Soil organic carbon

6.5.3.3.1. Mineral soil

This section addresses CO₂ emissions resulting from alterations in soil carbon stocks in grassland ecosystems.

Grassland remaining grassland

Annual variations in carbon stocks within mineral soils of grassland that remains undisturbed are presumed absent, as specified in the Tier 1 methodology of the 2006 IPCC Guidelines; therefore, no annual changes are documented for this carbon pool.

Land converted to grassland

Annual variations in mineral soil carbon stocks on land transitioned to grassland are assessed utilizing the Tier 1 method as outlined in Equation 2.25, Chapter 2, Volume 4 of the 2006 IPCC Guidelines. Reference SOC values before and after conversion, along with other parameters, utilize default values.

6.5.3.3.2. Organic soil

This section examines CO₂ and non-CO₂ emissions from organic soils resulting from grassland management practices.

Grassland remaining grassland

Estimates of CO₂ emissions from drained peatlands are derived using Equation 2.3 from Chapter 2 of the 2013 Wetlands Supplement, incorporating country-specific EFs. In contrast,

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non-CO₂ emissions from drained peatlands are calculated using Equation 2.6 from the same chapter, applying country-specific EFs for CH₄ and default values for N₂O. GHG emissions from organic soils are documented across all land-use categories.

Land converted to grassland

Estimates of CO₂ and non-CO₂ emissions for land converted to grassland are derived using Equations 2.3 and 2.6 from Chapter 2 of the 2013 Wetlands Supplement. The equations utilized are identical to those employed in the grassland remaining grassland sub-category. Annual emissions are documented for each year within the conversion category.

6.5.3.4. Activity data

The remaining grassland areas and those converted to grassland are presented in Tables 6-32 and 6-33 below. Additional information is provided in the CRTs appended to this document within the CRT Annex.

Table 6 - 32 Land use and land-use change areas from grasslands category on mineral soils 2000 - 2022 (ha)

Year	GL-GL	FL-GL	CL-GL	WL-GL	SL-GL	OL-GL
1996/2000	19,353,205	3,689,631	335,574	85,697	1,012	188,926
2000/2003	23,050,186	882,978	40,097	14,065	55	49,050
2003/2006	23,058,400	1,153,293	60,990	195,786		71,633
2006/2009	22,631,164	1,099,909	166,874	4,172	741	181,361
2009/2011	23,767,757	410,687	37,960	4,978	486	23,278
2011/2012	23,615,434	299,890	22,238	705	460	11,244
2012/2013	23,000,761	241,883	602,215	2,426	5	55,762
2013/2014	22,705,805	108,808	390,204	32,943	7,199	185,567
2014/2015	20,678,813	134,877	568,057	65,207	8,618	154,292
2015/2016	19,804,664	351,432	1,257,487	60,824	12,052	699,573
2016/2017	20,217,850	259,453	2,743,151	35,903	3,915	185,782
2017/2018	18,185,477	929,294	1,598,168	163,791	9,151	418,770
2018/2019	20,515,776	37,944	32,047	927	295	153,208
2019/2020	18,919,771	17,673	41,663	6,952		48,239
2020/2021	18,164,998	14,048	79,138	558		106,949
2021/2022	17,109,697	21,989	48,036	341	23	39,332
1996/2000	19,353,205	3,689,631	335,574	85,697	1,012	188,926
2000/2003	23,050,186	882,978	40,097	14,065	55	49,050

Table 6 - 33 Land use and land-use change areas from grasslands category on organic soils 2000 - 2022 (ha)

Year	GL-GL	FL-GL	CL-GL	WL-GL	SL-GL	OL-GL
1996/2000	1,561,872	961,021	3,669	2,369		3,870
2000/2003	2,331,800	137,517	823	14,447		15,835
2003/2006	2,288,077	314,532	41	79,829		29,013
2006/2009	2,536,414	426,045	2,733	7		59,113
2009/2011	2,702,409	132,333	1,183	384	31	19,296
2011/2012	2,819,534	60,161	13			1,858
2012/2013	2,659,567	58,508	2,380	6,526		419

Year	GL-GL	FL-GL	CL-GL	WL-GL	SL-GL	OL-GL
2013/2014	2,656,459	33,664	9,033	7,839	13	15,963
2014/2015	2,275,678	30,599	23,021	17,614	244	28,411
2015/2016	2,224,039	30,683	12,072	14,269	2	170,010
2016/2017	2,230,967	23,013	82,027	1,289	0	63,676
2017/2018	2,087,112	91,049	40,343	6,976	100	109,154
2018/2019	2,237,859	1,886	5,086	220		18,763
2019/2020	2,163,391	1,343	1,563	1,009		10,845
2020/2021	2,219,662	9,749	118	83		11,473
2021/2022	2,109,726	804	583	2,963		8,708
1996/2000	1,561,872	961,021	3,669	2,369		3,870
2000/2003	2,331,800	137,517	823	14,447		15,835

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The extent of grassland fires is sourced from the Directorate General of Climate Change, Ministry of Environment and Forestry, based on the analysis of remote sensing satellite imagery (Table 6 - 34).

Table 6 - 34 Extent of fires in grassland (in ha)

Year	Swamp	Dry Shrub
2000	73,967	8,946
2001	66,352	85,995
2022	148,512	307,451
2003	152,712	146,271
2004	136,331	302,820
2005	97,832	191,526
2006	335,361	1,184,451
2007	65,242	103,386
2008	80,820	43,122
2009	124,349	313,920
2011	36,681	49,990
2010	50,243	124,724
2012	124,668	351,267
2013	58,856	92,701
2014	132,009	512,420
2015	236,700	599,854
2016	21,811	135,412
2017	36,363	8,841
2018	39,308	130,587
2019	104,368	538,752
2020	27,812	20,505
2021	37,842	21,385
2022	23,829	18,541

6.5.4. Uncertainty Assessment and Time-Series Consistency

The uncertainty in AD from grasslands primarily arises from issues in spatial data processing, whereas the uncertainty in above-ground biomass growth and carbon stocks in non-FL categories mainly results from standard errors in the national forest inventory, as indicated in

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Indonesia's FREL. The combined uncertainty for the grassland remaining grassland and land converted to grassland categories are 9.17% and 28.21% respectively. Additional details can be found in Annex 2. Time-series consistency is maintained by employing uniform methodologies and performing recalculations in response to methodological adjustments or changes in AD.

6.5.5. Category-Specific QA/QC and Verification

An explanation of this section can be found in sub-section 6.3.5.

6.5.6. Category-Specific Recalculations

Recalculations for the grassland category inventory (4.C.1 and 4.C.2) have been conducted for the entire period from 2000 to 2019. This process incorporated updates to AD, adjustments to EFs, and the application of GWP from AR5, utilizing the IPCC 2006 software version 2.93. Modifications to EFs, activity data, and parameters have influenced the emission estimates for the Grassland category. Table 6-35 illustrates the variations in AD and EFs utilized between BUR3 and BTR1.

Table 6 - 35 Changes in activity data and emission factors for the calculation of categories 4.C.1 and 4.C.2 GL

Type of Recalculation	Category	BUR3	BTR1	Adjustments
	GL-GL	0.4	0	In BUR3, the stock loss value was
	L-GL	0.4	0	used, while BTR1 used the Fraction of Biomass Lost (fd) approach
	Dry Shrub	5.18	12.28	EF for peat decomposition (drained
EE	Savanna	9.55	12.28	peat), where BUR3 used the IPCC
EF	Wet Shrub	5.18	12.28	default value, and BTR used a country-specific value (Novita et al. 2021)
	Dry Shrub	0.37	0.236	
	Savanna	0.00	0.236	EF for Ratio of below-ground
	Wet shrub	0.37	0.236	biomass to above-ground biomass
DA	Peatland (Million Hectare)	2.1-3.6	2.1-3.0	The peatland area has changed between what was used in BUR3 and BTR1. This change is due to the availability of updated data (reference)
DA	Mineral Soil (Million Hectare)	17.3- 25.1	17.3-24.5	The mineral land area data used in BUR3 differs from BTR1. This difference is due to changes in administrative boundaries each year, which were not recalculated retrospectively. The data in BTR now uses the latest administrative boundaries, which have been applied to all land uses

Type of Recalculation	Category	BUR3	BTR1	Adjustments
Category	Peat decomposition and peat fires	Separate category	Part of Forest Soil Carbon	CO ₂ emissions from peat decomposition and peat fires in grasslands are now part of the grassland category emissions
Metric		AR2	AR5	Use of GWP

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Table 6-36 presents a comparison of emissions from category 4.B between BUR3 and BTR1, revealing a substantial difference exceeding 100% in 2019. The observed difference arises not only from variations in EFs and parameters utilized, as indicated in the preceding table, but also from the incorporation of emissions resulting from peat decomposition and peat fires, which were documented as distinct emission sources (other) in the BUR3 Report.

Table 6-36 indicates that emissions from the grassland category were excluded from BUR3, whereas they were included in BTR1. The emission values for the grassland category in BTR1 exhibit significant variability.

Table 6 - 36 Comparison of grassland category emissions between BUR3 and BTR1

NGHGI Report	2000	2005	2010	2015	2019
Submission 2021 BUR3,					_
L-GL, kt CO ₂ e	270,956.75	88,878.27	54,603.06	27,449.54	77,806.33
Submission 2024 BTR1,					_
L-GL, kt CO ₂ e	50,434.52	120,240.62	68,119.13	7,350.82	-30,583.05
Difference, kt CO ₂ e	220,522.23	-31,362.35	-13,516.07	20,098.72	108,389.38
Difference, %	81.39	-35.29	-25.75	72.32	139.31

6.5.7. Plan of Improvements

Plan of improvements for this sub-category can be found in sub-section 6.3.7.

6.6. Wetlands (**4.D**)

6.6.1. Category Description

This category addresses GHG emissions from managed wetlands, encompassing drained and cultivated peatlands utilized for peat briquette production for energy, horticulture, and various applications, as well as flooded lands (reservoirs or impoundments) designated for energy production, irrigation, navigation, or recreation (IPCC 2006).

6.6.2. Trends in Greenhouse Gas Emissions by Category

In 2022, emissions from wetlands (4.D) were measured at 21.26 kt CO₂e, reflecting a decrease of 2,156.24% since 2000 and an increase of 99.45% since 2019 (see Table 6-37 and Figure 6-5). In 2022, WL-WL accounted for 92.19% of the total, whereas L-WL represented 7.81%.

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Table 6-37 Emissions from wetlands category

GHG Source and Sink Categories	2000	2005	2010	2015	2019	2022
4.D.1. Wetlands remaining						
wetlands	0.98	1,136.57	18.42	1,868.33	3,853.67	19.60
4.D.2. Land converted to						
wetlands	-0.04	483.04	590.22	1,374.33	1.71	1.66
Total	0.94	1,619.62	608.64	3,242.66	3,855.37	21.26

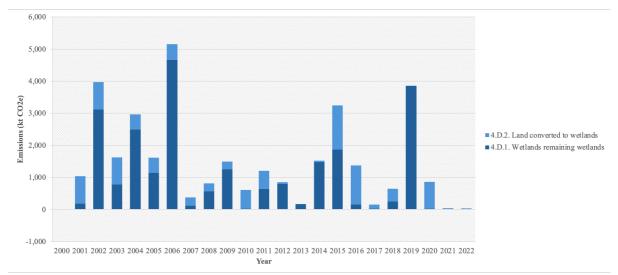


Figure 6-5 Wetlands category emission trends for the period 2000-2022

By source and sink, the primary emissions and removals are attributed to biomass burning due to fire within the grassland sub-category, accounting for 92.19%. In contrast, emissions from biomass changes and drained peat soils contribute 7.81% and 0.00%, respectively. In terms of gas composition, CH₄ is the predominant component, accounting for 92.19%, while CO₂ constitutes 7.81%, and N₂O represents 0.00% (Table 6 - 38).

Table 6 - 38 Wetland emissions by gas type (in kt CO₂e)

GHG Source and Sink Categories	2000	2005	2010	2015	2019	2022
CO ₂ Emissions/Removals	-0.04	483.04	590.22	1,374.33	1.71	1.66
Organic Soil CH ₄	0.00	0.00	0.00	0.00	0.00	0.00
Organic Soil N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00
Biomass Burning CH ₄	0.98	1,136.57	18.42	1,868.33	3,853.67	19.60
Biomass Burning N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.94	1,619.62	608.64	3,242.66	3,855.37	21.26

6.6.3. Methodological Issues

The Tier 1 method outlined in the 2006 IPCC Guidelines is utilized for all sub-categories of flooded land, employing default biomass values and EFs. Table 6-39 delineates the methods and EFs utilized by sub-category and GHG type.

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Table 6-39 Wetland methods and emission factors

	GHG Source and Sink	CO	O_2	CI	H_4	N ₂ C)
Code	Categories	Method	FE	Method	FE	Method	FE
4.D.1	WL-WL	NO	NO	T1	D	NO	NO
4.D.2	L-WL	NO	NO	NO	NO	NO	NO

T1 = Tier 1 IPCC

D = Default IPCC, NO = Not Occurred

6.6.3.1. Biomass

6.6.3.1.1. WL- WL: Flooded land remaining flooded land

CO₂ emissions from flooded land primarily originate from carbon inputs in the catchment area, which are assessed as emissions from the other managed land category (IPCC 2019). To prevent double counting in this category, emissions are not reported.

Non-CO₂ emissions, primarily CH₄, originating from freshwater and aquaculture ponds utilized for fisheries, aquaculture, or recreational activities are reported and estimated utilizing Equation 7.12 from Chapter 7 of the 2019 Refinement, employing default EFs.

6.6.3.1.2. L- WL: Land converted to flooded land

CO₂ emissions resulting from land conversions to flooded areas or artificial water bodies in this sub-category remain not estimated due to insufficient CO₂ emission methodologies and data (IPCC 2019). Similarly, there are no established methods for estimating emissions from CH₄ sources within this sub-category.

6.6.3.2. Activity data

The areas of wetland that remain as wetland and those converted to wetland are presented in Table 6-40 and Table 6-41 below. Additional information is provided in the CRTs appended to this document within the CRT Annex.

Table 6- 40 Land use and land-use change areas from wetlands category on mineral soils 2000-2022 (ha)

Year	WL-WL	FL-WL	CL-WL	GL-WL	SL-WL	OL-WL
1996/2000	3,704,778	227,525	20,259	156,410	981	2,853
2000/2003	4,091,566	34,245	1,424	57,493	3	4,838
2003/2006	3,975,987	39,594	2,113	49,790	155	13,065
2006/2009	4,050,917	16,226	3,021	8,999	66	1,225
2009/2011	4,060,685	6,998	1,873	29,432	167	1,165
2011/2012	4,098,090	3,705	1,839	2,778		469
2012/2013	4,101,713	3,386	255	1,037		303
2013/2014	4,049,765	801	26,858	26,672	4,121	3,885
2014/2015	3,944,602	5,058	32,790	47,612	482	3,877
2015/2016	3,863,692	13,663	47,236	55,461	4,320	33,036
2016/2017	3,928,546	11,419	56,767	78,897	3,778	15,425
2017/2018	3,834,182	61,732	62,229	43,346	5,843	13,384
2018/2019	4,011,583	1,401	1,002	6,063	7	7,000
2019/2020	4,048,940	1,072	1,671	46,686		2,308

Year	WL-WL	FL-WL	CL-WL	GL-WL	SL-WL	OL-WL
2020/2021	4,245,296	1,048	3,686	2,126		465
2021/2022	4.431.377	4 628	2.017	7 882	17	2 000

Table 6 - 41 Land use and land-use change areas from wetlands category on peat soils 2000-2022 (ha)

Year	WL-WL	FL-WL	CL-WL	GL-WL	SL-WL	OL-WL
1996/2000	248,210	43,740		20,518	5	309
2000/2003	297,599	2,118		17,136	50	24
2003/2006	237,056	985	61	10,317		
2006/2009	246,085	1,804	53			
2009/2011	225,684	278	256	10,916		12
2011/2012	237,146	142				
2012/2013	230,687	2				
2013/2014	222,058		24	390		293
2014/2015	191,048	975	358	8,892	0	0
2015/2016	185,380	515	471	9,622		4,794
2016/2017	195,253	140	120	533		91
2017/2018	185,391	4,054	2,002	1,362		554
2018/2019	192,974	8				
2019/2020	190,073		138	8,271		85
2020/2021	226,656	30	11	129		6
2021/2022	273,030			17		60

The area of wetland fires is sourced from the Directorate General of Forest and Land Rehabilitation, Ministry of Environment and Forestry, based on the interpretation of remote sensing satellite imagery (Table 6 - 42).

Table 6 - 42 Extent of fire in WL (in ha)

Year	Body of Water	Swamp	Fishpond/Aquaculture
2000	68	452	525
2001	535	32,129	1,394
2002	2,699	148,560	685
2003	1,117	62,973	4,975
2004	2,135	128,894	568
2005	447	17,379	112
2006	3,649	296,506	1,719
2007	1,234	8,603	8
2008	67	593,289	5
2009	1,033	48,733	554
2010	189	2,073	7
2011	646	63,859	71
2012	2,292	37,765	1,314
2013	90	7,529	
2014	4,506	94,876	1,002
2015	673	173,166	3,617
2016		47,918	1,818
2017	8	6,590	46
2018	422	37,376	266
2019	2,078	70,956	4,583
2020	203	8,183	211

Year	Body of Water	Swamp	Fishpond/Aquaculture
2021	129	3,602	398
2022	41	1,097	109

6.6.4. Uncertainty Assessment and Time-Series Consistency

The uncertainty in activity data for wetlands is primarily due to the variability in spatial data processing. In contrast, the uncertainty in above-ground biomass growth and carbon stocks within non-forest categories mainly results from the standard errors identified in the national forest inventory, as documented in Indonesia's FREL.

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The uncertainty for the wetland remaining wetland and land converted to wetland categories are estimated 9.17% and 28.21%. Additional details can be found in Annex 2. Time-series consistency is maintained by employing uniform methods and conducting recalculations in response to methodological advancements or alterations in activity data.

6.6.5. Category-Specific QA/QC and Verification

Explanations for this section can be found in sub-section 6.3.5.

6.6.6. Category-Specific Recalculations

No recalculations were performed for this category, as the emissions from wetland remaining wetland were first reported in the BTR1 document.

6.6.7. Plan of Improvements

Improvement plans for this sub-category can be found in sub-section 6.3.7.

6.7. Settlement (4.E)

6.7.1. Category Description

This category encompasses the estimated CO₂ emissions and removals resulting from alterations in CSs within biomass, dead organic matter, and soil. Emissions are calculated for land converted to settlements, whereas for existing settlements, only emissions from drained peat soils are estimated.

6.7.2. Trends in Greenhouse Gas Emissions by Category

In 2022, Settlement (4.E) emissions were recorded at 1,994.71 kt CO₂e, reflecting a 167.36% decrease since 2000 and a 24.49% increase since 2019 (Table 6-43 and Figure 6-6). Most emissions in this category result from land conversions for settlements. In 2022, the SL-SL sub-category accounted for 0%, whereas the L-SL sub-category represented 100% of the contribution.

Table 6 - 43 Emissions from settlement category

Source of Emissions and	2000	2005	2010	2015	2010	2022
Removals	2000	2005	2010	2013	2019	2022

4.E.1. Settlement remaining						
settlement	NO	NO	NO	NO	NO	NO
4.E.2. Land converted to						
settlements	746.07	2,731.73	3,540.32	44,407.68	1,602.26	1,994.71
Total	746.07	2,731.73	3,540.32	44,407.68	1,602.26	1,994.71

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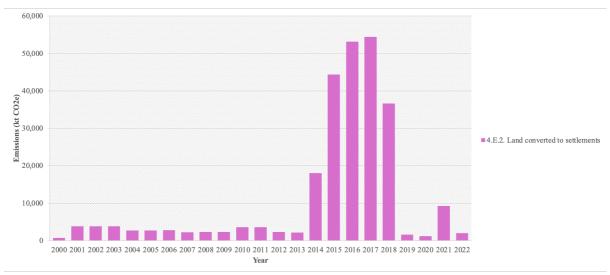


Figure 6-6 Settlement category emission trends for the period 2000-2022

The primary emissions and removals are attributed to biomass changes within the settlement sub-category, accounting for 100%, whereas emissions from drained peat soils and fires contribute none. Emission of CO₂ is the predominant gas type, accounting for 100% (Table 6 - 44).

Table 6 - 44 Settlement emissions by gas type (in kt CO₂e)

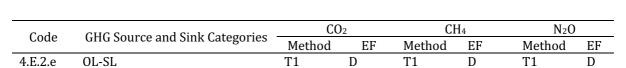
GHG Source and Sink Categories	2000	2005	2010	2015	2019	2022
CO ₂ Emissions/Removals	746.07	2,731.73	3,540.32	44,407.68	1,602.26	1,994.71
Organic Soil CH ₄	0.00	0.00	0.00	0.00	0.00	0.00
Organic Soil N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00
Biomass Burning CH ₄	0.00	0.00	0.00	0.00	0.00	0.00
Biomass Burning N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00
Total	746.07	2,731.73	3,540.32	44,407.68	1,602.26	1,994.71

6.7.3. Methodological Issues

The Tier 1 method from the 2006 IPCC Guidelines is typically utilized across all sub-categories in this category, employing default biomass values and peat soil EFs. Table 6-45 outlines the methods and EFs utilized by sub-category and GHG type.

Table 6 - 45 Settlement methods and emission factors

Code	CIIC Source and Sink Categories	CO ₂		CH ₄		N_2O	N_2O	
Code	GHG Source and Sink Categories	Method	EF	Method	EF	Method	EF	
4.E.1	SL-SL	T1	D	T1	D	T1	D	
4.E.2	L-SL	T1	D	T1	D	T1	D	
4.E.2.a	FL-SL	T1	D	T1	D	T1	D	
4.E.2.b	CL-SL	T1	D	T1	D	T1	D	
4.E.2.c	GL-SL	T1	D	T1	D	T1	D	
4.E.2.d	WL-SL	T1	D	T1	D	T1	D	



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T1 = Tier 1 IPCC

D = Default IPCC

6.7.3.1. Biomass

Emissions resulting from alterations in biomass carbon are calculated solely for land converted to settlements. The emission estimates for this sub-category are derived using Equation 2.16 from Chapter 2 of Volume 4 of the 2006 IPCC Guidelines. This equation determines the variation in biomass CSs resulting from conversion, based on the disparity between the initial land's carbon stock (pre-conversion) and the settlement's carbon stock (post-conversion). It is assumed that both settlement biomass and initial biomass carbon stocks are zero.

6.7.3.2.Dead wood and litter

The annual variation in dead organic matter carbon stocks for land converted to settlements is estimated using Equation 2.23 from Chapter 2, Volume 4 of the 2006 IPCC Guidelines.

6.7.3.3.Soil organic carbon

6.7.3.3.1. *Mineral soil*

This section presents data on CO₂ emissions resulting from alterations in soil carbon stocks within settlements.

Settlement remaining settlement

The annual variation in mineral soil carbon stocks for land converted to settlements is estimated utilizing the Tier 1 method and Equation 2.25, as outlined in Chapter 2, Volume 4 of the 2006 IPCC Guidelines. The reference values for SOC, both pre- and post-intervention, along with other parameters, utilize the established default values.

Land converted to settlements

The annual variation in mineral soil carbon stocks for land converted to settlements is estimated utilizing the Tier 1 method and Equation 2.25, as outlined in Chapter 2, Volume 4 of the 2006 IPCC Guidelines. The reference values for SOC, both pre- and post-intervention, along with other parameters, utilize the established default values. This section examines CO₂ and non-CO₂ emissions from organic soils within the settlement land-use category.

Settlement remaining settlement

The estimation of CO₂ emissions from drained peat soils is conducted using Equation 2.3 from Chapter 2 of the 2013 Wetlands Supplement, applying the CS EF. For non-CO₂ emissions, Equation 2.6 from the same chapter is utilized, employing the CS EF for CH₄ and the default factor for N₂O. GHG emissions from organic soils are documented across all land-use categories.

Land converted to settlements

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Estimates of CO₂ and non-CO₂ emissions for land converted to settlements are derived using Equations 2.3 and 2.6 from Chapter 2 of the 2013 Wetlands Supplement. The equations utilized are identical to those applied in the remaining settlements sub-category. Annual emissions are documented for each year within the conversion category.

6.7.3.4. Activity data

The area of land designated for settlements, including both existing and newly converted areas, is presented in Tables 6-46 and 6-47 below. Additional information is provided in the CRTs appended to this document within the CRT Annex.

Table 6 - 46 Land use and land-use change areas from settlement category on mineral soils 2000-2022 (ha)

Year	SL-SL	FL-SL	CL-SL	GL-SL	WL-SL	OL-SL
1996/2000	2,179,224	24,052	60,627	75,885	2,704	8,891
2000/2003	2,350,064	621	84,180	1,037	36	3,091
2003/2006	2,437,937	1,923	54,083	4,174	602	1,877
2006/2009	2,497,808	3,629	30,367	3,006	270	559
2009/2011	2,503,694	576	36,546	767	2,866	571
2011/2012	2,540,352	3,776	4,109	2,011		
2012/2013	2,549,187	471	16,608	315	100	556
2013/2014	2,478,120	132	109,521	8,037	554	2,697
2014/2015	2,530,401	3,625	207,290	34,919	1,030	16,397
2015/2016	2,649,595	2,342	345,588	24,960	2,670	6,765
2016/2017	2,897,780	1,624	367,843	26,629	8,434	5,766
2017/2018	3,233,146	65,109	302,304	51,945	1,571	12,335
2018/2019	3,661,321	40	7,947	1,437	127	543
2019/2020	3,813,772	369	3,501	2,124		849
2020/2021	3,969,630	35	39,761	6,482	364	921
2021/2022	4,405,562		27,429	240	148	2,066

Table 6 - 47 Land use and land-use change areas from settlement category on peat soils 2000-2022 (Ha)

	` '					
Year	SL-SL	FL-SL	CL-SL	GL-SL	WL-SL	OL-SL
1996/2000	20,984	1,048	7	536		
2000/2003	22,238		43	2		
2003/2006	22,283					
2006/2009	22,283	0	22			
2009/2011	22,186				5	
2011/2012	22,191	84				
2012/2013	22,276		68			
2013/2014	19,614					
2014/2015	18,206	51	3,635	416	13	603
2015/2016	22,491	0	2,540	85	50	1,929
2016/2017	25,008	39	2,280	218		247
2017/2018	26,509	271	3,617	470	14	500
2018/2019	31,250	5	3	394		
2019/2020	31,965	16		3		
2020/2021	43,279		2,224	315		
2021/2022	42,250		132	12		59
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The settlement fire area is sourced from the Directorate General of Forest and Land Rehabilitation, Ministry of Environment and Forestry, based on remote sensing satellite image analysis (Table 6 - 48).

Table 6 - 48 Extent of fire in SL (in ha)

Year	Settlement
2000	735
2001	2,964
2002	3,031
2003	12,498
2004	6,429
2005	2,789
2006	17,292
2007	2,857
2008	1,471
2009	6,943
2010	234
2011	419
2012	1,973
2013	1,285
2014	9,885
2015	8,031
2016	2,883
2017	639
2018	517
2019	2,577
2020	1,157
2021	1,277
2022	624

6.7.4. Uncertainty Assessment and Time-Series Consistency

The uncertainty in activity data for settlements primarily originates from the variability in spatial data processing. In contrast, the uncertainty in above-ground biomass growth and carbon stocks in non-forest categories mainly results from the standard errors associated with the national forest inventory, as indicated in Indonesia's FREL.

The estimated uncertainty in the land converted to settlements category is 2.35%. Additional details can be found in Annex 2.

Time-series consistency is maintained by employing uniform methods and recalculating when methodological advancements or alterations in activity data occur.

6.7.5. Category-Specific QA/QC and Verification

Details regarding this section are available in sub-section 6.3.5.

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6.7.6. Category-Specific Recalculations

Calculations for the settlement (4.E) category inventory in BTR1 have been conducted for the entire period from 2000 to 2019. Emissions and removals have been calculated based on updated activity data, adjusted EFs, the application of GWP from AR5, and the utilization of IPCC 2006 software version 2.93. Modifications to EF, AD, and parameters influence the estimates of settlement emissions. Table 6-49 illustrates the variations in activity data and EFs utilized between BUR3 and BTR1.

Table 6 - 49 Changes in activity data and EFs for calculation of 4.E.1 and 4.E.2 settlement categories

Type of Recalculation	Category	BUR3	BTR1	Adjustments
EF	Settlement	9.55	12.28	EFs for peat decomposition (drained peat) where BUR3 used IPCC default values, and BTR uses CS values (Novita et al. 2021)
	Settlement	0.37	0.291	EF for the Ratio of below- ground biomass to above- ground biomass
AD	Peatland (Million Hectare)	0.04-0.07	0.02-0.05	The peatland area has changed between what was used in BUR3 and BTR1. This change is due to the use of updated data (reference)
AD	Mineral land (Million Hectare)	2.3-4.5	2.4-4.4	The mineral land area data used in BUR3 is different from BTR1. This difference is due to changes in administrative boundaries each year that were not retrospectively recalculated. Meanwhile, the data in BTR uses the latest administrative boundaries that have been applied to all land uses
Category	Peatland decomposition and peat fire	Separate category	Part of Forest Soil Carbon	Emissions from peat decomposition and peat fires in settlements are now part of the settlement category emissions
Metric		AR2	AR5	Use of GWP

Table 6-50 presents the results of the recalculation of settlements sector emissions in BUR3 and the differences with the same emissions in BTR1, indicating a notable difference of 85.44% to 188.81% for emissions in BUR3. The observed differences arise from the use of the latest

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version of land use and peat soil map including the inclusion of fire emissions and peat decomposition in BTR1.

Table 6 - 50 Comparison of settlement category emissions between BUR3 and BTR1

NGHGI Report	2000	2005	2010	2015	2019
Submission 2021 BUR3, kt CO ₂ e	5,123.40	945.86	1,324.36	20,229.43	60,329.83
Submission 2024 BTR1, kt CO ₂ e	746.07	2,731.73	3,540.32	44,407.68	1,602.26
Difference, kt CO ₂ e	4,377.33	-1,785.87	-2,215.96	-24,178.25	58,727.57
Difference, %	85.44	-188.81	-167.32	-119.52	97.34

6.7.7. Plan of Improvements

Plan of Improvements for this sub-category can be found in sub-section 6.3.7.

6.8. Other Land Use (4.F)

6.8.1. Category Description

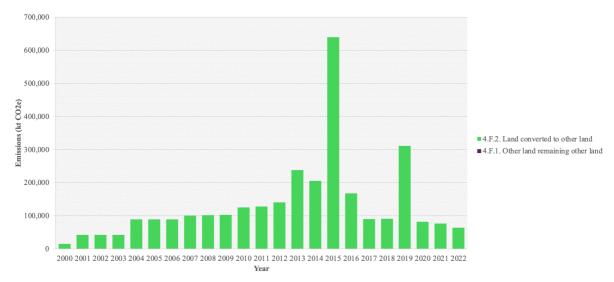
This category includes the estimated CO₂ emissions and removals based on changes in CSs in biomass, dead organic matter, and soils. These emissions are calculated for land converted to other land-use categories.

6.8.2. Trends in Greenhouse Gas Emissions by Category

In 2022, Settlement (4.E) emissions were recorded at 64,283.00 kt CO₂e, reflecting an 314.77% increase since 2000 and a 79.33% decrease since 2019 (Table 6-43 and Figure 6-6). Most emissions in this category result from land conversions for settlements. In 2022, the SL-SL sub-category accounted for 0%, whereas the L-SL sub-category represented 100% of the contribution.

Table 6 - 51 Emissions from other land-use category

GHG Source and Sink Categories	2000	2005	2010	2015	2019	2022
4.F.1. Other land use						
remaining other land use	NO	NO	NO	NO	NO	NO
4.F.2. Land converted to						
other land use	15,498.35	89,388.39	125,637.85	639,321.29	311,057.62	64,283.00
Total	15,498.35	89,388.39	125,637.85	639,321.29	311,057.62	64,283.00



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Figure 6-7 Emission trend of other land-use category for the period 2000 - 2022

The primary emission and removal source is the biomass change from the other land-use subcategory, accounting for 100%, with no contributions from drained peatlands or fires. The CO_2 is the predominant gas type, accounting for 100% (Table 6 – 52).

Table 6 - 52 Other land-use emissions by gas type (in kt CO₂e)

GHG Source and Sink Categories	2000	2005	2010	2015	2019	2022
CO ₂ Emissions/Removals	15,498.35	89,388.39	125,637.85	639,321.29	311,057.62	64,283.00
Organic Soil CH ₄	0.00	0.00	0.00	0.00	0.00	0.00
Organic Soil N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00
Biomass Burning CH ₄	0.00	0.00	0.00	0.00	0.00	0.00
Biomass Burning N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00
Total	15,498.35	89,388.39	125,637.85	639,321.29	311,057.62	64,283.00

6.8.3. Methodological Issues

The Tier 1 method from the 2006 IPCC Guidelines is generally applied across all subcategories in this category, utilizing default biomass and peat soil EFs. The methods and EFs for various land-use categories are detailed according to sub-categories and GHG types (Table 6-53).

Table 6 - 53 Methods and emission factors for other land use

- C 1	GHG Source and Sink	CO	O_2	CI	-1_4	N_2O)
Code	Categories	Method	EF	Method	EF	Method	EF
4.F.2	L-OL	T1	D	T1	D	T1	D
4.F.2.a	FL-OL	T1	D	T1	D	T1	D
4.F.2.b	CL-OL	T1	D	T1	D	T1	D
4.F.2.c	GL-OL	T1	D	T1	D	T1	D
4.F.2.d	WL-OL	T1	D	T1	D	T1	D
4.F.2.e	SL-OL	T1	D	T1	D	T1	D

T1 = Tier 1 IPCC



D = Default IPCC

6.8.3.1.Biomass

Emissions resulting from alterations in biomass carbon are calculated solely for land that has been converted to different land-use categories. The emission estimate for this sub-category is derived using Equation 2.16 from Chapter 2 of Volume 4 of the 2006 IPCC Guidelines. This equation determines the variation in biomass CSs resulting from conversion by assessing the difference between the initial land CS (prior to conversion) and the carbon stock of the alternative land use (subsequent to conversion). The biomass associated with other land use and the initial biomass CS are considered to be 0.

6.8.3.2.Dead wood and litter

The annual variation in carbon stocks of dead organic matter for land transitioned to alternative land use is estimated using Equation 2.23 from Chapter 2 of Volume 4 of the 2006 IPCC Guidelines.

6.8.3.3.Soil organic carbon

6.8.3.3.1. *Mineral soil*

This section presents data on CO₂ emissions resulting from alterations in soil carbon stocks within the other land-use category.

Other land use remaining other land use

The annual variation in mineral soil carbon stocks within the category of other land use is presumed to be negligible, as outlined in the Tier 1 methodology of the 2006 IPCC Guidelines; therefore, no annual change is documented for this carbon pool.

Land converted to other land use

The annual change in mineral soil carbon stocks for land converted to other land use is estimated using the Tier 1 method and Equation 2.25, Chapter 2, Volume 4, 2006 IPCC Guidelines. The reference values for SOC before and after, and other parameters, use the available default values.

6.8.3.3.2. Organic soil

This section discusses the CO₂ and non-CO₂ emissions from organic soils in the other land-use category.

Other land use remaining other land use

Estimates of CO₂ emissions from drained peatlands are derived from Equation 2.3 in Chapter 2 of the 2013 Wetlands Supplement, utilizing CS EFs. In contrast, non-CO₂ emissions from drained peatlands are calculated using Equation 2.6 from the same chapter, applying CS EFs for CH₄ and default values for N₂O. GHG emissions from organic soils are documented across all land-use categories.

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Land converted to other land use

Estimates of CO₂ and non-CO₂ emissions for land converted to other land uses are derived using Equations 2.3 and 2.6 from Chapter 2 of the 2013 Wetlands Supplement. The equations employed are identical to those utilized for the remaining land-use categorized as other land-use. Annual emissions are documented for each year within the conversion category.

6.8.3.4. Activity data

The areas of each land use for other land use remaining other land use and for land converted to other land use are reported in Table 6 - 54 and Table 6 - 55 below. Further details are included in the CRTs accompanying this document as part of the CRTs Annex.

Table 6 - 54 Land use and land-use change areas from other land-use category on mineral soils, 2000 - 2022 (ha)

Year	OL-OL	FL-OL	CL-OL	GL-OL	WL-OL	SL-OL
1996/2000	1,775,478	264,455	101,649	266,619	48,099	1,186
2000/2003	2,335,285	109,333	26,979	102,280	2,373	_
2003/2006	2,355,941	243,230	75,710	175,150	1,646	125
2006/2009	2,377,394	371,356	106,787	172,971	2,864	87
2009/2011	2,794,413	237,041	78,935	96,935	1,115	2,679
2011/2012	3,154,385	189,757	3,405	42,213	722	862
2012/2013	3,216,728	331,880	24,534	52,254	2,108	203
2013/2014	3,143,687	185,413	96,539	97,405	2,692	1,083
2014/2015	2,944,744	483,074	337,309	666,340	26,313	3,267
2015/2016	3,207,482	149,481	96,191	205,199	40,977	3,416
2016/2017	3,101,665	87,636	64,378	89,948	6,039	1,330
2017/2018	2,086,282	101,448	83,763	195,155	10,228	2,877
2018/2019	1,995,851	241,329	400,542	167,749	6,224	3,474
2019/2020	1,997,670	48,646	68,307	106,523	289	8
2020/2021	1,910,673	72,527	44,607	57,451	271	
2021/2022	1,813,856	65,694	36,767	80,152	944	

Table 6 - 55 Land use and land-use change areas from other land-use category on peatlands, 2000 - 2022 (ha)

Year	OL-OL	FL-OL	CL-OL	GL-OL	WL-OL	SL-OL
1996/2000	115,156	128,763	1,489	3,971	12	_
2000/2003	185,893	85,525	13,272	34,784	737	
2003/2006	192,650	190,557	2,128	113,384	29	
2006/2009	244,117	142,710	2,022	36,093	4	
2009/2011	276,908	188,015	5,269	46,385	1,791	21
2011/2012	413,701	87,749	197	8,512		
2012/2013	416,172	141,164	4,511	14,730	8	
2013/2014	433,777	182,392	3,714	12,997	9	
2014/2015	483,217	422,415	53,501	216,512	10,646	192
2015/2016	923,202	67,634	4,970	14,889	561	
2016/2017	848,497	14,158	13,588	16,582	1,332	204
2017/2018	228,440	8,086	2,933	4,508	4	38
2018/2019	190,046	157,524	67,053	47,542	126	76
2019/2020	140,034	17,262	4,333	38,843	20	
2020/2021	153,273	30,792	1,503	15,916		

Year	OL-OL	FL-OL	CL-OL	GL-OL	WL-OL	SL-OL
2021/2022	98,577	7,622	4,947	14,353	400	

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The areas of fires that occurred in other land use are sourced from the DG of Forest and Land Fire Control, Ministry of Environment and Forestry, based on the interpretation of remote sensing satellite imagery (Table 6 - 56).

Table 6 - 56 Extent of fire in OL(in ha)

17	D4/11	Minima	D I 1
Year	Port/harbor	Mining Area	Bare Land
2000	7	757	26,076
2001		499	65,800
2002		909	139,448
2003	267	9,630	102,757
2004		2,366	84,515
2005		3,124	213,791
2006	76	7,111	252,195
2007		2,860	62,985
2008		1,026	34,794
2009	17	3,112	109,728
2010		225	22,858
2011		725	43,121
2012	14	1,527	72,790
2013	4	2,004	61,746
2014	31	2,836	191,173
2015	105	3,826	235,923
2016		1,577	73,627
2017		32	5,334
2018	56	697	19,212
2019	8	2,249	108,644
2020	5	234	11,464
2021	12	50	5,360
2022	82	85	4,937

6.8.4. Uncertainty Assessment and Time-Series Consistency

The uncertainty in activity data for the other land-use category primarily arises from the spatial data processing uncertainties. In contrast, the uncertainty in growth and above-ground biomass carbon stocks within the non-forest category mainly derives from the standard errors reported in Indonesia's national forest inventory, as outlined in the country's FREL.

The estimated uncertainty for the land converted to other land use is 28.21%. Additional details can be found in Annex 2. Time-series consistency is maintained by employing uniform methodologies and conducting recalculations in response to methodological advancements or alterations in activity data.

6.8.5. Category-Specific QA/QC and Verification

The explanation for this section can be found in sub-section 6.3.5.

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6.8.6. Category-Specific Recalculations

Calculations for the inventory of the other land-use category (4.F) in the First Biennial Transparency Report (BTR1) have been conducted for the period 2000 to 2019. Emissions and removals have been calculated based on updated activity data and adjustments to EFs, utilizing the GWP from the AR5 and the 2006 IPCC software version 2.93. The modifications to EFs, activity data, and parameters have influenced the emission estimates for the settlements category. Table 6-57 illustrates the variations in activity data and EFs utilized between BUR3 and BTR1.

Table 6- 57 Changes in Activity Data and Emission Factors for The Calculation of Categories 4.F.1 and 4.F.2 OL

Type of Recalculation	Category	BUR3	BTR1	Adjustments
	Port/Harbor	0	0	EF for peat decomposition
	Mining Area	13.91	17.4	(drained peat), where BUR3
EF	Bare Land	13.91	17.4	used IPCC default values and BTR1 used country- specific values (Novita et al. 2021)
	Port/Harbor	0	0	EF for the ratio of below-
	Mining Area	0	0	ground biomass to above-
	Bare Land	0.37	0.235	ground biomass
AD	Peatland (Million Hectare)	0.1-1.2	0.1-1.2	The peatland area has changed between what was used in BUR3 and BTR1, due to updates in the latest reference data
AD	Mineral Soil (Million Hectare)	2.0-4.4	2.0-4.5	The mineral land area used in BUR3 differs from BTR1, due to changes in administrative boundaries over time that were not retroactively recalculated. The BTR1 data uses the latest administrative boundaries applied to all land uses
Category	Peatland decomposition and peat fire	Separate category	Part of Forest Soil Carbon	Emissions from peat decomposition and peat fires in other land use are now included in the other land-use category
Metric		AR2	AR5	Use of GWP

Table 6-58 presents the results of the recalculation of settlements sector emissions in BUR3 and the differences with the same emissions in BTR1, indicating a notable difference of 33.43% to 70.20% for emissions in BUR3. The observed differences arise from the use of the latest version of land use and peat soil map, updated EFs including the inclusion of fire emissions and peat decomposition in BTR1.

Table 6 - 58 Comparison of emissions for other land-use category between BUR3 and BTR1

NGHGI Report	2000	2005	2010	2015	2019
Submission 2021 BUR3, kt CO ₂ e	52,000.44	66,995.03	76,010.52	395,719.21	189,604.25
Submission 2024 BTR1, kt CO ₂ e	15,498.35	89,388.39	125,637.85	639,321.29	311,057.62
		-		-	_
Difference, kt CO ₂ e	36,502.09	22,393.36	-49,627.33	243,602.08	121,453.37
Difference, %	70.20	-33.43	-65.29	-61.56	-64.06

6.8.7. Plan of Improvements

Plan of Improvements for this sub-category can be found in sub-section 6.3.7.

VII. WASTE (CRT SECTOR 5)

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7.1. General Overview (CRT Sector 5)

7.1.1. Sector Description

The sources of GHG emissions from the waste sector, categorized by sub-sector, are as follows: (a) management and handling of domestic solid waste (DSW or MSW) in landfills, biological treatment or composting, open burning, and incineration; (b) management of domestic wastewater, including centralized treatment and septic systems; (c) treatment of industrial waste, encompassing both industrial liquid and solid waste; and (d) other waste types, which include medical and infectious waste and other waste that cannot be categorized into the 3 categories mentioned previously.

The GHGs in the waste sector include carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O). CO₂ emissions arise from the incineration of waste and the treatment of sludge for biomass fuel in the context of industrial solid waste. Methane emissions arise from anaerobic processes, including the degradation of organic solid waste in landfills and wastewater treatment facilities. N₂O is released during composting and the discharge of domestic wastewater.

7.1.2. Categories and Total Emissions

In 2022, the waste sector contributed about 10.04% to total national emissions, with total emissions reaching 138,862.07 kt CO₂e. GHG emissions from the sector by GHG type were 2,383.23 kt CO₂, 4,762.21 kt CH₄ and 11.44 kt N₂O. The CO₂ is the most dominant gas, accounting for 99.89% of total waste sector emissions (Table 7-1). Further and more detailed information on GHG emissions can be found in the specific section of each category.

Table 7 - 1 Summary of GHG emissions from the waste sector in 2022.

Code	GHG Source Categories	CO2 (kt)	CH4 (kt)	N2O (kt)
5	Waste	2,383.23	4,762.21	11.84
5.A	Solid waste disposal		775.88	
5.B	Biological treatment of solid waste		0.07	0.13
5.C	Incineration and open burning of waste	2,381.81	72.12	0.88
5.D	Wastewater treatment and discharge		3,907.99	10.83
5.E	Other (please specify)	1.43	6.15	NO

The IPCC classifies GHG emissions from the waste sector according to the methods of treatment and management employed. GHG emissions from the waste sector for the period 2000 - 2022 based on treatments are presented in Figure 7-1 below. Figure 7-1 (b) also shows the percentage of waste sector emissions based on gas type.

160000 (b) 2022 ■ 5E Other: Industrial Solid Waste Treatment & Handling ■5D2 Industrial WWTP & Discharge 140000 2% 2% (a) Waste Sect ■5D1 Domestic WWTP & Discharge 120000 ■5C2 Open Burning ■5B1 Composting 100000 ■5A2 Unmanaged SWDS kt CO2e 5A1 Managed SWDS 80000 60000 40000 96% 20000 ■ CO2 ■ CH4 ■ N2O 2002 2003 2004 2006 2006 2007 2009 2010 2011 2013 2013 2015 2015 2015 2017 2017 2017 2017 2017

Figure 7 - 1 GHG emissions in the waste sector for the period 2000 - 2022 by treatment (left) (in kt CO₂e) and by GHG type in 2022 in percentage (right)

The GHG emissions from each sub-sector and their corresponding treatment types, including DSW management, composting, domestic wastewater treatment, industrial wastewater treatment, and the 'Other' category for industrial solid waste, are illustrated in Figures 7 - 2, 7 - 3, 7 - 4, and 7 - 5, respectively.

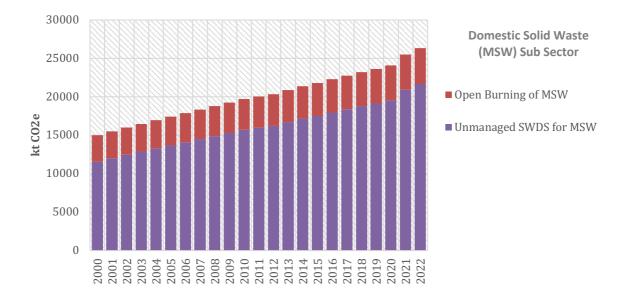


Figure 7 - 2 GHG emissions from domestic solid waste management for the period 2000 - 2022 by source (in kt CO_2e)

Figure 7 - 2 illustrates the primary GHG emissions resulting from the treatment of DSW, specifically highlighting landfills (SWDS) and open waste burning. A more detailed

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explanation of these emission sources can be found in categories 5.A.2 and 5.C.2. Alongside these two waste management methods, waste composting is also present (Figure 7 - 3 and category 5.B.1).

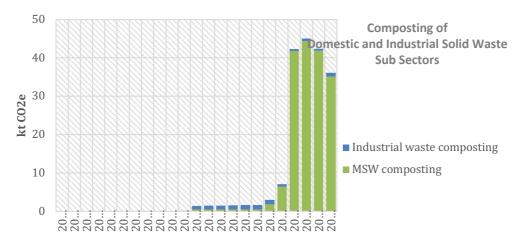


Figure 7 - 3 GHG emissions from composting of domestic and industrial solid waste for the period 2000 - 2022 by source (in kt CO₂e)

Figure 7 - 3 illustrates a diagram depicting GHG emissions associated with composting treatment. Composting is conducted to manage and process both domestic and industrial solid waste, including sludge).

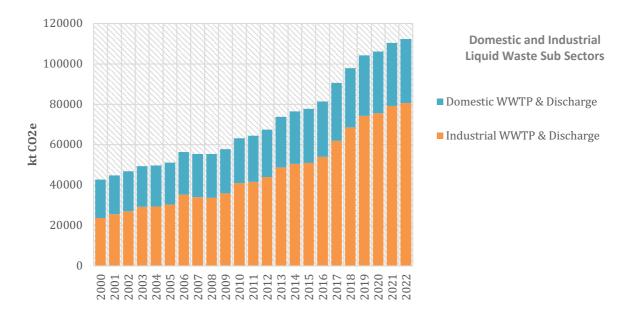


Figure 7- 4 GHG emissions from domestic and industrial wastewater treatment for the period 2000 - 2022 by source (in kt CO₂e)



Figure 7 - 4 illustrates the GHG emissions associated with domestic and industrial wastewater treatment processes. A more comprehensive explanation of emissions from these sources is available in categories 5.D.1 and 5.D.2.

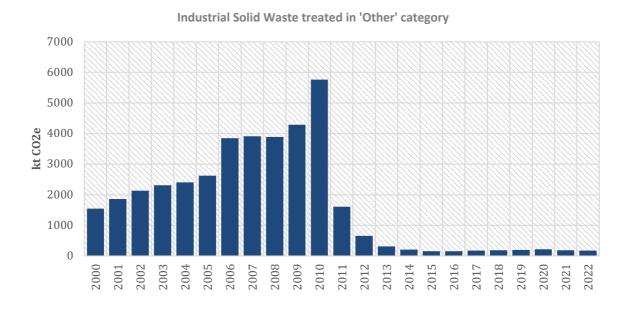


Figure 7 - 5 GHG emissions from industrial solid waste treatment in the 'other' category for the period 2000 - 2022 by Source (in kt CO₂e)

Figure 7 - 5 illustrates a diagram depicting GHG emissions resulting from the treatment of industrial solid waste, encompassing both landfilled sludge and waste categorized as 'Other.' Industrial solid waste encompasses palm oil empty fruit bunches (EFB) and wastewater sludge from the pulp and paper industry. The figure indicates an increase in emissions from 2000 to 2010 resulting from the combustion of palm oil EFB stockpiles. In 2009, a policy was enacted to ban burning, leading to the utilization of some of the EFB as a source of electrical energy since 2010. This utilization has led to a substantial reduction in emissions, culminating in zero emissions by 2015. Emissions from the treatment of wastewater sludge in the pulp and paper industry commenced in 2015. A more detailed explanation of emissions from the treatment of industrial solid waste is presented in category 5.E. Emissions from landfills (managed SWDS) arise from pulp industry sludge, including that associated with paper, as detailed in category 5.A.1.



7.1.3. Methodological Issues

The GHGI for the waste sector adheres to the 2006 IPCC methodology, employing the Global Warming Potential from the AR5 report. Emission estimation utilizes activity data sourced from the MoEF and the Ministry of Public Works (PUPR).

The waste data incorporates both Tier 1 and Tier 2 data within the GHGI. The EFs employed are reference values derived from the IPCC, whereas data regarding waste generation estimates and waste characteristics are sourced locally. The methodology and associated issues concerning the GHGI will be elaborated upon in the methodological issues section, organized according to the nine categories established by the IPCC.

7.1.4. Uncertainty Assessment and Time-Series Consistency

The quantitative evaluation of uncertainty in the GHGI for the waste sector employs the IPCC 2006 Guidelines Approach 1 for error propagation. The uncertainty values are derived from the IPCC 2006 Guidelines (Table 7-2), with specific values for each emission source utilized in the uncertainty assessment detailed in Table 7-3. The uncertainty levels from various emission sources can be calculated using the IPCC default values.

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Table 7 - 2 Source of Uncertainty Values Used

4A1	Managed	SWDS:	Industrial	Solid Was	te
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	ivity Data:		Uncertainty's sources and values	
а	MSWT sent to SWDS (MSW _F)	Collecting data on disposal at SWDS	2006 IPCC GL, Vol. 5, Ch. 3, Table 3.5	30.0%
			the same as the default value for	
b	Dry matter content	IPCC 2006 Default values	Degradable Organic Carbon (DOC) (2006	20.0%
	A stiritor determinante		IPCC GL, Vol. 5, Ch. 3, Table 3.5)	36.1%
Em	Activity data uncertainty ission Factor (CH ₄):		Uncortainty's courses and values	30.1%
a	DOC	IPCC 2006 Default values	Uncertainty's sources and values 2006 IPCC GL, Vol. 5, Ch. 3, Table 3.5	20.0%
b	DOCf	IPCC 2006 Default values	2006 IPCC GL, Vol. 5, Ch. 3, Table 3.5.	20.0%
C	MCF	Anaerobic Landfill	2006 IPCC GL, Vol. 5, Ch. 3, Table 3.5.	10.0%
d	Fraction of CH ₄ in generated Landfill Gas (F)	IPCC 2006 Default values	2000 11 00 02, 1011 0, 0111 0, 10210 0101	5.0%
	Emission factor uncertainty			30.4%
4A2	2 Unmanaged SWDS: MSW Landfill			
	ivity Data:		Uncertainty's sources and values	
а	MSWT sent to SWDS (MSW _F)	Collecting data on disposal at SWDS	2006 IPCC GL, Vol. 5, Ch. 3, Table 3.5	20.0%
b	Waste Composition	Country-specific data, based on studies	2006 IPCC GL, Vol. 5, Ch. 3, Table 3.5.	20.0%
С	Dry matter content	Country-specific data, based on studies	same as the default value for DOC	20.0%
	Activity data uncertainty			34.6%
Em	ission Factor (CH ₄):		Uncertainty's sources and values	
<u>a</u>	DOC	IPCC 2006 Default values	2006 IPCC GL, Vol. 5, Ch. 3, Table 3.5	20.0%
b	DOCf	IPCC 2006 Default values	2006 IPCC GL, Vol. 5, Ch. 3, Table 3.5.	20.0%
С	MCF	Unmanaged Deep	2006 IPCC GL, Vol. 5, Ch. 3, Table 3.5.	20.0%
d	Fraction of CH ₄ in generated Landfill Gas (F) = 0.5	IPCC default values		5.0%
40	Emission factor uncertainty			35.0%
	I Composting: MSW and Pulp & Paper Sludge ivity Data:		Uncertainty's sources and values	
ACI	Total annual amount treated by biological treatment		Uncertainty's sources and values	
а	facilities	Collecting data on facilities	2006 IPCC GL, Vol. 5, Ch. 3, Table 3.5	30.0%
b	Emission FactorCH ₄	IPCC 2006 Default values	Estimates based on default EF values	100.0%
	ission Factor (N ₂ O):			
а	N ₂ O Emission Factor	IPCC 2006 Default values	Estimates based on default EF values	166.7%
4C2	2 Open Burning			
Act	ivity Data:		Uncertainty's sources and values	
а	Population	Statistics Indonesia	2006 IPCC GL, Vol. 5, Ch. 6, Table 6.7	5.0%
b	Fraction of population burning waste	Other data (poor quality data)	2006 IPCC GL, Vol. 5, Ch. 3, Table 3.5	200.0%
С	MSW generation rate (ton/capita/year)	Specific-country default value	2006 IPCC GL, Vol. 5, Ch. 3, Table 3.5	30.0%
d	Fraction of the waste amount burned relative to the total amount of waste treated	IPCC 2006 Default values	Estimates based on default EF values	20.0%
e Em	AD uncertainty: Total Amount of MSW Open-burned ission Factor (CO ₂):	= a x b x c x d x 365		203.3%
	<u> </u>	Country-specific, based on MSW	0000 1000 01 1/1 5 01 5 5 5 60	10.00/
а	Gg CO ₂ per Gg wet waste open-burned	composition	2006 IPCC GL, Vol. 5, Ch. 5, page. 5.23	40.0%
Em	ission Factor (CH ₄):			
а	Methane Emission Factor	IPCC default values	2006 IPCC GL, Vol. 5, Ch. 5, page. 5.23	100.0%
_Em	ission Factor (N₂O):			
а	Nitrous Oxide EF (Dry weight basis)	IPCC default values	2006 IPCC GL, Vol. 5, Ch. 5, page. 5.23	100.0%
	Domestic Wastewater Treatment			
	ivity Data:		Uncertainty's sources and values	
a	Population (P)	Statistics Indonesia	2006 IPCC GL, Vol. 5, Ch. 6, Table 6.7	5.0%
b	BOD per person	IPCC 2006 Default values	2006 IPCC GL, Vol. 5, Ch. 6, Table 6.7	30.0%
С	Total Organically degradable material in wastewater	- o v b v 1		30.4%
d	(TOW) Fraction of population income group (U)	= a x b x 1 Statistics Indonesia	2006 IPCC GL, Vol. 5, Ch. 6, Table 6.7	15.0%
	Degree of utilization of treatment/ discharge			
е	pathway/system	Mostly individual pathway/system	2006 IPCC GL, Vol. 5, Ch. 6, Table 6.7	50.0%
f	Corr. factor for add.i industrial BOD discharged into sewers (I)	Uncollected	2006 IPCC GL, Vol. 5, Ch. 6, Table 6.7	0.0%
g	Activity data uncertainty: TOWREM.j	= c x d x x e x f		60.4%
	ission Factor (CH ₄):			
<u>a</u>	Maximum methane producing capacity	2006 IPCC GL default values	2006 IPCC GL, Vol. 5, Ch. 6, Table 6.7	30.0%
b	MCF for each treatment system	Untreated systems and latrines,	2006 IPCC GL, Vol. 5, Ch. 6, Table 6.7	50.0%
<u>C</u>	Emission factor uncertainty	c = a*b		58.3%
	ission Factor (N2O_effluen):	2006 IDOC CL defendance	2006 IDCC CL Vol 5 CL C T-LL- C 44	E 00'
<u>a</u>	Emission Factor (kg N ₂ O-N/kg N)	2006 IPCC GL default values	2006 IPCC GL, Vol. 5, Ch. 6, Table 6.11	5.0%
	2: Industrial Wastewater Treatment		Ilmonitalistis a	
	ivity Data:	Statistica data	Uncertainty's sources and values	25.00/
a	Industrial Production (P)	Statistics data	2006 IPCC GL, Vol. 5, Ch. 6, Table 6.10	25.0%
b	Wastewater/unit production (W)	IPCC default values/national data	2006 IPCC GL, Vol. 5, Ch. 6, Table 6.10	100.0%

COD/unit wastewater (COD)			
1	IPCC default values/national data	2006 IPCC GL, Vol. 5, Ch. 6, Table 6.10	
Activity data uncertainty: TOWi	= a x b x c		103.1%
ssion Factor (CH ₄):			
Maximum methane producing capacity	2006 IPCC GL default values	2006 IPCC GL, Vol. 5, Ch. 6, Table 6.10	30.0%
MCF for each treatment system	Lagoons, poorly managed treatment plants	Based on default value for dominant emission source/agro industry	30.0%
Emission factor uncertainty	c = a*b		42.4%
Other (Industrial solid waste handling: Paper inc	dustry sludge handling)		
vity Data:		Uncertainty's sources and value	ies
Industrial Production (P)	Statistics data	2006 IPCC GL, Vol. 5, Ch. 6, Table 6.10	25.0%
Sludge per ton product	IPCC default values/national data	2006 IPCC GL, Vol. 5, Ch. 6, Table 6.10	100.0%
COD/unit sludge (COD)	IPCC default values/national data	2006 IPCC GL, Vol. 5, Ch. 6, Table 6.10	100.0%
Activity data uncertainty	= a x b x c	· · · · · · · · · · · · · · · · · · ·	143.6%
ssion Factor (CH ₄):			
Maximum methane producing capacity	2006 IPCC GL default values	2006 IPCC GL, Vol. 5, Ch. 6, Table 6.10	30.0%
MCF for each treatment system	Lagoons, poorly managed treatment plants	Based on default value for dominant emission source/agro industry	30.0%
Emission factor uncertainty	c = a*b		42.4%
	ssion Factor (CH ₄): Maximum methane producing capacity MCF for each treatment system Emission factor uncertainty Other (Industrial solid waste handling: Paper industrial Production (P) Sludge per ton product COD/unit sludge (COD) Activity data uncertainty ssion Factor (CH ₄): Maximum methane producing capacity MCF for each treatment system	Activity data uncertainty Solor Factor (CH ₄): Maximum methane producing capacity MCF for each treatment system Emission factor uncertainty C = a*b Other (Industrial solid waste handling: Paper industry sludge handling) vity Data: Industrial Production (P) Statistics data Sludge per ton product IPCC default values/national data COD/unit sludge (COD) IPCC default values/national data Activity data uncertainty = a x b x c sion Factor (CH ₄): Maximum methane producing capacity MCF for each treatment system MCF for each treatment system 2006 IPCC GL default values Lagoons, poorly managed treatment plants	Maximum methane producing capacity Maximum methane producing capacity MCF for each treatment system Lagoons, poorly managed treatment plants Emission factor uncertainty C = a*b Other (Industrial solid waste handling: Paper industry sludge handling) vity Data: Industrial Production (P) Statistics data Sludge per ton product COD/unit sludge (COD) IPCC default values/national data COD/unit sludge (COD) Activity data uncertainty = a x b x c MAXIMUM methane producing capacity MCF for each treatment system Lagoons, poorly managed treatment plants Based on default value for dominant emission source/agro industry Based on default value for dominant emission source/agro industry 2006 IPCC GL, Vol. 5, Ch. 6, Table 6.10 2006 IPCC GL, Vol. 5, Ch. 6, Table 6.10 Activity data uncertainty = a x b x c Sision Factor (CH4): MAXIMUM methane producing capacity Lagoons, poorly managed treatment plants Based on default value for dominant emission source/agro industry

Note: Uncertainty for CO₂ is equal to that of open burning of MSW

Table 7-3 Uncertainty Values for Each Emission Source

GHG Source and Sink Categories	U_AD	E CO ₂ (kt CO ₂ e)	U_EF1	Uncombine EF1	E CH₄ (kt CO₂e)	U_EF2	Uncombine EF2	E N ₂ O (kt CO ₂ e)	U_EF3	Uncombine EF3	Total emission (kt CO ₂ e)	Total uncertainty
4A1 Managed SWDS	36.06%				33.08	30.41%	47.17%				33.08	47.17%
4A2 Unmanaged SWDS	34.64%				21,691.46	35.00%	49.24%				21,691.46	49.24%
4B1 Composting	30.00%				2.09	100.00%	104.40%	34.06	166.67°	169.35%	36.15	159.66%
4C2 Open Burning	203.29%	2,381.81	40.00%	207.18%	2,019.29	100.00%	226.55%	233.99	100.00°	226.55%	4,635.09	145.62%
4D1 Domestic Wastewater Treatment and Discharge	60.42%				28,853.89	58.31%	83.96%	2,868.82	5.00	60.62%	31,722.71	76.57%
4D2 Industrial Wastewater Treatment and Discharge	103.08%				80,157.96	42.43%	111.47%				80,157.96	111.47%
4E Other	143.61%	1.43	40.00%	149.08%	172.25	42.43%	149.75%				173.68	148.52%

7.1.5. Category-Specific QA/QC and Verification

QC and assurance processes are implemented during the conduct of the GHGI. The quality of the GHGI is ensured through QA/QC activities, including the verification of calculation accuracy and document archiving in accordance with the 2006 IPCC Guidelines, alongside field verification sampling. QC activities are conducted by personnel from the Directorate of GHGI and MRV within the Ministry of Environment and Forestry, as well as by Expert Teams and pertinent Ministries and Agencies. Table 7-4 outlines the QC activities within the waste sector.

A QA Working Group should be established to conduct Quality Assurance activities for the GHGI in future development. Furthermore, the development of a database is necessary to enable the traceability of the AD sources utilized in the emission assessment, which may enhance the QA and QC processes.

Table 7 - 4 Recapitulation of QC Activities

Implementing Entity		Main Activities
DG PPI KLHK/MoEF	•	Preparing a plan and coordinating QC activities for the GHGI.
	•	Conducting general QC checks.

Implementing Entity	Main Activities
	 Archiving records of QC activities, as well as relevant data and documents. Revising the QC plan.
Dir. IGRK and MPV/ GHGI and MRV	 Preparing a plan and coordinating QC activities for the GHGI. Conducting general QC checks. Archiving records of QC activities, as well as relevant data and documents. Revising the QC plan.
Ministry/Agency	• Checking AD and EFs in the Worksheets prepared by the Directorate of GHG Inventory and MRV
MRV Team and GHG Methodology Panel Team	• Discussing and assessing estimation methods, EFs, and ADs.

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7.1.6. Category-Specific Recalculations

The BTR1 Report utilized GWP AR 5 for GHG emissions calculation, in contrast to the BUR3 Report, which employed GWP SAR for the same purpose. Several waste data sources have been updated, and these changes will be detailed in each sub-section pertaining to the waste type.

7.1.7. Plan of Improvements

- Improving the quality of waste stream data through surveys conducted in local or provincial governments, focusing on the composition and characteristics of waste disposed of in landfills, including dry matter content (DMC) and degradable organic carbon (DOC).
- Refining data concerning domestic wastewater treatment, including the types and quantities of septic tanks, the Volume of sludge processed, various treatment methods (biodigesters, centralized, aerobic, or anaerobic), characteristics of domestic wastewater, wastewater treatment MCF, and EFs for each treatment method. The refinement will occur through the collection of data produced by research, the Research and Development Center for Settlements, and other pertinent institutions.
- Enhancing prior GHG emissions estimates, which relied on activity data concerning the
 population utilizing septic tanks versus those not utilizing them, by incorporating
 activity data on individuals using septic tanks, centralized wastewater treatment
 systems (integrated WWTP), communal bio-digester septic tanks (with biogas
 recovery), and the various types of domestic wastewater treatment in residential and
 apartment buildings.
- Improving sludge recovery data from wastewater treatment plant installations can be achieved by integrating data collection with existing monitoring activities conducted by the Directorate of Waste, Waste and Hazardous Materials Management (PSLB3) MoEF.



- Incorporating GHG emissions from industrial and commercial sources, including office buildings, malls, markets, schools and universities, as well as emissions from industrial sludge treatment in wastewater treatment plants, into the NGHGI.
- Improving data collection on methane recovery and utilization from industrial wastewater treatment plants, which are typically integrated with renewable or alternative energy utilization data.

7.2. Managed Waste Disposal Sites (5.A.1)

7.2.1. Category Description

Landfills classified as 'managed disposal sites' typically consist of industrial waste landfills. The GHG produced in this category is methane (CH₄).

7.2.2. Trends in Greenhouse Gas Emissions by Category

Table 7- 5 Emission by gas type (kt CO₂e)

GHG	2000	2005	2010	2015	2020	2022
CO_2						
CH ₄	0.00	0.00	12.97	18.11	30.38	33.08
N ₂ O						

CH4 Landfill of sludge removal (pulp & paper)

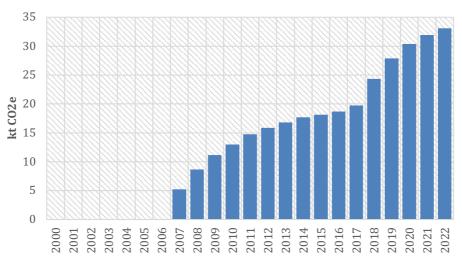


Figure 7- 6 Emission trends by gas sub-category 2000-2022

7.2.3. Methodological Issues

The methodology for calculating emissions is based on the IPCC Guidelines, utilizing the First Order Decay (FOD) method for waste management in landfills. The MCF for managed solid waste disposal sites (SWDS) is 1. Waste data employs both Tier-1 and Tier-2 data sources. The EFs utilized are based on IPCC reference values, whereas data regarding waste quantity and characteristics are derived from local sources within the pulp and paper industry. The DOC continues to reference the IPCC default value for sludge, which is 0.05.



7.2.4. Uncertainty Assessment and Time-Series Consistency

The quantitative evaluation of uncertainty in the GHGI for this category employs Approach 1 (error propagation). The uncertainty level from AD is estimated at 36.10%, while the EF is estimated at 30.40%, according to the IPCC 2006 default uncertainty values (refer to Table 7-1). The uncertainty for the Managed Waste Disposal Sites category is estimated to be 47.17% (refer to Table 7-2).

7.2.5. Category-Specific QA/QC and Verification

QC activities for the GHGI are conducted, including the verification of calculation accuracy and document archiving, in alignment with the 2006 IPCC Guidelines. QC activities are carried out by personnel from the GHGI and MRV Directorate of the Ministry of Environment and Forestry, Expert Teams, and associated Ministries/Agencies. A Quality Assurance Working Group should be established for the execution of GHGI QA activities (refer to Table 7-3).

7.2.6. Category-Specific Recalculations

The recalculation process for BTR1 was conducted in the reporting year, utilizing the GWP from AR-5 in place of the previously employed GWP from SAR. The data regarding the volume of waste processed at managed SWDS is obtained from pertinent industries. Currently, the relevant industries remain confined to the pulp and paper sector, with the pulp and paper industry association (APKI) providing support for the data used in the calculations for this category.

7.2.7. Plan of Improvements

Improving industrial waste stream data through surveys, focusing on characteristics such as DMC and DOC.

7.3. Unmanaged Waste Disposal Sites (5.A.2)

7.3.1. Category Description

Unmanaged Waste Disposal Sites constitute the GHGI on final disposal sites (TPA), originating from residential areas, parks, markets, commercial zones, and other locations in both urban and rural settings. In urban areas, DSW is typically transported and processed at transfer points or landfills. The GHG produced is methane (CH₄).

Since 2018, annual national DSW data has been sourced from the Directorate of Waste Management, Directorate General of PSLB3, utilizing processed provincial, district, and city data entered through the SIPSN (National Waste Management Information System) portal. DSW management data was previously sourced from the Directorate of Waste Management, Directorate General of PSLB3, utilizing information from the ADIPURA program. The

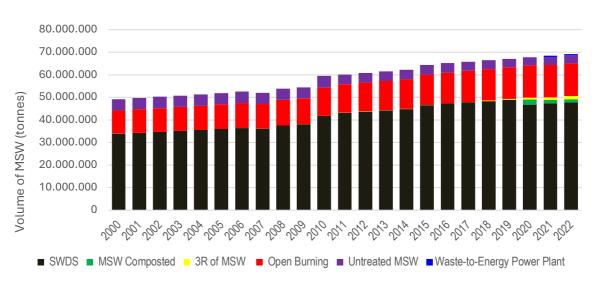
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ADIPURA program has been in existence since 2003; however, until 2013, the data entered at the provincial, district, and city levels was insufficient to satisfy national and international reporting standards, including BUR and Natcom. Post-2014, ADIPURA data became accessible, incorporating additional provincial, district, and city data, and has further enhanced with the introduction of the SIPSN portal. As of 2022, SIPSN has gathered bottom-up data from 412 of the 514 districts/cities, representing 80.16% of the total data; however, validation has been completed for only 309 districts/cities.

The management of DSW has seen advancements in the estimation of GHG emissions through the refinement of data regarding the volume of waste processed in landfills, composted waste, recycling efforts (notably of waste paper), and the installation of landfill gas recovery systems at disposal sites.

According to the 2023 GHGI and MRV Report, biodegradable waste constitutes a significant portion of MSW in Indonesia, with food waste accounting for 49.86%, paper for 10.82%, garden waste for 7.39%, wood for 0.95%, and textiles for 3.97% (link: https://www.ditjenppi.org/indonesia/dokumen). When MSW is disposed of in landfills, a fraction of the MSW undergoes anaerobic decomposition, resulting in the production of methane (CH₄).

Figure 7-7 illustrates the MSW balance from 2000 to 2022. In 2022, the total MSW amounted to 52,371,028 tons. Of this total, 44.03% was landfilled, 3.00% was composted, 3.14% of paper was recycled, 21.19% was openly burned, 0.59% was processed at Waste-to-Energy Plants (PLTSa), Refuse-Derived Fuel (RDF), or Solid Recovery Fuel (SRF), while the remaining 28.62% was categorized as other handling, including unmanaged waste. The waste composition is derived from average values obtained from studies conducted in South Sumatra, North Sumatra, East Java, DKI Jakarta, and Riau Provinces (Figure 7-8). n contrast, the DMC is based on average values from studies in North Sumatra and South Sumatra Provinces (Figure 7-9).



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Figure 7-7 Municipal solid waste generation and treatment data

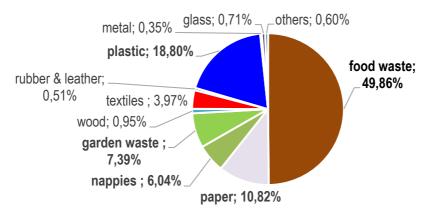


Figure 7-8 Municipal solid waste composition

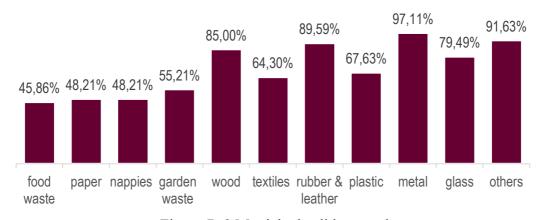


Figure 7-9 Municipal solid waste dry matter content

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7.3.2. Trends in Greenhouse Gas Emissions by Category

Table 7- 6 Emission by gas type (kt CO₂e)

GHG	2000	2005	2010	2015	2020	2022
CO_2						
CH ₄	11,555	13,701	15,702	17,531	19,541	21,691
N ₂ O						

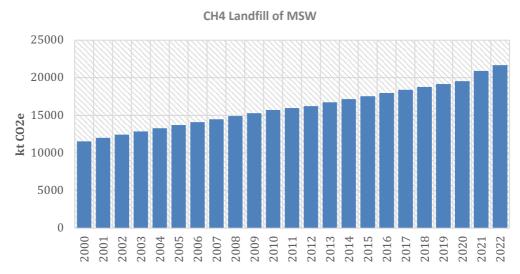


Figure 7- 10 Emission trend by gas type

7.3.3. Methodological Issues

The emission levels for this category are estimated utilizing the FOD method (IPCC 2006). The FOD method was chosen while retaining certain default parameters, specifically: DOC, Fraction of Degradable Organic Carbon Decomposed (DOCf), MCF, and Fraction of CH₄ in Landfill Gas.

The AD utilized specific national data regarding current and historical waste disposal practices at landfills. The data regarding landfill waste disposal has been updated utilizing the SIPSN (2019-present) database, while the data from 2000 to 2018 was estimated through extrapolation.

Data regarding MSW landfilled at disposal sites and MSW managed through non-landfill methods, such as biological waste treatment, is sourced from the National Waste Management Information System (SIPSN) portal, accessible at: https://sipsn.menlhk.go.id/sipsn/. The use of MSW as raw material for livestock, composting, recycling, and energy production is classified as non-landfill waste treatment, as collected in SIPSN.

Since 2018, the Directorate of Waste Management, Directorate General of PSLB3, MoEF has collected annual national urban waste data in the form of provincial, district, and city data via the National Waste Management Information System (SIPSN) portal, accessible at:

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https://sipsn.menlhk.go.id/sipsn/. As of 2022, SIPSN has gathered bottom-up data from 412 of the 514 districts/cities, representing 80.16% of the total data. Since 2014, MSW data has been sourced from the ADIPURA program administered by the same Directorate.

The advertisement for this category utilizes national data (Table 7-7), yet it incorporates data characterized by significant uncertainty, including:

- The data regarding MSW landfilled at disposal sites is derived from national sources available on the SIPSN portal; however, not all of this data is of high quality, such as that obtained from weighbridges.
- The composition and DMC of MSW are derived from national data; however, they are still based on studies or sampling rather than high-quality data obtained from routine sampling at multiple landfills.

Table 7-7 Comparison of AD Used with Default Values in IPCC 2006

Parameter	2006 IPCC GL	Values used in estimat	ing GHG emission levels	Source of data
rarameter	Default values	BUR3 (2021)	NIR (2023)	(NIR, 2023)
MSWT sent to SWDS (MSW _F)	80% (Table 2A.1, Chapter 2, Vol. 5, 2006 IPCC GL))	68.7% (ADIPURA Data)	Using the volume of MSW deposited in landfills (not the fraction of waste that dumped to landfills)	SIPSN portal, link: https://sipsn.menlhk.go.i d/sipsn/
MSW Composition (% of wet weight)	food waste = 43.50%; paper = 12.90%; nappies = -; garden waste = -; wood = 9.90%; textiles = 2.90%; rubber & leather = 0.60%; plastic = 6.30%; metal = 1.30% glass = 2.20%; others = 5.40%	values	food waste = 49.86%; paper	results in the provinces of South Sumatra, North Sumatra, East Java, DKI
DMC of MSW (% of wet weight)	food waste = 40%; paper = 90%; nappies = N/A; garden waste = N/A; wood = 85%; textiles = 80%; rubber & leather = 84%; plastic = 100%; metal = 100%; glass = 100%; others = N/A	food waste = 46%; paper = 48%; nappies = N/A; garden waste = N/A; wood = 55%; textiles = 64%; rubber & leather = 90%; plastic = 68%; metal = 97%; glass = 79%; others = 92%		the average values from studies in North Sumatra and South Sumatra

The EFs for this source continue to utilize the default values established in the 2006 IPCC Guidelines. Table 7-8 presents the EFs utilized for estimating methane emissions from MSW landfills.

Table 7-8 Emission factors used for the Unmanaged Waste Disposal Sites category

Parameter	Values used in e emission		Source
	BUR3 (2021)	NIR (2023)	
DOC, in % of dry waste	IPCC 2006 Default values	IPCC 2006 Default values	2006 IPCC GL, Volume 5, Chapter 2, pp. 2.14 (Table 2.4).

Parameter	Values used in e emission		Source
-	BUR3 (2021)	NIR (2023)	
Fraction of DOC dissimilated (DOCf)	IPCC 2006 Default values	IPCC 2006 Default values	2006 IPCC GL, Volume 5, Chapter 3, pp. 3.13
MCF -> Unmanaged deep (>5 m waste) and	IPCC 2006 Default values	IPCC 2006 Default values	2006 IPCC GL, Volume 5, Chapter 3, pp. 3.13 (Table 3.1).
/or high-water table			l.
Methane generation rate constant (k)	IPCC 2006	IPCC 2006	2006 IPCC GL, Volume 5, Chapter 3,
-> Tropical, Moist and Wet	Default values	Default values	pp. 3.17 (Table 3.3).
Delay time, 6 months	IPCC 2006	IPCC 2006	2006 IPCC GL, Volume 5, Chapter 3,
	Default values	Default values	pp. 3.36.
Fraction of methane (F) in developed	IPCC 2006	IPCC 2006	2006 IPCC GL, Volume 5, Chapter 3,
gas	Default values	Default values	pp. 3.13
= 0.5			
Oxidation factor (OX), $= 0$	IPCC 2006 Default values	IPCC 2006 Default values	2006 IPCC GL, Volume 5, Chapter 3, pp. 3.15 (Table 3.2)

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7.3.4. Uncertainty Assessment and Time-Series Consistency

Quantitative evaluation of uncertainty in the GHGI for this category utilizing the Tier 1 approach (error propagation). The uncertainty level of the AD is 34.60%, while the EF has an uncertainty level of 35.00%, as indicated by the IPCC 2006 default uncertainty values (refer to Table 7-1). The uncertainty for the Unmanaged Waste Disposal Sites category is estimated at 49.24% (refer to Table 7-2).

7.3.5. Category-Specific QA/QC and Verification

Refer to sub-chapter 7.1.4.

7.3.6. Category-Specific Recalculations

Recalculations were conducted with an updated GWP, utilizing the AR 5 GWP as detailed in chapter 7.1.5. The data regarding waste entering landfills or SWDS has been revised by replacing the JAKSTRANAS data with SIPSN (National Waste Management Information System) data. The JAKSTRANAS data provides estimated information to aid regions in the development of waste treatment and management programs. Updating the data through SIPSN will result in a reduction of data uncertainty.

7.3.7. Plan of Improvements

Given its significance, employing Tier 2 for estimating GHG emission levels is preferable, utilizing high-quality country-specific activity data. The Directorate of Waste Management has established the National Waste Management Information System (SIPSN), accessible at https://sipsn.menlhk.go.id/sipsn/, which compiles data on waste characteristics and management across all cities and districts in Indonesia. According to the President's Regulation of the Republic of Indonesia Number 97 of 2017 and the Regulation of the Minister of

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Environment and Forestry No. 6 of 2022, local governments are responsible for collecting information and entering waste data into SIPSN. This portal provides annual data, including waste generation and composition, as well as the volume of waste disposed of in landfills. This data may be biased due to the lack of information regarding the location of the waste composition measurement, specifically whether it was conducted at the source, during temporary storage, or at the landfill. Data regarding the type of landfill is currently unavailable in SIPSN; however, it can be accessed through SIGN SMART, the NGHGI reporting platform online.

7.4. Composting (5.B.1)

7.4.1. Category Description

The primary emission sources in this category are methane (CH₄) and nitrous oxide (N_2O) emissions resulting from the composting of solid waste. The composting process is applicable not only to DSW but also to industrial solid waste, such as industrial wastewater sludge. Currently, the estimated emissions of CH₄ and N_2O from composting are derived from DSW and industrial wastewater sludge, especially within the pulp and paper sector.

7.4.2. Trends in Greenhouse Gas Emissions by Category

The table and figure illustrate the trend of GHG emissions from composting. N₂O emissions exceed CH₄ emissions due to a higher N₂O EF associated with waste composting and an elevated GWP for N₂O. The figure illustrates a notable rise in N₂O and CH₄ emissions during the 2018-2019 period. This is directly proportional to the increasing volume of waste composting resulting from mitigation programs in the DSW sector. Between 2020 and 2022, composting emissions experienced a minor decline attributed to a slight decrease in the volume of waste composted.

Table 7- 9 Emission by gas type (kt CO₂e)

GHG	2000	2005	2010	2015	2020	2022
CO_2						
CH ₄	0.0018	0.0031	0.0043	0.76	2.22	2.09
N ₂ O	0.04	0.07	0.10	0.90	42.82	34.06



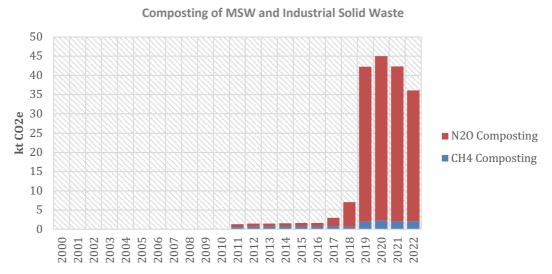


Figure 7- 11 Trend of composting emissions by gas sub-category 2000-2022

7.4.3. Methodological Issues

The GHGI methodology for this category employs default EFs from the IPCC (Tier 1) because of the restricted availability of national data sources. Nonetheless, the AD utilizes data from the processing facilities (Tier 2), specifically: (i) the quantity of waste composted from SIPSN, and (ii) wastewater sludge from the pulp and paper industry sourced from industry associations (plant level data).

In Indonesia, composting organic waste, including food waste, garden waste, and park waste, is a prevalent practice. Compost serves as a fertilizer and soil conditioner, or it may be disposed of in SWDS as an alternative daily cover. Emissions of CH₄ and N₂O from composting are documented in this category. Composting is an aerobic process in which a significant portion of the DOC present in organic waste is transformed into CO₂. Methane (CH₄) is produced in the anaerobic regions of compost, while a significant portion is oxidized in the aerobic regions. Composting may generate N₂O emissions.

The volume of biological waste data refers to the aggregation of waste data utilized as compost raw material across multiple waste management facilities, including Parent Waste Banks, 3R Transfer Stations, PDU, home composting, and landfill composting. The data is obtained from the National Waste Management Information System (SIPSN) portal (https://sipsn.menlhk.go.id/sipsn/).

The EFs for this category utilize the lower bound of the value range specified in the 2006 IPCC Guidelines. Table 7-10 presents the EFs utilized for estimating the levels of CH_4 and N_2O emissions resulting from waste composting. The lower bound EF values are utilized due to observations indicating that composting in Indonesia predominantly employs aerobic

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processes, resulting in a reduced likelihood of CH₄ and N₂O emissions. Windrow composting is a method characterized by its aerobic nature.

Table 7- 10 Emission factors used for the unmanaged waste disposal sites category

D	2000	5 IPCC GL Default Values	Values used in estimating GHG emission levels		
Parameter	Qty	Source	BUR3 (2021)	NIR (2023)	Source (NIR 2023)
CH ₄ EF	10	2006 IPCC GL, Volume 5,	0.08	0.08	GHGI and MRV
(g CH ₄ /kg dry waste treated)	(0.08 - 20)	Chapter 4, pp. 4.6 (Table 4.1)			Report 2023
N ₂ O EF	0.6	2006 IPCC GL, Volume 5,	0.20	0.20	GHGI and MRV
(g N ₂ O/kg wet waste treated))	(0.2 - 1.6)	Chapter 4, pp. 4.6 (Table 4.1)			Report 2023

7.4.4. Uncertainty Assessment and Time-Series Consistency

Quantitative evaluation of uncertainty in the GHGI for this category utilizing the Tier 1 approach (error propagation). According to the IPCC 2006 default uncertainty values (refer to Table 7-1), the uncertainty level for the AD is 30.00%, the CH₄ EF is 100.00%, and the N₂O EF is 166.67%. The estimated uncertainty for the composting category is 159.66% (refer to Table 7-2).

7.4.5. Category-Specific QA/QC and Verification

Refer to sub-chapter 7.1.4

7.4.6. Category-Specific Recalculations

Refer to sub-chapter 7.1.5

7.4.7. Plan of Improvements

Enhancing the volume of composting data at the regional level, where presently only 80.16% of district/city data is recorded in the SIPSN portal. Quality assessment requires the dissemination and verification of composting data derived from daily or weekly logbooks, rather than relying on capacity metrics.

To mitigate uncertainty, it is essential to establish local EFs for different biological waste treatment methods, including bio drying, composting, anaerobic digestion, biomass conversion, and chemical conversion. The final disposal of solid waste in Indonesia is urgently transitioning toward alternative waste treatment methods, such as biological and thermal processes, rather than relying on landfilling. This approach aligns with the zero waste zero emission concept.



7.5. Open Burning of Waste (5.C.2)

7.5.1. Category Description

Open burning of waste refers to the incineration of undesirable flammable materials, including paper, wood, plastics, textiles, rubber, used oil, and other refuse in outdoor settings or at open waste disposal sites. In this process, smoke and other emissions are discharged directly into the atmosphere without passing through a chimney. Open waste burning frequently takes place in rural regions lacking waste collection services. The open burning of waste contributes to GHG emissions, specifically releasing carbon dioxide, methane, and nitrous oxide.

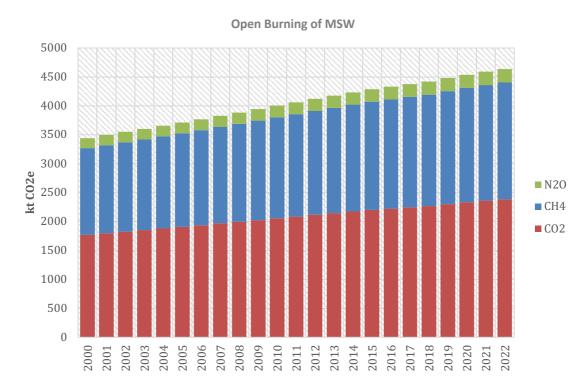
The IPCC Guidelines specify that only CO₂ emissions resulting from the oxidation of fossil carbon in waste materials, such as plastics, textiles, and rubber, during open burning are accounted for. CO₂ emissions resulting from the combustion of waste biomass, including paper, food waste, and wood waste, are classified as biogenic and are excluded from the overall national emission estimates.

In Indonesia, plastics constitute a significant portion of plastic waste, accounting for 18.80% (source: 2023 GHGI and NDC Report). At present, it is assumed that all plastic waste is derived from fossil sources, necessitating further research to ascertain the proportion of organic plastics present in Indonesia. Alongside the ongoing open burning of MSW, open burning was also prevalent on palm oil empty fruit bunch piles from 2000 to 2010.

7.5.2. Trends in Greenhouse Gas Emissions by Category

Table 7- 11 Emission by gas type (kt CO₂e)

GHG	2000	2005	2010	2015	2020	2022
CO_2	1,769.48	1,908.10	2,057.46	2,203.61	2,332.33	2,381.81
CH ₄	1,500.16	1,617.68	1,744.31	1,868.22	1,977.34	2,019.29
N ₂ O	173.84	187.46	202.13	216.49	229.13	233.99



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Figure 7- 12 Trend of open burning emissions by gas sub-category 2000-2022

7.5.3. Methodological Issues

The estimation of DSW emissions in regions, particularly rural areas, where some waste is still processed locally through open burning, employs the IPCC Tier 1 methodology. The advertisement regarding the volume of waste openly incinerated employs a statistical data methodology focused on community waste burning practices. The pertinent statistical data is derived from the Indonesian Environmental Statistics (BPS), specifically referencing the Housing and Settlement Statistics (Susenas 2004), as more recent statistics do not encompass indicators related to community waste burning. The parameters associated with AD and EFs continue to utilize the IPCC default values.

7.5.4. Uncertainty Assessment and Time-Series Consistency

The quantitative evaluation of uncertainty in the GHGI for this category employs the Tier 1 approach (error propagation). The uncertainty level of the AD is 203.30%, according to the IPCC 2006 default uncertainty values (refer to Table 7-1). The CO₂ EF is 40%, while both the CH₄ and N₂O EFs are 100.00%. The uncertainty for the Open Burning of Solid Waste category is estimated at 145.62% (refer to Table 7-2).

7.5.5. Category-Specific QA/QC and Verification

Refer to sub-chapter 7.1.4

7.5.6. Category-Specific Recalculations

Refer to sub-chapter 7.1.5



7.5.7. Plan of Improvements

The information regarding open burning can be found in the annually published Housing and Settlement Statistics document by the Central Bureau of Statistics (BPS). Utilizing this data necessitates additional agreements with pertinent institutions, including the Central Bureau of Statistics as the data collector, the Directorate of Waste Management of the Ministry of Environment and Forestry as the regulatory body, the Directorate of Cleanliness of the Ministry of PUPR concerning facilities and infrastructure, and the Ministry of Home Affairs, which supervises Regional Governments as both regulator and operator at the regional level. An annual waste balance must be established in the future.

The existing data regarding the proportion of the population that engages in waste burning relies on low-quality sources, while the information on waste generation rates continues to utilize national default figures. Interoperability and enhanced data quality from all pertinent stakeholders are essential for accurately assessing the proportion of the population that incinerates waste and the waste generation rate in each city or district, thereby facilitating the production of high-quality data.

Additionally, it is still assumed that all plastic waste originates from fossil sources. Consequently, additional research is required to ascertain the proportion of organic plastics present in Indonesia.

7.6. Domestic Wastewater (5.d.1)

7.6.1. Category Description

Domestic wastewater is typically treated on-site, directed to centralized wastewater treatment facilities, or released untreated into rivers via drainage channels. The calculated emissions are methane (CH₄) and nitrous oxide (N₂O).

7.6.2. Trends in Greenhouse Gas Emission by Category

Table 7- 12 Emission by gas type (kt CO₂e)

GHG	2000	2005	2010	2015	2020	2022
CO_2						
CH ₄	17,351.23	18,658.61	20,047.85	24,330.87	27,767.18	28,853.89
N ₂ O	1,678.46	2,049.69	2,193.77	2,353.87	2,806.85	2,868,82



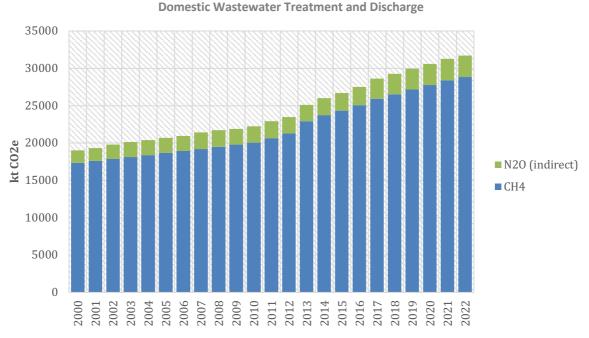


Figure 7- 13 Emission trends by gas sub-category 2000-2022

7.6.3. Methodological Issues

The AD for domestic wastewater is represented by the TOW (Total Organics in Wastewater), which is calculated as the total BOD (kg) based on the population size multiplied by the per capita BOD (kg). The BOD/person/year parameter estimates the TOW (Total Organics in Wastewater) value, while the emission factor (EF = Bo* MCF, kg CH₄ /kg BOD) is derived from the default value provided in the 2006 IPCC Guidelines for Asian, Middle Eastern, and African countries, which is 40 grams/capita/day. The protein consumption parameter utilizes specific data for Indonesia, published annually by the BPS.

The treatment of domestic wastewater enhances the coverage of the GHGI by incorporating data on sludge removal from septic tanks and its treatment at sludge facilities, the replacement of septic tanks with biodigesters that include biogas recovery, and the volume of Domestic Waste Water (DWW) processed at centralized WWTPs. The GHG emissions from domestic wastewater treatment in the Third National Communication (TNC) document were estimated using data from domestic wastewater treatment facilities published by the Ministry of Health (RISKESDAS). In contrast, the NGHGI reports, including BUR2 and BUR3, utilized the more comprehensive and regularly available People's Welfare Statistics data from BPS for estimating domestic wastewater emissions.

The estimation of domestic wastewater is significantly influenced by population size, with additional parameters adhering to the IPCC Guidelines. The availability of data regarding the

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distribution of sanitation facility usage (bathing, washing, toilet) according to technology types is limited. The locations of pit latrines have not been precisely documented. The existing data solely indicates the presence or absence of sanitation facilities and the distribution of domestic wastewater, without providing insights into the technologies employed. Furthermore, challenges exist in quantifying the BOD from recovered sludge, necessitating a distinct study for accurate assessment.

7.6.4. Uncertainty Assessment and Time-Series Consistency

The quantitative evaluation of uncertainty in the GHGI for this category employs Approach 1 (error propagation). The default IPCC uncertainty values for 2006 indicate that the uncertainty level of the AD is 60.40%, the CH₄ EF is 58.30%, and the N₂O EF is 5.00%. The estimated uncertainty for the Domestic Wastewater Treatment and Discharge category is 76.57% (refer to Table 7-2).

7.6.5. Category-Specific QA/QC and Verification

Refer to sub-chapter 7.1.4

7.6.6. Category-Specific Recalculations

Refer to sub-chapter 7.1.5

7.6.7. Plan of Improvements

Enhancement of data concerning domestic wastewater treatment, including the types and quantities of septic tanks, the volume of sludge processed, alternative treatment methods (biodigesters, centralized systems, aerobic or anaerobic processes), the properties of domestic wastewater, the MCF of wastewater treatment, and the EFs associated with each treatment method. Data generated from research, the Research and Development Center for Settlements, and other pertinent institutions will be utilized for refinements. Data on septic tank usage may include information from the Ministry of Health (Kemenkes), the Welfare Statistics (SKR BPS), and monitoring results from the Ministry of PUPR (KemenPUPR).

The future plan involves enhancing previous GHG emission estimates, which relied on the AD of the population utilizing septic tanks versus those not using them. The revised estimates will incorporate AD data from populations using septic tanks, centralized sewer systems (integrated wastewater treatment plants), communal bio-digester septic tanks (with biogas recovery), and various domestic wastewater treatment methods in residential housing and apartments. Furthermore, the assessment of GHG emissions from wastewater treatment across industrial,

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commercial (including offices, malls, markets, schools, and universities), and other sectors should be incorporated into the GHG emission estimation for the wastewater treatment category.

Local EFs can be developed to decrease the level of uncertainty, including biochemical oxygen demand per capita and wastewater discharge per capita. The establishment of local EFs is particularly crucial for primary sources of emissions, including individual and communal septic tanks.

7.7. Industrial Wastewater (5.d.2)

7.7.1. Category Description

This category includes the calculation of GHG types, specifically CH₄, resulting from the treatment of industrial wastewater in industrial wastewater treatment plants (WWTPs). Methane emissions are contingent upon the designated MCF, which varies based on the treatment technology employed in the WWTP.

7.7.2. Trends in Greenhouse Gas Emissions by Category

Table 7- 13 Emission trends by gas type (kt CO₂e)

GHG	2000	2005	2010	2015	2020	2022
CO_2						
CH ₄	23,646.79	30,350.34	40,931.64	51,018.13	75,562,07	80,569.06
N ₂ O						

Figure 7-14 illustrates methane (CH₄) emissions from industrial wastewater treatment during the period 2000-2022. The data presented in the table and figure indicate a continuous increase in emissions from this category, directly correlating with the volume of wastewater treated. The estimation of treated industrial wastewater is based on levels of industrial production. During the period of 2020-2021, GHG emissions experienced a notable rise attributed to substantial production increases across various sectors, including palm oil and margarine, dairy products, palm-based oleochemicals, biodiesel, vegetables, fruits and juices, fish processing, sugar refining, vegetable oils, and the establishment of new pulp and paper mills.



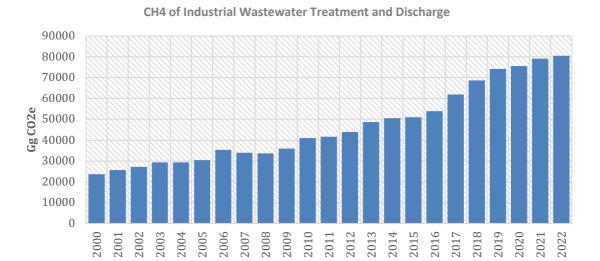


Figure 7- 14 Emission trends by gas sub-category 2000-2022

7.7.3. Methodological Issues

The calculation of emissions from industrial wastewater treatment employs activity data derived from processed production statistics across 22 industry types, measured in tons per year. The processed production data is sourced mainly from the Ministry of Industry via the Green Industry Center (PIH) and the Directorate of Tobacco and Refreshment Products Industry, covering the period up to 2019. Since 2020, the Ministry of Industry has supplied processed production data obtained from the National Industrial Information System (SIINas). The data from SIINas encompasses a restricted range of industries, as not all sectors submit reports to SIINas. The data entry into SIINas by each industry remains inconsistent, with not all industries regularly updating their information in the system. The data from SIINas exhibits fluctuations.

Consequently, certain industrial processing production data from 2020 to 2022 incorporates information from multiple sources. The references utilized encompass the Performance Report of the Indonesian Palm Oil Association (GAPKI), primary data from the Indonesian Pulp and Paper Association (APKI), HEESI, Livestock and Animal Health Statistics, National Featured Plantation Statistics from the Directorate General of Plantations, and data from Index Mundi, along with projection figures through extrapolation.

GHG emissions from industrial wastewater are estimated by considering the volume of wastewater treated, its characteristics, and the type of treatment unit employed. Parameters including COD/m³ and wastewater discharge are utilized to estimate the TOW (total organics degradable material in wastewater for each industry sector, kg COD/yr) value. This report

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presents the COD and wastewater discharge values, along with EFs, derived from multiple sources, including PROPER, local research institutions (BPPT and universities), environmental ministerial regulations, and industry associations. In certain industry categories lacking current research, the default values from the 2006 IPCC Guidelines continue to be utilized.

The estimation of GHG emissions from industrial wastewater remains significantly reliant on production levels. Obtaining production data is challenging for less common industries, whereas it is more readily accessible for more common industries.

The future plan aims to enhance the AD by improving the accuracy of production levels and capacity, as this significantly affects emission estimates, leading to more reliable outcomes. The introduction of a new category, empty palm fruit bunches (TKKS), will have a substantial impact on overall emission calculations, as TKKS produces methane through the FOD method. Furthermore, enhancing data on methane (CH₄) recovery and the utilization of sludge from industrial WWTPs in the pulp and paper sector will refine the precision of our evaluation. The refining EFs for starch and crude palm oil contribute to a more precise and thorough assessment.

7.7.4. Uncertainty Assessment and Time-Series Consistency

The quantitative evaluation of uncertainty in the GHGI for this category employs Approach 1 (error propagation). The default IPCC uncertainty values for 2006 indicate that the uncertainty level of the AD is 143.60%, while the CH₄ EF is 42.40%. The estimated uncertainty for the Industrial Wastewater Treatment and Discharge category is 149.75% (refer to Table 7-2).

7.7.5. Category-Specific QA/QC and Verification

Refer to sub-chapter 7.1.4

7.7.6. Category-Specific Recalculations

Refer to sub-chapter 7.1.5

7.7.7. Plan of Improvements

- Enhancing the data regarding the utilization of sludge from industrial solid waste treatment facilities can be achieved by integrating data collection with the monitoring activities currently performed by the Directorate of Waste and Hazardous Waste Management -MoEF.
- Incorporating GHG emissions from industrial estate WWTPs and sludge management from industrial WWTPs into the NGHGI.



- Enhancing data collection regarding the utilization and recovery of methane from industrial WWTPs, typically integrated with data on renewable or alternative energy use.
- Establishing a system for the collection and compilation of data related to industrial production and wastewater characteristics, including COD and the volume of wastewater treated in WWTPs, with a focus on primary emission sources such as agro-industrial wastewater.

7.8. Other (5.E)

7.8.1. Category Description

The types of waste and their treatment reported in this category include sludge from WWTPs and empty palm fruit bunches (TKKS), collectively referred to as 'industrial solid waste handling'. The available data on WWTP sludge pertains to that from paper industry wastewater treatment plants, which is managed in retention ponds and is estimated to contribute to CH₄ emissions. The management of TKKS results in emissions of CH₄ and N₂O from combustion, as well as CH₄ from the stockpiling of TKKS. CO₂ emissions result from the preparation of wastewater treatment plant sludge in the paper industry for utilization as biomass fuel.

7.8.2. Trends in Greenhouse Gas Emissions by Category

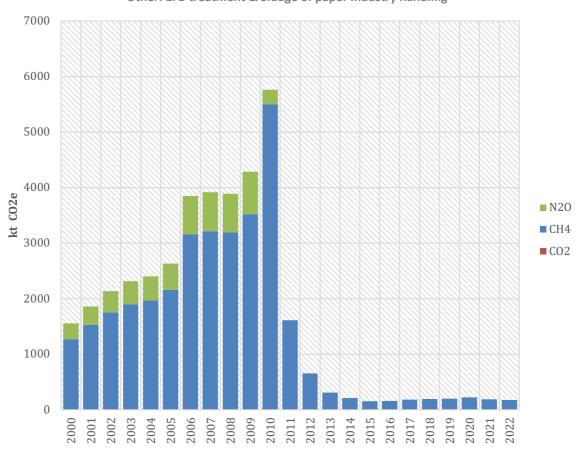
The emission trend for the other (5.E) category, derived from paper industry WWTP sludge, is illustrated in Table 7-14 below.

Table 7- 14 Emission by gas type (kt CO₂e)

GHG	2000	2005	2010	2015	2020	2022
CO_2	0.00	0.00	1.10	0.87	0.54	1.43
CH ₄	1,274.09	2,158.81	5,495.21	152.03	219.12	172.25
N ₂ O	278,27	471,50	268,28	NO	NO	NO

Since 2015, emissions from TKKS (empty palm fruit bunches) have ceased, as 100% of TKKS is utilized, eliminating stockpiles, and all TKKS can be utilized or sold. Prior to 2015, TKKS emissions were assessed according to the method of handling: (a) burning, which occurred before the implementation of the burning ban in 2010, and (b) stockpiling, which characterized the 2010-2015 period following the ban. During this latter period, TKKS was primarily stockpiled, with some instances of utilization as an energy source and subsequent sale.





Other: EFB treatment & Sludge of paper industry handling

Figure 7- 15 Emission trends by gas sub-category 2000-2022

7.8.3. Methodological Issues

The calculation of emissions is contingent upon the waste type and the technology employed for its treatment. Methods for each waste treatment technology or type are detailed in subchapters 7.2 to 7.7. The methane emissions generated from the retention ponds storing WWTP sludge in the paper industry are estimated using the methodology outlined in sub-chapter 7.6. TKKS emissions are determined according to the method of handling. (a) burning occurred prior to the regulation that prohibited it (before 2010), and (b) stockpiling took place during the 2010-2015 period, following the regulation's implementation, during which TKKS was primarily stockpiled and subsequently utilized as an energy source and sold. Since 2015, it has been assumed that emissions from TKKS have ceased, as there are no remaining stockpiles, and all TKKS can be utilized or sold. The methodology for calculating emissions from TKKS burning is detailed in sub-chapter 7.5, while the methodologies for TKKS stockpiling are outlined in sub-chapters 7.2 and 7.3.

7.8.4. Uncertainty Assessment and Time-Series Consistency

The quantitative evaluation of uncertainty in the GHGI for this category employs Approach 1 (error propagation). The default IPCC uncertainty values for 2006 indicate that the uncertainty



level of the AD is 143.60%, while the CH₄ EF is 42.40%. The estimated uncertainty for this category is 148.52% (refer to Table 7-2).

7.8.5. Category-Specific QA/QC and Verification

Refer to sub-chapter 7.2.4, 7.3.4, 7.5.4, 7.7.4.

7.8.6. Category-Specific Recalculations

Refer sub-chapter 7.2.5, 7.3.5, 7.5.5, 7.7.5.

7.8.7. Plan of Improvements

The plan of improvements encompasses initiatives to incorporate infectious waste types into the GHG emission sources within the waste category. A data collection and compilation system for this category must be established to acquire high-quality data.

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VIII. INDIRECT CARBON DIOXIDE AND NITROUS OXIDE EMISSIONS

(Related to non- mandatory provisions as per para. 52 of the MPGs)

Indonesia decided not to report indirect CO2 emissions from the atmospheric oxidation of CH4, CO and NMVOCs; and indirect nitrogen oxides from sources other than agriculture and LULUCF.

IX. RECALCULATION AND IMPROVEMENTS

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The 2024 GHGI in the Inventory Document reveals notable discrepancies when compared to the inventory submitted to the UNFCCC in BUR3, which encompasses the period from 2000 to 2019, in contrast to the period from 2000 to 2022. The observed differences stem from the availability of supplementary data that fill inventory gaps, alterations in data sources, enhancements in activity data, methodological adjustments, the incorporation of newly identified sources, and modifications in the application of Global Warming Potential for the GHGI in this Biennial Update Report, thereby ensuring consistent comparisons throughout the time-series.

9.1. Explanation and Justification for Recalculations

The GHGI in this BTR1 has been compiled in accordance with the 2006 IPCC Guidelines, similar to the previous GHGI reports in BUR3. The methodological aspects for the five reported sectors—energy, IPPU, agriculture, LULUCF, and waste—have been improved for this inventory, encompassing the entire time-series. Furthermore, particular EFs and methodological elements from the 2019 Refinement of the 2006 IPCC Guidelines, along with the 2013 Wetlands Supplement, have been integrated.

The primary justifications for the recalculations in this inventory are detailed in the sectoral chapters and summarized in Table 9-1. Recalculations of prior emission estimates have been conducted for all years in the time-series to ensure accuracy and maintain consistency.

Table 9-1 Recalculations of GHGI in NID 2024 compared to the previous report (BUR3 2021)

Sector	Sub-sector	Category/ Chapter	Reason for Recalculation
Energy	Electricity Generation,	1.A.1.a.i,	Recalculations for the emission estimates for
	Petroleum Refining,	1.A.1.b,	2000-2019 have been performed due to
	Manufacturing	1.A.2.m,	changes in emission factors using Tier-2 EF
	Industries and	1.A.4.a,	for gas/diesel oil, which in the 3 rd BUR used
	Construction, Commercial/Institutional Agriculture/Forestry/Fis hing/Fish Farms	1.A.4.c	 an aggregate gas/diesel oil, becoming more detailed as diesel oil and gas/diesel oil CN 48 Changes of GWP from 2AR to 5AR, making the GHG estimation for 2000-2019 recalculated using 5AR and the estimation for 2020-2022 calculated using 5AR. Changes in methods from Tier 1 to higher Tier 2, leading to the recalculation of the
			GHG emission estimates for 2000 - 2019 and the calculation of GHG emissions for 2020 - 2022 using Tier 2.
	Road Transportation	1.A.3.b	Recalculations for the emission estimates for 2000-2019 have been performed due to changes in emission factors using Tier-2 EF

Sector	Sub-sector	Category/ Chapter	Reason for Recalculation
			for gas/diesel oil and gasoline, which in the 3 rd BUR used an aggregate gas/diesel oil becoming gas/diesel oil CN 48, gas/diesel oil CN 51, gas/diesel oil CN 53 and an aggregate gasoline becoming gasoline RON 88, gasoline RON 90, gasoline RON 92, gasoline RON 98. • Disaggregation of gasoline and gas/diesel oil data into sub-categories of consumers and types of petroleum products (CN 48, gas/diesel oil CN 51, gas/diesel oil CN 53) and disaggregated gasoline to become gasoline RON 88, gasoline RON 90, gasoline RON 92, gasoline RON 98. In the 3 rd BUR, the GHG emissions during 2000-2019 were estimated using aggregate gas/diesel oil and aggregate gasoline data.
	Railways	1.A.3.c	Recalculations for the emission estimates for 2000-2019 have been performed because in the 3 rd BUR, the AD for Railways was still accounted for in 1.A.3.b Road Transportation. The AD for gas/diesel oil use in Railways for 2020-2022 is now available. The AD for gas/diesel oil use in 2000-2019 is estimated from the specific fuel consumptions (km.passenger/unit-gasoline and km.ton/unit-gas/diesel oil) for 2020-2022 multiplied by the km.passenger and km.ton data for 2000-2019.
			 Changes of GWP from 2AR to 5AR makes the GHG estimation for 2000-2019 recalculated using 5AR and the estimation for 2020-2022 calculated using 5AR. Changes in methods from Tier 1 to higher Tier 2 leads to the recalculation of the GHG emission estimates for 2000 - 2019 using Tier 2. Changes in AD on road transport, in which fuels in railway transport can be disaggregated from road transport. However, gas/diesel oil usage in railway is
IPPU	Cement Industry	2 A 1	available only for 2020-2022, so the AD of fuel oil usage in railway transport during 2000-2019 is estimated by multiplying specific consumptions extrapolated from 2020-2022 data with the data of km passenger and km.ton in 2000-2019. Recalculations for the emission estimates for
-			2000-2019 have been performed due to:

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Sector	Sub-sector	Category/ Chapter	Reason for Recalculation
			 (a) changes in AD for 2010-2019, where the 3rd BUR used a cementitious data approach, while the recalculation used a clinker-based approach (b) changes in emission factors using Tier-2 EF (c) changes in the use of GWP from AR2 to AR5
			 Changes of GWP from 2AR to 5AR makes the GHG estimation for 2000-2019 recalculated using 5AR and the estimation for 2020-2022 calculated using 5AR Changes in AD in 2010-2019, where the previous estimation of GHG emissions (3rd BUR) used cementitious data while the recalculation used a clinker-based approach Changes of methods for estimating GHG emissions from Tier 1 to higher Tier 2 leads to recalculate the GHG emission 2000-2019 using Tier 2 and to calculate GHG emission in 2000-2019 using Tier 2
	Ammonia Industry	2 B 1	Recalculations for the emission estimates for 2000-2019 have been performed due to: (a) Changes in ammonia and urea production AD for the years 2010-2019 (b) Changes in EFs related to feedstock consumption and carbon content for the years 2000-2019, where BUR3 still utilized the Tier 1 default values from the IPCC (c) Changes in the application of GWPs from AR2 to AR • Changes of GWP from 2AR to 5AR, makes GHG estimation 2000-2019 are recalculated using 5AR and estimation 2020-2022 is calculated using 5AR • Changes of AD of ammonia and urea production in 2010-2019 • Changes of EF related to natural gas
Agricultu re	Enteric Fermentation	3.A	consumption for feedstock and fuels in ammonia plant and carbon content • Changes of methods for estimating GHG emissions from Tier 1 to higher Tier 2 leads to recalculate the emissions 2000-2019 using Tier 2 and to calculate emissions 2020-2022 using Tier 2. The 3 rd BUR still use Tier1 with default value of IPCC Recalculation of the emission estimates for 2000 - 2019 was undertaken due to (a)

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Sector	Sub-sector	Category/ Chapter	Reason for Recalculation
			changes in the CS EFs derived using national parameters and defaults available in the 2016 IPCC software; (b) changes in the proportion of livestock species by age; (c) changes in the use of GWP from AR2 to AR5
		Chapter 5.2	
	Manure Management	3.B	Recalculation of the emission estimates for 2000 - 2019 was undertaken due to (a) changes in the CS EFs derived using national parameters and defaults available in the 2016 IPCC software; (b) changes in the proportion of livestock species by age; (c) changes in the use of GWP from AR2 to AR5
		Chapter 5.2	
	Rice Cultivation	5.3 3.C	Recalculation of the emission estimates for 2000 - 2019 was undertaken due to (a) changes in the amount of manure applied to rice cultivation; (b) changes in the amount of crop residues returned to rice soils; (c) changes in the national level emission estimates previously calculated at the provincial level; and (d) changes in the use of GWP from AR2 to AR5
		Chapter 5.4	
	Agricultural Soils	3.D	Recalculation of the emission estimates for 2000 - 2019 was undertaken due to (a) changes in the AD for N fertilizer amount due to the availability of additional N fertilizer data for large plantations; (b) changes in the assumption of the amount of N in manure following Equation 11.4, Chapter 11, Volume 4, 2006 IPCC Guidelines; (c) the addition of urine and dung emission sources; (d) availability in the 2016 IPCC software, and changes in the use of GWP from AR2 to AR5
		Chapter 5.5	
	Controlled Burning of Grassland	3.E	Recalculation of the emission estimates for 2000 - 2019 was undertaken due to (a) changes in the AD on grassland fire area sourced from the interpretation of Landsat satellite imagery; (b) changes in the national level emission estimates previously calculated at the provincial level; and (c) changes in the use of GWP from AR2 to AR5
		Chapter 5.6	ges in the tip of one in hom the to the

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Sector	Sub-sector	Category/ Chapter	Reason for Recalculation
	Agricultural Residue Burning	3.F	Recalculation of the emission estimates for 2000 - 2019 was undertaken due to (a) changes in the AD on rice field fire area sourced from the interpretation of Landsat satellite imagery; (b) changes in the national level emission estimates previously calculated at the provincial level; and (c) changes in the use of GWP from AR2 to AR5
		Chapter 5.7	
	Liming	3.G	Recalculation of the emission estimates for 2000 - 2019 was undertaken due to changes in the use of GWP from AR2 to AR5
	Urea Application	Bab 5.7 3.H Chapter	Recalculation of the emission estimates for 2000 - 2019 was undertaken due to (a) changes in the AD for N fertilizer amount due to the availability of additional N fertilizer data for large plantations; and (b) changes in the use of GWP from AR2 to AR5
		5.7	
LULUCF	Forest Land	4.A	• Improvement of the EF (Gw) data from natural forests for primary and secondary forests. • Difference in the EF value from peat decomposition (drained peat) where BUR3 used the IPCC default value, while BTR1 used the CS (Novita et al. 2021). • Difference in the EF value of the Ratio of below-ground biomass to above-ground biomass. • Differences in peatland area have changed between that used in BUR3 of (6.9-9.3) and in BTR1 (6.7-8.7) million hectares. This change is due to the availability of the latest updated data. • Differences in the mineral land area used between BUR3 of (86.4-100.9) and BTR1 (86.9-95.5) million hectares. Where the area data in BTR1 has used the latest administrative boundaries that have been applied to all land uses. • CO ₂ emissions from peat decomposition and peat fires in forested land become part of the emissions from the forested land category. • Change in the use of GWP from AR2 (BUR3) to AR5 (BTR1).
	Cropland	4.B	 Improvement of EF data in the Third Biennial Update Report (BUR3) using stock loss values, while the First Biennial Transparency Report (BTR1) used the Fraction of biomass loss (fd) approach. Difference in EF values for peat decomposition (drained peat), where BUR3

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Sector	Sub-sector	Category/ Chapter	Reason for Recalculation
			used the IPCC default value, while BTR1 used a country-specific value (Novita et al. 2021). • Difference in EF values for the Ratio of below-ground biomass to above-ground biomass. • Change in peatland area used, with BUR3 reporting (2.0-4.3) million hectares and BTR1 reporting (1.5-3.6) million hectares. This change is due to the availability of updated data. • Difference in mineral land area used, with BUR3 reporting (47.7-59.5) million hectares and BTR1 reporting (48.0-60.3) million hectares. The land area data in BTR1 now uses the latest administrative boundaries applied across all land-use categories. • CO ₂ emissions from peat decomposition and peat fires in cropland are now included in the cropland emissions category. • Change in the use of GWP from 2AR (BUR3) to 5AR (BTR1).
	Grassland	4.C	 Improvement of EF data in BUR3 using stock loss values, while BTR1 used the Fraction of biomass loss (fd) approach. Difference in EF values for peat decomposition (drained peat), where BUR3 used the IPCC default value, while BTR1 used a country-specific value (Novita et al. 2021). Difference in EF values for the Ratio of below-ground biomass to above-ground biomass. Change in peatland area used, with BUR3 reporting (2.1-3.6) million hectares and BTR1 reporting (2.1-3.0) million hectares. This change is due to the availability of updated data. Difference in mineral land area used, with BUR3 reporting (17.3-25.1) million hectares and BTR1 reporting (17.3-24.5) million hectares. The land area data in BTR1 now uses the latest administrative boundaries applied across all land-use categories. CO₂ emissions from peat decomposition and peat fires in grassland are now included in the grassland emissions category. Change in the use of GWP from 2AR (BUR3) to 5AR (BTR1).

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Sector	Sub-sector	Category/ Chapter	Reason for Recalculation
	Settlements	4.E	 Difference in EF values for peat decomposition (drained peat), where BUR3 used the IPCC default value, while BTR1 used a country-specific value (Novita et al. 2021). Difference in EF values for the Ratio of below-ground biomass to above-ground biomass. Change in peatland area used, with BUR3 reporting (0.04-0.07) million hectares and BTR1 reporting (0.02-0.05) million hectares. This change is due to the availability of updated data. Difference in mineral land area used, with BUR3 reporting (2.3-4.5) million hectares and BTR1 reporting (2.4-4.4) million hectares. The land area data in BTR1 now uses the latest administrative boundaries applied across all land-use categories. CO₂ emissions from peat decomposition and peat fires in settlements are now included in the settlements emissions category. Change in the use of GWP from 2AR (BUR3) to 5AR (BTR1).
	Other Land	4.F	 Difference in EF values for peat decomposition (drained peat), where BUR3 used the IPCC default value, while BTR1 used a country-specific value (Novita et al. 2021). Difference in EF values for the Ratio of below-ground biomass to above-ground biomass. Change in peatland area used, with BUR3 reporting (0.1-1.2) million hectares and BTR1 reporting (0.1-1.2) million hectares. This change is due to the availability of updated data. Difference in mineral land area used, with BUR3 reporting (2.0-4.4) million hectares and BTR1 reporting (2.0-4.5) million hectares. The land area data in BTR1 now uses the latest administrative boundaries applied across all land-use categories. CO₂ emissions from peat decomposition and peat fires in settlements are now included in the settlements emissions category. Change in the use of GWP from 2AR (BUR3) to 5AR (BTR1).
Waste	Unmanaged SWDS (Unmanaged Landfills)	5 A 2	Reasons for recalculation of GHG emission estimates:

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Sector	Sub-sector	Category/ Chapter	Reason for Recalculation
I	Domestic Wastewater		 Change in GWP from 2AR to 5AR requires the GHG estimation for 2000-2022 to be recalculated using GWP 5AR. Updates of MSW data dumped in SWDS assumed unmanaged landfill) during 2000-2022, using data from the National Waste Management Information System (SIPSN, 2019-2022) and extrapolation (2000-2018). SIPSN is an improved version of the APDIPURA database, which provides data on MSW treatment is landfills and other facilities (composting, recycling, etc.). ADIPURA is an award for cities in Indonesia that have succeede in cleanliness and urban environmental management. Previous GHG emissions inventory for 2000-2022 was calculated based on the National Policy and Strategy (JAKSTRANAS) on Waste Management where the amount of MSW dumped in landfills was the difference between the amount of MSW generated (referred to it JAKSTRANAS) and MSW handled

9.2. Implications on Emission Levels and Removals

The modifications in AD, EFs, methodologies, the incorporation of new emission sources, the addition of new carbon pools, and the expansion of emission sub-categories, as outlined in subsection 10.1, have influenced the estimates of GHG emissions and removals following the 2013 Supplement to the 2006 IPCC Guidelines for the LULUCF sector.

Table 9-2 displays the revised estimates for the prior GHGI reports across all categories from 2000 to 2019, while Figure 9 - 1 and 9 - 2 depicts the differences in BUR3 and BTR1 emission trends with and without LULUCF for the period 2000 - 2019. The two figures below indicate a significant variation in emissions between NGHGI in BTR1 and BUR3, especially when the LULUCF sector is included, with an average difference exceeding 45%. On the other hand, excluding LULUCF sector from GHGI results in a lower average difference in emissions, specifically less than 5%.

Table 9-2 Comparison of emissions between BUR3 and BTR1

Sector	NGHGI Report	2000	2005	2010	2015	2019
Energy	Submission 2021 BUR3, kt CO ₂ e	317,609.08	376,988.05	434,715.47	527,102.76	636,452.69
	Submission 2024 BTR1, kt CO ₂ e	305,290.56	377,182.69	454,958.50	549,955.87	655,567.89
	Difference, kt CO2e	-12,318.52	194.64	20,243.03	22,853.11	19,115.20

Sector	NGHGI Report	2000	2005	2010	2015	2019
	Difference, %	-3.88	0.05	4.66	4.34	3.00
	Submission 2021 BUR3, kt CO ₂ e	42,920.09	42,349.20	35,731.89	48,744.82	58,173.48
IPPU	Submission 2024 BTR1, kt CO ₂ e	39,804.94	39,017.26	31,550.31	47,847.23	58,681.57
	Difference, kt CO ₂ e	-3,115.15	-3,331.94	-4,181.58	-897.59	508.09
	Difference, %	-7.26	-7.87	-11.70	-1.84	0.87
Agriculture	Submission 2021 BUR3, kt CO ₂ e	84,537.46	87,410.58	96,955.06	100,684.66	105,300.85
	Submission 2024 BTR1, kt CO ₂ e	107,188.93	110,131.56	108,081.76	128,045.26	126,675.16
	Difference, kt CO ₂ e	22,651.47	22,720.98	11,126.70	27,360.60	21,374.31
	Difference, %	26.79	25.99	11.48	27.17	20.30
	Submission 2021 BUR3, kt CO ₂ e	601,229.14	253,535.55	139,611.94	1,358,580.12	709,181.79
LULUCF	Submission 2024 BTR1, kt CO ₂ e	342,991.31	709,681.07	529,522.17	1,730,275.90	818,653.99
	Difference, kt CO ₂ e	-258,237.83	456,145.52	389,910.23	371,695.78	109,472.20
	Difference, %	-42.95	179.91	279.28	27.36	15.44
	Submission 2021 BUR3, kt CO ₂ e	62,190.74	72,870.89	87,766.10	97,539.33	120,333.20
Waste	Submission 2024 BTR1, kt CO ₂ e	59,227.57	71,102.81	88,657.23	99,694.68	128,107.25
	Difference, kt CO ₂ e	-2,963.17	-1,768.08	891.13	2,155.35	7,774.05
	Difference, %	-4.76	-2.43	1.02	2.21	6.46

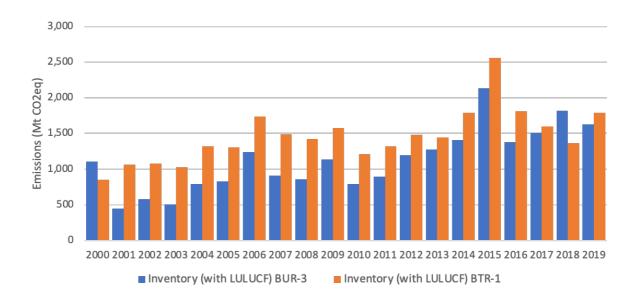


Figure 9 - 1 Comparation of emissions trends between BUR3 and BTR1 with LULUCF

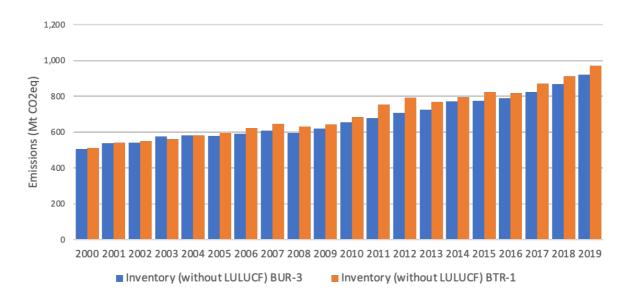


Figure 9 - 2 Comparation of emissions trends between BUR3 and BTR1 without LULUCF



ANNEX 1: KEY CATEGORIES

This section outlines the methodology employed to identify the principal categories within the NGHGI. Key categories refer to those classifications in the national inventory that substantially affect the overall national GHG emissions, either through the total emissions volume or their impact on emission trends over time, or both.

The key category assessment utilizes a Tier 1 level assessment and a Tier 1 trend assessment, as outlined in Chapter 4 of the 2006 IPCC Guidelines. The level assessment examines key categories for one reporting year, whereas the trend assessment analyses key categories over a two-year reporting period. When inventory data spans multiple years, it is advisable to assess the contribution of each category to both the level and trend of the national inventory.

In the national context, the level assessment utilizes the 2022 inventory data, whereas the trend assessment is conducted from the base year 2000 to the current year 2022. The primary categories are those that, when arranged in descending order of magnitude, collectively represent 95% of the total level assessment.

Level Assessment

The level assessment seeks to determine the source categories accountable for 95% of total national emissions in the base year. The total national inventory is derived from the contribution of each source or sink category, as outlined in Equation 4.1 of Chapter 4, Volume 1 of the 2006 IPCC Guidelines.

Trend Assessment

The trend assessment aims to identify categories that may be too small to be recognized through the level assessment, yet exhibit trends that significantly diverge from the overall inventory trend, thus necessitating special attention. The trend assessment is determined using Equation 4.2 from Chapter 4 of Volume 1 of the 2006 IPCC Guidelines.

Tables A1-1 to A1-4 provide a comprehensive list of all sub-categories included in the Tier 1 key category analysis for level assessment, whereas Tables A1-5 and A1-6 illustrate the Tier 1 KCA for trend assessment.

When considering the LULUCF sector, 19 and 17 sources and sinks were identified as key categories based on level assessment for years 2000 and 2022, respectively. Conversely, in the case of without LULUCF sector, 15 sources and sinks were identified as the key categories for year 2000, while 14 were identified for the year 2022.

The top 5 key categories based on the 2022 level assessment of emissions/removals are: 4.B.1. cropland remaining cropland; 1.A.1. energy industries; 4.A.1. FL remaining FL; 1.A.2. manufacturing industries and construction; and 1.A.3. transport. Conversely, in the case of the



LULUCF sector excluded, the top 5 key categories are: 1.A.1. energy industries; 1.A.2. manufacturing industries and construction; 1.A.3. transport; 5.D. wastewater treatment and discharge; and 3.C. rice cultivation.

Additionally, the trend assessment of emissions and removals from 2000 to 2022 identifies the top five key categories as follows: 4.B.1. cropland remaining cropland; 4.A.1. FL remaining FL; 1.A.1. energy industries; 1.A.2. manufacturing industries and construction; and 4.B.2. land converted to cropland. If LULUCF categories are excluded, the top 5 key categories are: 1.A.1. energy industries; 1.A.2. manufacturing industries and construction; 3.C. rice cultivation; 1.B.2. oil and natural gas and other emissions from energy production; and 1.A.4. other sectors.

Table A1 - 1 Tier 1 Key Category Assessment: 2000 Level Assessment with LULUCF

IPCC Category	GHG	Emissions and Removals Year in 2000 (kt CO ₂ e)	Absolute of Emissions and Removals in Year 2000 (kt CO ₂ e)	Level Assessment (%)	Cumulative Total (%)
		$\mathbf{E}_{\mathbf{x},\mathbf{t}}$	$ \mathbf{E}_{\mathbf{x},\mathbf{t}} $	$\mathbf{L}_{\mathbf{x},\mathbf{t}}$	
4.B.1. Cropland remaining cropland	CO ₂	355,297.66	355,297.66	27.61	27.61
4.A.1. Forest land remaining forest land	CO ₂	-209,511.58	209,511.58	16.28	43.89
1.A.1. Energy industries	CO ₂	83,784.19	83,784.19	6.51	50.40
1.A.2. Manufacturing industries and construction	CO ₂	71,664.82	71,664.82	5.57	55.97
4.B.2. Land converted to cropland	CO ₂	65,282.48	65,282.48	5.07	61.04
4.C.1. Grassland remaining grassland	CO ₂	60,689.15	60,689.15	4.72	65.75
1.A.3. Transport	CO ₂	57,641.71	57,641.71	4.48	70.23
4.C.2. Land converted to grassland	CO ₂	50,434.52	50,434.52	3.92	74.15
3.C. Rice cultivation	CH ₄	46,243.01	46,243.01	3.59	77.74
5.D. Wastewater treatment and discharge	CH ₄	40,998.02	40,998.02	3.19	80.93
1.A.4. Other sectors	CO ₂	38,737.04	38,737.04	3.01	83.94
1.B.2. Oil and natural gas and other emissions from energy production	CH ₄	30,489.99	30,489.99	2.37	86.31
2.A. Mineral industry	CO ₂	28,523.25	28,523.25	2.22	88.52
3.A. Enteric fermentation	CH ₄	25,480.92	25,480.92	1.98	90.50
3.D.1. Direct N ₂ O emissions from managed soils	N ₂ O	16,686.40	16,686.40	1.30	91.80
4.F.2. Land converted to other land	CO ₂	15,498.35	15,498.35	1.20	93.01
5.A. Solid waste disposal (6)	CH ₄	11,555.21	11,555.21	0.90	93.90
1.A.4. Other sectors	CH ₄	10,514.00	10,514.00	0.82	94.72

IPCC Category	GHG	Emissions and Removals Year in 2000 (kt CO ₂ e)	Absolute of Emissions and Removals in Year 2000 (kt CO ₂ e)	Level Assessment (%)	Cumulative Total (%)
		$\mathbf{E}_{\mathbf{x},\mathbf{t}}$	$ \mathbf{E}_{\mathbf{x},\mathbf{t}} $	$\mathbf{L}_{\mathbf{x},\mathbf{t}}$	
3.B. Manure management	N_2O	8,136.27	8,136.27	0.63	95.35
1.B.2. Oil and natural gas and other emissions from energy production	CO ₂	8,088.01	8,088.01	0.63	95.98
2.B. Chemical industry	CO ₂	7,989.16	7,989.16	0.62	96.60
4.A.2. Land converted to forest land	CO ₂	-6,866.96	6,866.96	0.53	97.14
4.A.1. Forest land remaining forest land	N ₂ O	6,121.43	6,121.43	0.48	97.61
3.D.2. Indirect N ₂ O Emissions from managed soils	N ₂ O	4,435.23	4,435.23	0.34	97.96
3.H. Urea application	CO ₂	3,435.33	3,435.33	0.27	98.22
4.B.1. Cropland remaining cropland	CH ₄	2,199.66	2,199.66	0.17	98.39
2.C. Metal industry	CO ₂	1,828.43	1,828.43	0.14	98.54
5.C. Incineration and open burning of waste (6)	CO ₂	1,769.48	1,769.48	0.14	98.67
5.D. Wastewater treatment and discharge	N ₂ O	1,678.46	1,678.46	0.13	98.80
3.B. Manure management	CH ₄	1,663.83	1,663.83	0.13	98.93
4.A.1. Forest land remaining forest land	CH ₄	1,526.52	1,526.52	0.12	99.05
5.C. Incineration and open burning of waste (6)	CH ₄	1,500.16	1,500.16	0.12	99.17
1.A.4. Other sectors	N ₂ O	1,393.92	1,393.92	0.11	99.28
5.E. Other (6)	CH ₄	1,274.09	1,274.09	0.10	99.38
4.C.1. Grassland remaining grassland	CH ₄	1,058.06	1,058.06	0.08	99.46
2.D. Non-energy products from fuels and solvent use	CO ₂	831.33	831.33	0.06	99.52
3.G. Liming	CO ₂	791.63	791.63	0.06	99.58
1.A.3. Transport	N ₂ O	790.59	790.59	0.06	99.65

IPCC Category	GНG	Emissions and Removals Year in 2000 (kt CO ₂ e)	Absolute of Emissions and Removals in Year 2000 (kt CO ₂ e)	Level Assessment (%)	Cumulative Total
		$\mathbf{E}_{\mathbf{x},\mathbf{t}}$	$ \mathbf{E}_{\mathbf{x},\mathbf{t}} $	$\mathbf{L}_{\mathbf{x},\mathbf{t}}$	
4.E.2. Land converted to settlements	CO ₂	746.07	746.07	0.06	99.70
1.B.1. Solid fuels	CH ₄	578.11	578.11	0.04	99.75
1.A.2. Manufacturing industries and construction	N ₂ O	537.65	537.65	0.04	99.79
1.A.3. Transport	CH ₄	418.92	418.92	0.03	99.82
1.A.2. Manufacturing industries and construction	CH ₄	399.24	399.24	0.03	99.85
4.C.1. Grassland remaining grassland	N ₂ O	365.44	365.44	0.03	99.88
5.E. Other (6)	N ₂ O	278.27	278.27	0.02	99.90
3.E. Prescribed burning of savannahs	CH ₄	195.10	195.10	0.02	99.92
1.A.1. Energy industries	N ₂ O	190.07	190.07	0.01	99.93
5.C. Incineration and open burning of waste (6)	N ₂ O	173.84	173.84	0.01	99.95
4.B.1. Cropland remaining cropland	N ₂ O	149.56	149.56	0.01	99.96
2.B. Chemical industry	N ₂ O	127.59	127.59	0.01	99.97
3.E. Prescribed burning of savannahs	N ₂ O	118.51	118.51	0.01	99.98
2.B. Chemical industry	CH ₄	93.75	93.75	0.01	99.98
2.H. Other (4)	CO ₂	92.25	92.25	0.01	99.99
1.A.1. Energy industries	CH ₄	46.42	46.42	0.00	100.00
2.C. Metal industry	CH ₄	37.96	37.96	0.00	100.00
1.B.2. Oil and natural gas and other emissions from energy production	N ₂ O	15.88	15.88	0.00	100.00
3.F. Field burning of agricultural residues	CH ₄	1.45	1.45	0.00	100.00
3.F. Field burning of agricultural residues	N ₂ O	1.25	1.25	0.00	100.00

IPCC Category	GHG	Emissions and Removals Year in 2000 (kt CO ₂ e)	Absolute of Emissions and Removals in Year 2000 (kt CO ₂ e)	Level Assessment (%)	Cumulative Total (%)
4.D.1. Wetlands remaining wetlands	CH4	0.98	0.98	0.00	100.00
5.B. Biological treatment of solid waste	N ₂ O	0.04	0.04	0.00	100.00
4.D.2. Land converted to wetlands	CO_2	-0.04	0.04	0.00	100.00
5.B. Biological treatment of solid waste	CH ₄	0.00	0.00	0.00	100.00
Total		854,222.08	1,286,979.23	100.00	

Table A1 - 2 Tier 1 Key Category Assessment: 2000 Level Assessment without LULUCF

IPCC Category	GHG	Emissions and Removals Year in 2000 (kt CO ₂ e)	Absolute of Emissions and Removals in Year 2000 (kt CO ₂ e)	Level Assessment (%)	Cumulative Total (%)
		$\mathbf{E}_{\mathbf{x},\mathbf{t}}$	$ \mathbf{E}_{\mathbf{x},\mathbf{t}} $	$\mathbf{L}_{\mathbf{x},\mathbf{t}}$	
1.A.1. Energy industries	CO ₂	83,784.19	83,784.19	16.39	16.39
1.A.2. Manufacturing industries and construction	CO ₂	71,664.82	71,664.82	14.02	30.41
1.A.3. Transport	CO ₂	57,641.71	57,641.71	11.28	41.68
3.C. Rice cultivation	CH ₄	46,243.01	46,243.01	9.05	50.73
5.D. Wastewater treatment and discharge	CH ₄	40,998.02	40,998.02	8.02	58.75
1.A.4. Other sectors	CO_2	38,737.04	38,737.04	7.58	66.32
1.B.2. Oil and natural gas and other emissions from energy production	CH ₄	30,489.99	30,489.99	5.96	72.29
2.A. Mineral industry	CO ₂	28,523.25	28,523.25	5.58	77.87
3.A. Enteric fermentation	CH ₄	25,480.92	25,480.92	4.98	82.85
3.D.1. Direct N ₂ O emissions from managed soils	N ₂ O	16,686.40	16,686.40	3.26	86.12
5.A. Solid waste disposal (6)	CH ₄	11,555.21	11,555.21	2.26	88.38
1.A.4. Other sectors	CH ₄	10,514.00	10,514.00	2.06	90.43
3.B. Manure management	N ₂ O	8,136.27	8,136.27	1.59	92.02
1.B.2. Oil and natural gas and other emissions from energy production	CO ₂	8,088.01	8,088.01	1.58	93.61
2.B. Chemical industry	CO ₂	7,989.16	7,989.16	1.56	95.17
3.D.2. Indirect N ₂ O Emissions from managed soils	N ₂ O	4,435.23	4,435.23	0.87	96.04
3.H. Urea application	CO ₂	3,435.33	3,435.33	0.67	96.71
2.C. Metal industry	CO ₂	1,828.43	1,828.43	0.36	97.07

IPCC Category	GHG	Emissions and Removals Year in 2000 (kt CO ₂ e)	Absolute of Emissions and Removals in Year 2000 (kt CO ₂ e)	Level Assessment (%)	Cumulative Total (%)
		$\mathbf{E}_{\mathbf{x,t}}$	$ \mathbf{E}_{\mathbf{x},\mathbf{t}} $	$L_{x,t}$	
5.C. Incineration and open burning of waste (6)	CO ₂	1,769.48	1,769.48	0.35	97.41
5.D. Wastewater treatment and discharge	N ₂ O	1,678.46	1,678.46	0.33	97.74
3.B. Manure management	CH ₄	1,663.83	1,663.83	0.33	98.07
5.C. Incineration and open burning of waste (6)	CH ₄	1,500.16	1,500.16	0.29	98.36
1.A.4. Other sectors	N ₂ O	1,393.92	1,393.92	0.27	98.63
5.E. Other (6)	CH ₄	1,274.09	1,274.09	0.25	98.88
2.D. Non-energy products from fuels and solvent use	CO_2	831.33	831.33	0.16	99.04
3.G. Liming	CO_2	791.63	791.63	0.15	99.20
1.A.3. Transport	N ₂ O	790.59	790.59	0.15	99.35
1.B.1. Solid fuels	CH ₄	578.11	578.11	0.11	99.47
1.A.2. Manufacturing industries and construction	N_2O	537.65	537.65	0.11	99.57
1.A.3. Transport	CH ₄	418.92	418.92	0.08	99.65
1.A.2. Manufacturing industries and construction	CH ₄	399.24	399.24	0.08	99.73
5.E. Other (6)	N ₂ O	278.27	278.27	0.05	99.79
3.E. Prescribed burning of savannahs	CH ₄	195.10	195.10	0.04	99.82
1.A.1. Energy industries	N_2O	190.07	190.07	0.04	99.86
5.C. Incineration and open burning of waste (6)	N ₂ O	173.84	173.84	0.03	99.90
2.B. Chemical industry	N_2O	127.59	127.59	0.02	99.92
3.E. Prescribed burning of savannahs	N_2O	118.51	118.51	0.02	99.94
2.B. Chemical industry	CH ₄	93.75	93.75	0.02	99.96

IPCC Category	GHG	Emissions and Removals Year in 2000 (kt CO ₂ e)	Absolute of Emissions and Removals in Year 2000 (kt CO ₂ e)	Level Assessment (%)	Cumulative Total (%)
2.H. Other (4)	CO ₂	92.25	92.25	0.02	99.98
1.A.1. Energy industries	CH ₄	46.42	46.42	0.01	99.99
2.C. Metal industry	CH ₄	37.96	37.96	0.01	100.00
1.B.2. Oil and natural gas and other emissions from energy production	N ₂ O	15.88	15.88	0.00	100.00
3.F. Field burning of agricultural residues	CH ₄	1.45	1.45	0.00	100.00
3.F. Field burning of agricultural residues	N ₂ O	1.25	1.25	0.00	100.00
5.B. Biological treatment of solid waste	N ₂ O	0.04	0.04	0.00	100.00
5.B. Biological treatment of solid waste	CH ₄	0.00	0.00	0.00	100.00
Total		511,230.77	511,230.77	100.00	

Table A1 - 3 Tier 1 Key Category Assessment: 2022 Level Assessment with LULUCF

IPCC Category	GНG	Emissions and Removals Year in 2000 (kt CO ₂ e)	Absolute of Emissions and Removals in Year 2000 (kt CO ₂ e)	Level Assessment (%)	Cumulative Total (%)
		$\mathbf{E}_{\mathbf{x},\mathbf{t}}$	$ \mathbf{E}_{\mathbf{x},\mathbf{t}} $	$L_{x,t}$	
4.B.1. Cropland remaining cropland	CO ₂	364,677.31	364,677.31	18.92	18.92
1.A.1. Energy industries	CO ₂	314,393.28	314,393.28	16.31	35.23
4.A.1. Forest land remaining forest land	CO ₂	-262,231.05	262,231.05	13.61	48.84
1.A.2. Manufacturing industries and construction	CO ₂	204,612.78	204,612.78	10.62	59.46
1.A.3. Transport	CO ₂	154,955.56	154,955.56	8.04	67.49
5.D. Wastewater treatment and discharge	CH ₄	109,423.80	109,423.80	5.68	73.17
4.C.1. Grassland remaining grassland	CO ₂	91,638.95	91,638.95	4.75	77.93
4.F.2. Land converted to other land	CO ₂	64,283.00	64,283.00	3.34	81.26
4.B.2. Land converted to cropland	CO ₂	47,581.58	47,581.58	2.47	83.73
3.C. Rice cultivation	CH ₄	46,841.59	46,841.59	2.43	86.16
3.A. Enteric fermentation	CH ₄	36,720.88	36,720.88	1.91	88.07
1.A.4. Other sectors	CO ₂	33,759.49	33,759.49	1.75	89.82
2.A. Mineral industry	CO ₂	31,480.03	31,480.03	1.63	91.45
3.D.1. Direct N ₂ O emissions from managed soils	N ₂ O	24,317.43	24,317.43	1.26	92.71
5.A. Solid waste disposal (6)	CH ₄	21,724.54	21,724.54	1.13	93.84
1.B.2. Oil and natural gas and other emissions from energy production	CH4	14,406.42	14,406.42	0.75	94.59

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IPCC Category	GНG	Emissions and Removals Year in 2000 (kt CO ₂ e)	Absolute of Emissions and Removals in Year 2000 (kt CO ₂ e)	Level Assessment (%)	Cumulative Total (%)
		$\mathbf{E}_{\mathbf{x},\mathbf{t}}$	$ \mathbf{E}_{\mathbf{x},\mathbf{t}} $	$L_{x,t}$	
3.B. Manure management	N ₂ O	12,962.28	12,962.28	0.67	95.26
2.C. Metal industry	CO ₂	10,981.37	10,981.37	0.57	95.83
2.B. Chemical industry	CO_2	9,366.80	9,366.80	0.49	96.32
3.D.2. Indirect N ₂ O Emissions from managed soils	N ₂ O	5,828.66	5,828.66	0.30	96.62
4.B.1. Cropland remaining cropland	CH ₄	5,585.53	5,585.53	0.29	96.91
4.C.2. Land converted to grassland	CO ₂	-5,539.89	5,539.89	0.29	97.20
4.A.1. Forest land remaining forest land	N ₂ O	5,018.35	5,018.35	0.26	97.46
1.B.2. Oil and natural gas and other emissions from energy production	CO ₂	4,650.71	4,650.71	0.24	97.70
4.A.2. Land converted to forest land	CO ₂	-4,510.48	4,510.48	0.23	97.93
2.D. Non-energy products from fuels and solvent use	CO ₂	4,358.07	4,358.07	0.23	98.16
1.B.1. Solid fuels	CH ₄	4,243.97	4,243.97	0.22	98.38
3.H. Urea application	CO ₂	4,047.21	4,047.21	0.21	98.59
5.D. Wastewater treatment and discharge	N ₂ O	2,868.82	2,868.82	0.15	98.74
3.B. Manure management	CH ₄	2,530.56	2,530.56	0.13	98.87
5.C. Incineration and open burning of waste (6)	CO ₂	2,381.81	2,381.81	0.12	98.99
4.A.1. Forest land remaining forest land	CH ₄	2,371.39	2,371.39	0.12	99.11
3.G. Liming	CO ₂	2,159.22	2,159.22	0.11	99.23

IPCC Category	GНG	Emissions and Removals Year in 2000 (kt CO ₂ e)	Absolute of Emissions and Removals in Year 2000 (kt CO ₂ e)	Level Assessment (%)	Cumulative Total (%)
		$\mathbf{E}_{\mathbf{x},\mathbf{t}}$	$ \mathbf{E}_{\mathbf{x},\mathbf{t}} $	$\mathbf{L}_{\mathbf{x},\mathbf{t}}$	
1.A.3. Transport	N ₂ O	2,128.74	2,128.74	0.11	99.34
5.C. Incineration and open burning of waste (6)	CH ₄	2,019.29	2,019.29	0.10	99.44
4.E.2. Land converted to settlements	CO ₂	1,994.71	1,994.71	0.10	99.55
1.A.3. Transport	CH ₄	1,255.10	1,255.10	0.07	99.61
1.A.2. Manufacturing industries and construction	N ₂ O	1,103.20	1,103.20	0.06	99.67
1.A.1. Energy industries	N ₂ O	1,090.08	1,090.08	0.06	99.72
4.C.1. Grassland remaining grassland	CH ₄	1,077.74	1,077.74	0.06	99.78
1.A.4. Other sectors	CH ₄	989.40	989.40	0.05	99.83
2.B. Chemical industry	N ₂ O	865.45	865.45	0.04	99.88
1.A.2. Manufacturing industries and construction	CH ₄	807.54	807.54	0.04	99.92
1.A.4. Other sectors	N ₂ O	238.50	238.50	0.01	99.93
5.C. Incineration and open burning of waste (6)	N ₂ O	233.99	233.99	0.01	99.94
4.C.1. Grassland remaining grassland	N ₂ O	186.74	186.74	0.01	99.95
5.E. Other (6)	CH ₄	172.25	172.25	0.01	99.96
4.B.1. Cropland remaining cropland	N ₂ O	156.45	156.45	0.01	99.97
2.H. Other (4)	CO ₂	151.46	151.46	0.01	99.98
1.A.1. Energy industries	CH ₄	111.07	111.07	0.01	99.98
3.E. Prescribed burning of savannahs	CH ₄	103.38	103.38	0.01	99.99

IPCC Category	GHG	Emissions and Removals Year in 2000 (kt CO2e) Ex,t	Absolute of Emissions and Removals in Year 2000 (kt CO ₂ e)	Level Assessment (%)	Cumulative Total (%)
2.B. Chemical industry	CH ₄	102.84	102.84	0.01	99.99
3.E. Prescribed burning of savannahs	N ₂ O	52.81	52.81	0.00	100.00
5.B. Biological treatment of solid waste	N ₂ O	34.06	34.06	0.00	100.00
4.D.1. Wetlands remaining wetlands	CH ₄	19.60	19.60	0.00	100.00
1.B.2. Oil and natural gas and other emissions from energy production	N ₂ O	7.56	7.56	0.00	100.00
5.B. Biological treatment of solid waste	CH ₄	2.09	2.09	0.00	100.00
4.D.2. Land converted to wetlands	CO ₂	1.66	1.66	0.00	100.00
5.E. Other (6)	CO ₂	1.43	1.43	0.00	100.00
3.F. Field burning of agricultural residues	CH ₄	0.98	0.98	0.00	100.00
3.F. Field burning of agricultural residues	N ₂ O	0.85	0.85	0.00	100.00
Total		1,382,798.90	1,927,361.75	100.00	

Table A1 - 4 Tier 1 Key Category Assessment: 2022 Level Assessment without LULUCF

IPCC Category	GHG	Emissions and Removals Year in 2022 (kt CO ₂ e)	Absolut of Emissions and Removals in Year 2022 (kt CO ₂ e)	Level Assessment (%)	Cumulative Total
		$\mathbf{E}_{\mathbf{x},\mathbf{t}}$	$ \mathbf{E}_{\mathbf{x},\mathbf{t}} $	$L_{x,t}$	
1.A.1. Energy industries	CO_2	314,393.28	314,393.28	29.37	29.37
1.A.2. Manufacturing industries and construction	CO ₂	204,612.78	204,612.78	19.11	48.48
1.A.3. Transport	CO ₂	154,955.56	154,955.56	14.48	62.96
5.D. Wastewater treatment and discharge	CH ₄	109,423.80	109,423.80	10.22	73.18
3.C. Rice cultivation	CH ₄	46,841.59	46,841.59	4.38	77.56
3.A. Enteric fermentation	CH ₄	36,720.88	36,720.88	3.43	80.99
1.A.4. Other sectors	CO ₂	33,759.49	33,759.49	3.15	84.14
2.A. Mineral industry	CO ₂	31,480.03	31,480.03	2.94	87.08
3.D.1. Direct N ₂ O emissions from managed soils	N ₂ O	24,317.43	24,317.43	2.27	89.35
5.A. Solid waste disposal (6)	CH ₄	21,724.54	21,724.54	2.03	91.38
1.B.2. Oil and natural gas and other emissions from energy production	CH4	14,406.42	14,406.42	1.35	92.73
3.B. Manure management	N ₂ O	12,962.28	12,962.28	1.21	93.94
2.C. Metal industry	CO ₂	10,981.37	10,981.37	1.03	94.96
2.B. Chemical industry	CO ₂	9,366.80	9,366.80	0.88	95.84
3.D.2. Indirect N ₂ O Emissions from managed soils	N ₂ O	5,828.66	5,828.66	0.54	96.38

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IPCC Category	GНG	Emissions and Removals Year in and Removals in Year 2022 (kt CO ₂ e) EHG Emissions and Removals in Year 2022 (kt CO ₂ e)		Level Assessment (%)	Cumulative Total
		$\mathbf{E}_{\mathbf{x},\mathbf{t}}$	$ \mathbf{E}_{\mathbf{x},\mathbf{t}} $	$L_{x,t}$	
1.B.2. Oil and natural gas and other emissions from energy production	CO ₂	4,650.71	4,650.71	0.43	96.82
2.D. Non-energy products from fuels and solvent use	CO ₂	4,358.07	4,358.07	0.41	97.23
1.B.1. Solid fuels	CH4	4,243.97	4,243.97	0.40	97.62
3.H. Urea application	CO ₂	4,047.21	4,047.21	0.38	98.00
5.D. Wastewater treatment and discharge	N ₂ O	2,868.82	2,868.82	0.27	98.27
3.B. Manure management	CH ₄	2,530.56	2,530.56	0.24	98.50
5.C. Incineration and open burning of waste (6)	CO ₂	2,381.81	2,381.81	0.22	98.73
3.G. Liming	CO ₂	2,159.22	2,159.22	0.20	98.93
1.A.3. Transport	N ₂ O	2,128.74	2,128.74	0.20	99.13
5.C. Incineration and open burning of waste (6)	CH ₄	2,019.29	2,019.29	0.19	99.32
1.A.3. Transport	CH ₄	1,255.10	1,255.10	0.12	99.43
1.A.2. Manufacturing industries and construction	N ₂ O	1,103.20	1,103.20	0.10	99.54
1.A.1. Energy industries	N ₂ O	1,090.08	1,090.08	0.10	99.64
1.A.4. Other sectors	CH ₄	989.40	989.40	0.09	99.73
2.B. Chemical industry	N ₂ O	865.45	865.45	0.08	99.81
1.A.2. Manufacturing industries and construction	CH4	807.54	807.54	0.08	99.89

IPCC Category	GНG	Emissions and Removals Year in 2022 (kt CO ₂ e)	Absolut of Emissions and Removals in Year 2022 (kt CO ₂ e)	Level Assessment (%)	Cumulative Total
		$\mathbf{E}_{\mathbf{x},t}$	$ \mathbf{E}_{\mathbf{x},\mathbf{t}} $	$L_{x,t}$	
1.A.4. Other sectors	N ₂ O	238.50	238.50	0.02	99.91
5.C. Incineration and open burning of waste (6)	N ₂ O	233.99	233.99	0.02	99.93
5.E. Other (6)	CH ₄	172.25	172.25	0.02	99.95
2.H. Other (4)	CO ₂	151.46	151.46	0.01	99.96
1.A.1. Energy industries	CH ₄	111.07	111.07	0.01	99.97
3.E. Prescribed burning of savannahs	CH ₄	103.38	103.38	0.01	99.98
2.B. Chemical industry	CH ₄	102.84	102.84	0.01	99.99
3.E. Prescribed burning of savannahs	N ₂ O	52.81	52.81	0.00	100.00
5.B. Biological treatment of solid waste	N ₂ O	34.06	34.06	0.00	100.00
1.B.2. Oil and natural gas and other emissions from energy production	N ₂ O	7.56	7.56	0.00	100.00
5.B. Biological treatment of solid waste	CH ₄	2.09	2.09	0.00	100.00
5.E. Other (6)	CO ₂	1.43	1.43	0.00	100.00
3.F. Field burning of agricultural residues	CH ₄	0.98	0.98	0.00	100.00
3.F. Field burning of agricultural residues	N ₂ O	0.85	0.85	0.00	100.00
Total		1,070,487.32	1,070,487.32	100.00	

Table A1 - 5 Tier1 Key Category Assessment: 2000-2022 Trend Assessment with LULUCF

IPCC Category	GHG	Base Year Estimate (2000), kt CO ₂ e	Latest Year Estimate (2022), kt CO ₂ e	Absolute of Base Year Estimate (2000), kt CO ₂ e	Trend Assessment	% Contribution to Trend	Cumulative Total, %
		$E_{x,0}$	Ex,t	Ex,0	Tx,t		
4.B.1. Cropland remaining cropland	CO_2	355,297.66	364,677.31	355,297.66	0.16	18.48	18.48
4.A.1. Forest land remaining forest land	CO ₂	-209,511.58	-262,231.05	209,511.58	0.14	16.01	34.49
1.A.1. Energy industries	CO_2	83,784.19	314,393.28	83,784.19	0.14	15.70	50.19
1.A.2. Manufacturing industries and construction	CO ₂	71,664.82	204,612.78	71,664.82	0.07	7.78	57.96
4.C.2. Land converted to grassland	CO ₂	50,434.52	-5,539.89	50,434.52	0.07	7.65	65.62
1.A.3. Transport	CO ₂	57,641.71	154,955.56	57,641.71	0.05	5.41	71.03
4.B.2. Land converted to cropland	CO ₂	65,282.48	47,581.58	65,282.48	0.05	5.10	76.13
5.D. Wastewater treatment and discharge	CH ₄	40,998.02	109,423.80	40,998.02	0.03	3.78	79.91
4.F.2. Land converted to other land	CO ₂	15,498.35	64,283.00	15,498.35	0.03	3.44	83.35
1.B.2. Oil and natural gas and other emissions from energy production	CH4	30,489.99	14,406.42	30,489.99	0.03	3.07	86.42
1.A.4. Other sectors	CO ₂	38,737.04	33,759.49	38,737.04	0.02	2.54	88.96
3.C. Rice cultivation	CH ₄	46,243.01	46,841.59	46,243.01	0.02	2.46	91.42
1.A.4. Other sectors	CH4	10,514.00	989.40	10,514.00	0.01	1.41	92.83
2.A. Mineral industry	CO ₂	28,523.25	31,480.03	28,523.25	0.01	1.29	94.12
1.B.2. Oil and natural gas and other emissions from energy production	CO ₂	8,088.01	4,650.71	8,088.01	0.01	0.74	94.86
2.C. Metal industry	CO ₂	1,828.43	10,981.37	1,828.43	0.01	0.70	95.57

IPCC Category	GHG	Base Year Estimate (2000), kt CO ₂ e	Latest Year Estimate (2022), kt CO ₂ e	Absolute of Base Year Estimate (2000), kt CO ₂ e	Trend Assessment	% Contribution to Trend	Cumulative Total, %
		$E_{x,0}$	Ex,t	Ex,0	Tx,t		
4.C.1. Grassland remaining grassland	CO ₂	60,689.15	91,638.95	60,689.15	0.01	0.58	96.15
4.A.1. Forest land remaining forest land	N ₂ O	6,121.43	5,018.35	6,121.43	0.00	0.43	96.58
3.A. Enteric fermentation	CH ₄	25,480.92	36,720.88	25,480.92	0.00	0.40	96.97
2.B. Chemical industry	CO ₂	7,989.16	9,366.80	7,989.16	0.00	0.31	97.29
1.B.1. Solid fuels	CH ₄	578.11	4,243.97	578.11	0.00	0.29	97.58
5.A. Solid waste disposal (6)	CH ₄	11,555.21	21,724.54	11,555.21	0.00	0.27	97.84
2.D. Non-energy products from fuels and solvent use	CO ₂	831.33	4,358.07	831.33	0.00	0.26	98.11
3.D.1. Direct N ₂ O emissions from managed soils	N ₂ O	16,686.40	24,317.43	16,686.40	0.00	0.24	98.34
4.B.1. Cropland remaining cropland	CH ₄	2,199.66	5,585.53	2,199.66	0.00	0.18	98.52
1.A.4. Other sectors	N ₂ O	1,393.92	238.50	1,393.92	0.00	0.18	98.70
4.A.2. Land converted to forest land	CO ₂	-6,866.96	-4,510.48	6,866.96	0.00	0.17	98.86
5.E. Other (6)	CH ₄	1,274.09	172.25	1,274.09	0.00	0.17	99.03
3.H. Urea application	CO ₂	3,435.33	4,047.21	3,435.33	0.00	0.13	99.16
3.D.2. Indirect N ₂ O Emissions from managed soils	N ₂ O	4,435.23	5,828.66	4,435.23	0.00	0.12	99.28
3.G. Liming	CO ₂	791.63	2,159.22	791.63	0.00	0.08	99.36
1.A.3. Transport	N ₂ O	790.59	2,128.74	790.59	0.00	0.07	99.43
4.E.2. Land converted to settlements	CO ₂	746.07	1,994.71	746.07	0.00	0.07	99.50
1.A.1. Energy industries	N ₂ O	190.07	1,090.08	190.07	0.00	0.07	99.57

IPCC Category	GHG	Base Year Estimate (2000), kt CO ₂ e	Latest Year Estimate (2022), kt CO ₂ e	Absolute of Base Year Estimate (2000), kt CO ₂ e	Trend Assessment	% Contribution to Trend	Cumulative Total, %
		$E_{x,0}$	Ex,t	Ex,0	Tx,t		
2.B. Chemical industry	N ₂ O	127.59	865.45	127.59	0.00	0.06	99.63
4.C.1. Grassland remaining grassland	CH ₄	1,058.06	1,077.74	1,058.06	0.00	0.06	99.68
1.A.3. Transport	CH ₄	418.92	1,255.10	418.92	0.00	0.05	99.73
5.C. Incineration and open burning of waste (6)	CO ₂	1,769.48	2,381.81	1,769.48	0.00	0.04	99.78
5.C. Incineration and open burning of waste (6)	CH ₄	1,500.16	2,019.29	1,500.16	0.00	0.04	99.81
4.C.1. Grassland remaining grassland	N ₂ O	365.44	186.74	365.44	0.00	0.04	99.85
1.A.2. Manufacturing industries and construction	N ₂ O	537.65	1,103.20	537.65	0.00	0.02	99.87
3.E. Prescribed burning of savannahs	CH ₄	195.10	103.38	195.10	0.00	0.02	99.89
3.B. Manure management	N ₂ O	8,136.27	12,962.28	8,136.27	0.00	0.02	99.91
3.B. Manure management	CH ₄	1,663.83	2,530.56	1,663.83	0.00	0.01	99.92
1.A.2. Manufacturing industries and construction	CH ₄	399.24	807.54	399.24	0.00	0.01	99.93
5.D. Wastewater treatment and discharge	N ₂ O	1,678.46	2,868.82	1,678.46	0.00	0.01	99.95
3.E. Prescribed burning of savannahs	N ₂ O	118.51	52.81	118.51	0.00	0.01	99.96
4.A.1. Forest land remaining forest land	CH ₄	1,526.52	2,371.39	1,526.52	0.00	0.01	99.97
4.B.1. Cropland remaining cropland	N ₂ O	149.56	156.45	149.56	0.00	0.01	99.98
2.C. Metal industry	CH ₄	37.96	0.00	37.96	0.00	0.01	99.98

IPCC Category	GHG	Base Year Estimate (2000), kt CO ₂ e	Latest Year Estimate (2022), kt CO ₂ e	Absolute of Base Year Estimate (2000), kt CO ₂ e	Trend Assessment	% Contribution to Trend	Cumulative Total, %
		$E_{x,0}$	Ex,t	Ex,0	Tx,t		
2.B. Chemical industry	CH ₄	93.75	102.84	93.75	0.00	0.00	99.99
5.C. Incineration and open burning of waste (6)	N ₂ O	173.84	233.99	173.84	0.00	0.00	99.99
1.A.1. Energy industries	CH ₄	46.42	111.07	46.42	0.00	0.00	99.99
5.B. Biological treatment of solid waste	N ₂ O	0.04	34.06	0.04	0.00	0.00	100.00
1.B.2. Oil and natural gas and other emissions from energy production	N ₂ O	15.88	7.56	15.88	0.00	0.00	100.00
4.D.1. Wetlands remaining wetlands	CH ₄	0.98	19.60	0.98	0.00	0.00	100.00
2.H. Other (4)	CO ₂	92.25	151.46	92.25	0.00	0.00	100.00
5.B. Biological treatment of solid waste	CH ₄	0.00	2.09	0.00	0.00	0.00	100.00
4.D.2. Land converted to wetlands	CO ₂	-0.04	1.66	0.04	0.00	0.00	100.00
3.F. Field burning of agricultural residues	CH ₄	1.45	0.98	1.45	0.00	0.00	100.00
3.F. Field burning of agricultural residues	N ₂ O	1.25	0.85	1.25	0.00	0.00	100.00
5.E. Other (6)	CO ₂		1.43			0.00	100.00
5.E. Other (6)	N ₂ O	278.27		278.27		0.00	100.00
Total		854,222.08	1,382,798.90	1,286,979.23	0.89	100.00	

Table A1 - 6 Tier 1 Key Category Assessment: 2000-2022 Trend Assessment without LULUCF

IPCC category	GHG	Base Year Estimate (2000), kt CO ₂ e	Latest Year Estimate (2022), kt CO ₂ e	Absolute of Base Year Estimate (2000), kt CO ₂ e	Trend Assessment	% Contribution to Trend	Cumulative Total, %
		$E_{x,0}$	Ex,t	Ex,0	Tx,t		
1.A.1. Energy industries	CO_2	83,784.19	314,393.28	83,784.19	0.27	26.04	26.04
1.A.2. Manufacturing industries and construction	CO ₂	71,664.82	204,612.78	71,664.82	0.11	10.22	36.26
3.C. Rice cultivation	CH ₄	46,243.01	46,841.59	46,243.01	0.10	9.37	45.63
1.B.2. Oil and natural gas and other emissions from energy production	CH ₄	30,489.99	14,406.42	30,489.99	0.10	9.26	54.89
1.A.4. Other sectors	CO ₂	38,737.04	33,759.49	38,737.04	0.09	8.87	63.76
1.A.3. Transport	CO ₂	57,641.71	154,955.56	57,641.71	0.07	6.42	70.18
2.A. Mineral industry	CO ₂	28,523.25	31,480.03	28,523.25	0.06	5.29	75.47
5.D. Wastewater treatment and discharge	CH ₄	40,998.02	109,423.80	40,998.02	0.05	4.42	79.89
1.A.4. Other sectors	CH ₄	10,514.00	989.40	10,514.00	0.04	3.94	83.83
3.A. Enteric fermentation	CH ₄	25,480.92	36,720.88	25,480.92	0.03	3.12	86.95
1.B.2. Oil and natural gas and other emissions from energy production	CO ₂	8,088.01	4,650.71	8,088.01	0.02	2.30	89.25
3.D.1. Direct N ₂ O emissions from managed soils	N ₂ O	16,686.40	24,317.43	16,686.40	0.02	1.99	91.24
2.B. Chemical industry	CO ₂	7,989.16	9,366.80	7,989.16	0.01	1.38	92.62
2.C. Metal industry	CO ₂	1,828.43	10,981.37	1,828.43	0.01	1.34	93.96
3.B. Manure management	N ₂ O	8,136.27	12,962.28	8,136.27	0.01	0.76	94.73

IPCC category	GHG	Base Year Estimate (2000), kt CO ₂ e	Latest Year Estimate (2022), kt CO ₂ e	Absolute of Base Year Estimate (2000), kt CO ₂ e	Trend Assessment	% Contribution to Trend	Cumulative Total, %
		$E_{x,0}$	Ex,t	Ex,0	Tx,t		
3.D.2. Indirect N ₂ O Emissions from managed soils	N ₂ O	4,435.23	5,828.66	4,435.23	0.01	0.65	95.37
3.H. Urea application	CO_2	3,435.33	4,047.21	3,435.33	0.01	0.59	95.96
1.B.1. Solid fuels	CH ₄	578.11	4,243.97	578.11	0.01	0.57	96.53
1.A.4. Other sectors	N ₂ O	1,393.92	238.50	1,393.92	0.01	0.50	97.03
2.D. Non-energy products from fuels and solvent use	CO ₂	831.33	4,358.07	831.33	0.01	0.49	97.52
5.E. Other (6)	CH ₄	1,274.09	172.25	1,274.09	0.00	0.47	97.99
5.A. Solid waste disposal (6)	CH ₄	11,555.21	21,724.54	11,555.21	0.00	0.46	98.45
5.C. Incineration and open burning of waste (6)	CO ₂	1,769.48	2,381.81	1,769.48	0.00	0.25	98.70
5.C. Incineration and open burning of waste (6)	CH ₄	1,500.16	2,019.29	1,500.16	0.00	0.21	98.91
3.B. Manure management	CH ₄	1,663.83	2,530.56	1,663.83	0.00	0.18	99.09
1.A.1. Energy industries	N ₂ O	190.07	1,090.08	190.07	0.00	0.13	99.22
5.D. Wastewater treatment and discharge	N ₂ O	1,678.46	2,868.82	1,678.46	0.00	0.12	99.34
2.B. Chemical industry	N ₂ O	127.59	865.45	127.59	0.00	0.11	99.45
3.G. Liming	CO_2	791.63	2,159.22	791.63	0.00	0.09	99.55
1.A.3. Transport	N ₂ O	790.59	2,128.74	790.59	0.00	0.09	99.64
1.A.3. Transport	CH ₄	418.92	1,255.10	418.92	0.00	0.07	99.71
3.E. Prescribed burning of savannahs	CH ₄	195.10	103.38	195.10	0.00	0.06	99.77

IPCC category	GHG	Base Year Estimate (2000), kt CO ₂ e	Latest Year Estimate (2022), kt CO ₂ e	Absolute of Base Year Estimate (2000), kt CO ₂ e	Trend Assessment	% Contribution to Trend	Cumulative Total, %
		$E_{x,0}$	Ex,t	Ex,0	Tx,t		
3.E. Prescribed burning of savannahs	N ₂ O	118.51	52.81	118.51	0.00	0.04	99.80
5.C. Incineration and open burning of waste (6)	N ₂ O	173.84	233.99	173.84	0.00	0.02	99.83
2.B. Chemical industry	CH ₄	93.75	102.84	93.75	0.00	0.02	99.84
2.C. Metal industry	CH ₄	37.96	0.00	37.96	0.00	0.01	99.86
2.H. Other (4)	CO ₂	92.25	151.46	92.25	0.00	0.01	99.87
5.B. Biological treatment of solid waste	N ₂ O	0.04	34.06	0.04	0.00	0.01	99.87
1.A.2. Manufacturing industries and construction	CH ₄	399.24	807.54	399.24	0.00	0.01	99.88
1.B.2. Oil and natural gas and other emissions from energy production	N ₂ O	15.88	7.56	15.88	0.00	0.00	99.88
1.A.2. Manufacturing industries and construction	N ₂ O	537.65	1,103.20	537.65	0.00	0.00	99.89
1.A.1. Energy industries	CH ₄	46.42	111.07	46.42	0.00	0.00	99.89
5.B. Biological treatment of solid waste	CH ₄	0.00	2.09	0.00	0.00	0.00	99.89
3.F. Field burning of agricultural residues	CH ₄	1.45	0.98	1.45	0.00	0.00	99.89
3.F. Field burning of agricultural residues	N ₂ O	1.25	0.85	1.25	0.00	0.00	99.89
5.E. Other (6)	CO ₂		1.43			0.00	99.89
5.E. Other (6)	N ₂ O	278.27		278.27	0.00	0.11	100.00
Total		511,230.77	1,070,487.32	511,230.77	1.04	100.00	



ANNEX 2: UNCERTAINTY ASSESSMENT

Inventory uncertainty significantly influences estimates of GHG emissions and removals. After determining the uncertainties in the AD, EFs, or emissions for a category, these uncertainties can be aggregated to estimate the uncertainty for the base year inventory and the overall inventory trend from the base year to the most recent year.

In the national context, uncertainties are determined using the Tier 1 error propagation method outlined in the 2006 IPCC Guidelines, focusing on the base year 2000, the current reporting year 2022, and the trend from 2000 to 2022.

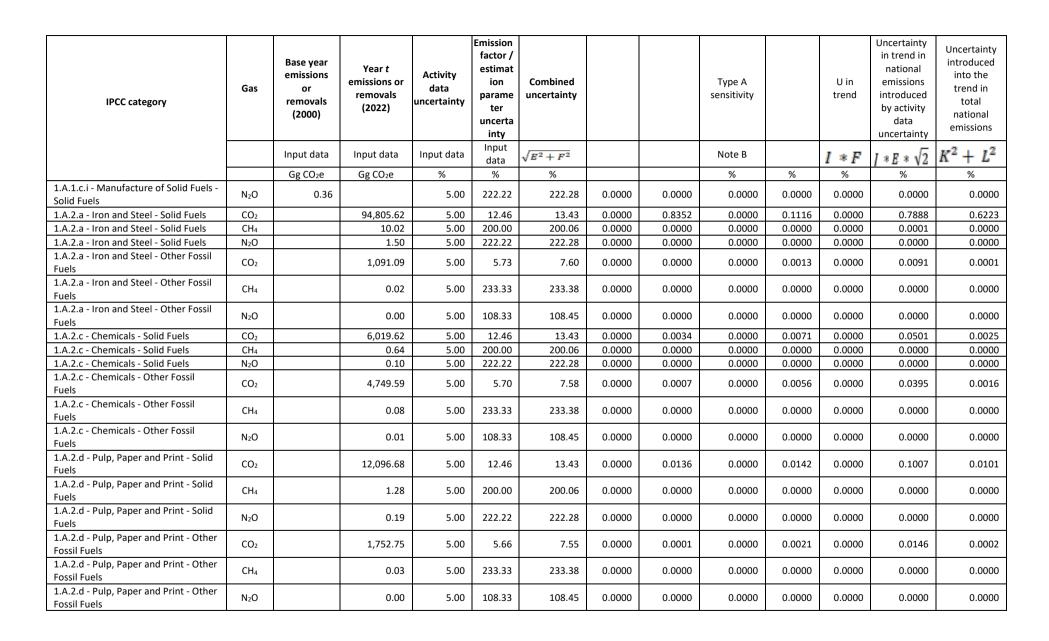
Error Propagation

The Tier 1 method utilizes error propagation to estimate uncertainties across individual categories, the overall inventory, and the trend from the base year to the current year. Uncertainties are assessed through a two-step error propagation equation. The initial step involves estimating the combined uncertainty through Equation 3.1, as outlined in Chapter 3 of Volume 1 of the 2006 IPCC Guidelines, by integrating the uncertainties associated with the EFs and activity data. The subsequent step involves estimating the uncertainty associated with the overall national emissions and the trend in national emissions from the base year to the current year. The uncertainty analysis results for the 2000 and 2022 inventories are presented in the table below.

The results of the uncertainty analysis show that the overall uncertainty of the Indonesian NGHGI with LULUCF for 2000 and 2022 is around 16.39% and 13.79%, respectively, with an uncertainty trend reaching 28.95%. Lower levels of uncertainty, 13.73% for 2000 and 10.27% for 2022 with an uncertainty trend reaching 31.62%, occur when LULUCF is excluded from the analysis.

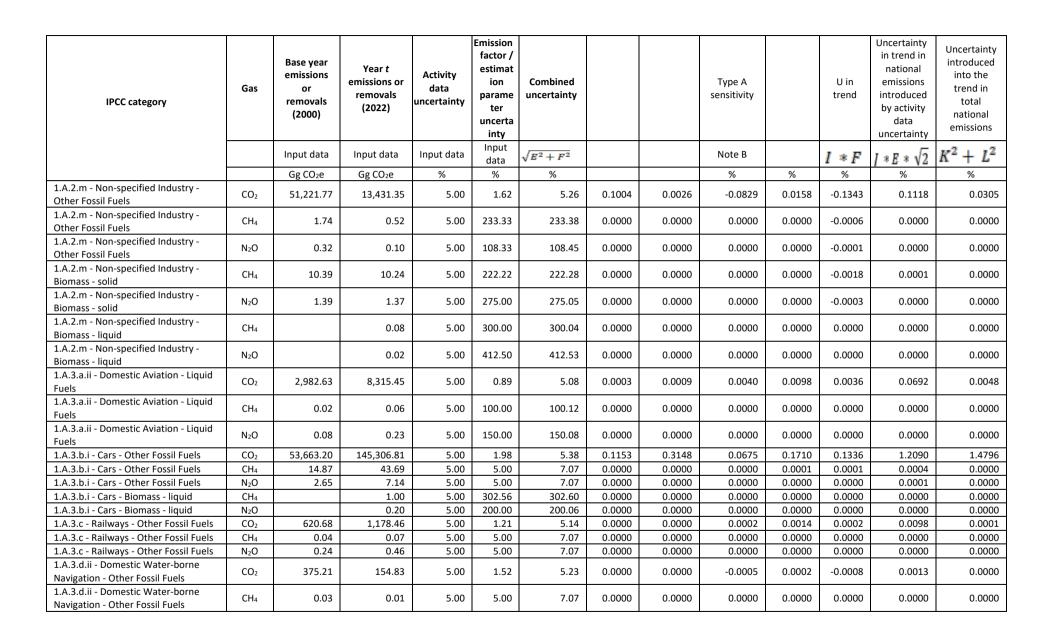
Table A2 - 1 Uncertainty estimated GHG with LULUCF

IPCC category	Gas	Base year emissions or removals (2000)	Year t emissions or removals (2022)	Activity data uncertainty	Emission factor / estimat ion parame ter uncerta inty	Combined uncertainty			Type A sensitivity		U in trend	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data	$\sqrt{E^2+F^2}$			Note B		I * F		$K^2 + L^2$
		Gg CO₂e	Gg CO₂e	%	%	%			%	%	%	%	%
1.A - Fuel Combustion Activities 1.A.1.a.i - Electricity Generation -													
Solid Fuels	CO ₂	32,523.74	252,062.16	5.00	12.46	13.43	0.2640	5.9038	0.2338	0.2966	2.9131	2.0973	12.8847
1.A.1.a.i - Electricity Generation - Solid Fuels	CH ₄	0.34	2.62	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000	0.0000
1.A.1.a.i - Electricity Generation - Solid Fuels	N ₂ O	0.51	3.93	5.00	222.22	222.28	0.0000	0.0000	0.0000	0.0000	0.0008	0.0000	0.0000
1.A.1.a.i - Electricity Generation - Other Fossil Fuels	CO ₂	29,606.77	43,524.03	5.00	4.56	6.77	0.0556	0.0447	-0.0059	0.0512	-0.0268	0.3621	0.1319
1.A.1.a.i - Electricity Generation - Other Fossil Fuels	CH ₄	0.86	0.93	5.00	233.33	233.38	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0000	0.0000
1.A.1.a.i - Electricity Generation - Other Fossil Fuels	N ₂ O	0.15	0.12	5.00	275.00	275.05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.1.a.i - Electricity Generation - Biomass - solid	CH ₄	0.00		5.00	222.22	222.28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.1.a.i - Electricity Generation - Biomass - solid	N ₂ O	0.00		5.00	275.00	275.05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.1.a.i - Electricity Generation - Biomass - liquid	CH ₄		0.02	5.00	300.00	300.04	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.1.a.i - Electricity Generation - Biomass - liquid	N ₂ O		0.00	5.00	412.50	412.53	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.1.b - Petroleum Refining - Other Fossil Fuels	CO ₂	12,005.01	8,530.22	5.00	4.11	6.47	0.0084	0.0016	-0.0131	0.0100	-0.0539	0.0710	0.0079
1.A.1.b - Petroleum Refining - Other Fossil Fuels	CH ₄	0.29	0.22	5.00	233.33	233.38	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0000	0.0000
1.A.1.b - Petroleum Refining - Other Fossil Fuels	N ₂ O	0.04	0.03	5.00	275.00	275.05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.1.c.i - Manufacture of Solid Fuels - Solid Fuels	CO ₂	174.49		5.00	12.46	13.43	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.1.c.i - Manufacture of Solid Fuels - Solid Fuels	CH ₄	0.03		5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000



IPCC category	Gas	Base year emissions or removals (2000)	Year t emissions or removals (2022)	Activity data uncertainty	Emission factor / estimat ion parame ter uncerta inty	Combined uncertainty			Type A sensitivity		U in trend	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data	$\sqrt{E^2+F^2}$			Note B		I * F	$J*E*\sqrt{2}$	$K^2 + L^2$
		Gg CO₂e	Gg CO₂e	%	%	%			%	%	%	%	%
1.A.2.e - Food Processing, Beverages and Tobacco - Solid Fuels	CO ₂			5.00	12.46	13.43	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.e - Food Processing, Beverages and Tobacco - Other Fossil Fuels	CO ₂		14,600.01	5.00	5.73	7.60	0.0000	0.0064	0.0000	0.0172	0.0000	0.1215	0.0148
1.A.2.e - Food Processing, Beverages and Tobacco - Other Fossil Fuels	CH ₄		0.25	5.00	233.33	233.38	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.e - Food Processing, Beverages and Tobacco - Other Fossil Fuels	N₂O		0.03	5.00	108.33	108.45	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.f - Non-Metallic Minerals - Solid Fuels	CO ₂		41,295.33	5.00	12.46	13.43	0.0000	0.1585	0.0000	0.0486	0.0000	0.3436	0.1181
1.A.2.f - Non-Metallic Minerals - Solid Fuels	CH ₄		4.37	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.f - Non-Metallic Minerals - Solid Fuels	N ₂ O		0.65	5.00	222.22	222.28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.f - Non-Metallic Minerals - Other Fossil Fuels	CO ₂		2,542.33	5.00	5.65	7.54	0.0000	0.0002	0.0000	0.0030	0.0000	0.0212	0.0004
1.A.2.f - Non-Metallic Minerals - Other Fossil Fuels	CH ₄		0.05	5.00	233.33	233.38	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.f - Non-Metallic Minerals - Other Fossil Fuels	N ₂ O		0.00	5.00	108.33	108.45	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.a - Commercial/Institutional - Other Fossil Fuels	CO ₂	3,426.03	1,794.45	5.00	3.90	6.34	0.0007	0.0001	-0.0045	0.0021	-0.0175	0.0149	0.0005
1.A.4.a - Commercial/Institutional - Other Fossil Fuels	CH ₄	0.42	0.19	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0000	0.0000
1.A.4.a - Commercial/Institutional - Other Fossil Fuels	N₂O	0.02	0.01	5.00	275.00	275.05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.a - Commercial/Institutional - Biomass - solid	CH ₄	2.56	2.29	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	-0.0004	0.0000	0.0000
1.A.4.a - Commercial/Institutional - Biomass - solid	N₂O	0.03	0.03	5.00	250.00	250.05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.a - Commercial/Institutional - Biomass - liquid	CH₄		0.01	5.00	275.00	275.05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.a - Commercial/Institutional - Biomass - liquid	N₂O		0.00	5.00	412.50	412.53	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

IPCC category	Gas	Base year emissions or removals (2000)	Year t emissions or removals (2022)	Activity data uncertainty	Emission factor / estimat ion parame ter uncerta inty	Combined uncertainty			Type A sensitivity		U in trend	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data	$\sqrt{E^2+F^2}$			Note B		I * F	$J*E*\sqrt{2}$	$K^2 + L^2$
		Gg CO₂e	Gg CO₂e	%	%	%			%	%	%	%	%
1.A.4.b - Residential - Solid Fuels	CO_2	48.90		5.00	12.46	13.43	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.b - Residential - Solid Fuels	CH₄	0.16		5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.b - Residential - Solid Fuels	N_2O	0.00		5.00	222.22	222.28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.b - Residential - Other Fossil Fuels	CO ₂	23,965.50	28,098.85	5.00	5.94	7.76	0.0479	0.0245	-0.0131	0.0331	-0.0781	0.2338	0.0608
1.A.4.b - Residential - Other Fossil Fuels	CH ₄	3.22	2.22	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	-0.0007	0.0000	0.0000
1.A.4.b - Residential - Other Fossil Fuels	N ₂ O	0.21	0.42	5.00	275.00	275.05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.b - Residential - Biomass - solid	CH ₄	367.61	29.97	5.00	200.00	200.06	0.0075	0.0000	-0.0007	0.0000	-0.1347	0.0002	0.0182
1.A.4.b - Residential - Biomass - solid	N ₂ O	4.90	0.40	5.00	250.00	250.05	0.0000	0.0000	0.0000	0.0000	-0.0022	0.0000	0.0000
1.A.4.b - Residential - Biomass - gas	CH ₄		0.01	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.b - Residential - Biomass - gas	N ₂ O		0.00	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.c.i - Stationary - Other Fossil Fuels	CO ₂	11,296.62	3,866.20	5.00	1.32	5.17	0.0047	0.0002	-0.0172	0.0045	-0.0227	0.0322	0.0016
1.A.4.c.i - Stationary - Other Fossil Fuels	CH ₄	1.54	0.52	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	-0.0005	0.0000	0.0000
1.A.4.c.i - Stationary - Other Fossil Fuels	N ₂ O	0.09	0.03	5.00	275.00	275.05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.c.i - Stationary - Biomass - liquid	CH ₄		0.13	5.00	275.00	275.05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.c.i - Stationary - Biomass - liquid	N ₂ O		0.01	5.00	412.50	412.53	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.1.c.ii - Other Energy Industries - Other Fossil Fuels	CO ₂	9,561.43	10,276.87	5.00	5.73	7.60	0.0073	0.0031	-0.0063	0.0121	-0.0364	0.0855	0.0086
1.A.1.c.ii - Other Energy Industries - Other Fossil Fuels	CH ₄	0.17	0.18	5.00	233.33	233.38	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.1.c.ii - Other Energy Industries - Other Fossil Fuels	N ₂ O	0.02	0.02	5.00	275.00	275.05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.m - Non-specified Industry - Solid Fuels	CO ₂	20,443.06	12,228.41	5.00	12.46	13.43	0.1043	0.0139	-0.0250	0.0144	-0.3119	0.1017	0.1076
1.A.2.m - Non-specified Industry - Solid Fuels	CH₄	2.13	1.27	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	-0.0005	0.0000	0.0000
1.A.2.m - Non-specified Industry - Solid Fuels	N ₂ O	0.32	0.19	5.00	222.22	222.28	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0000	0.0000

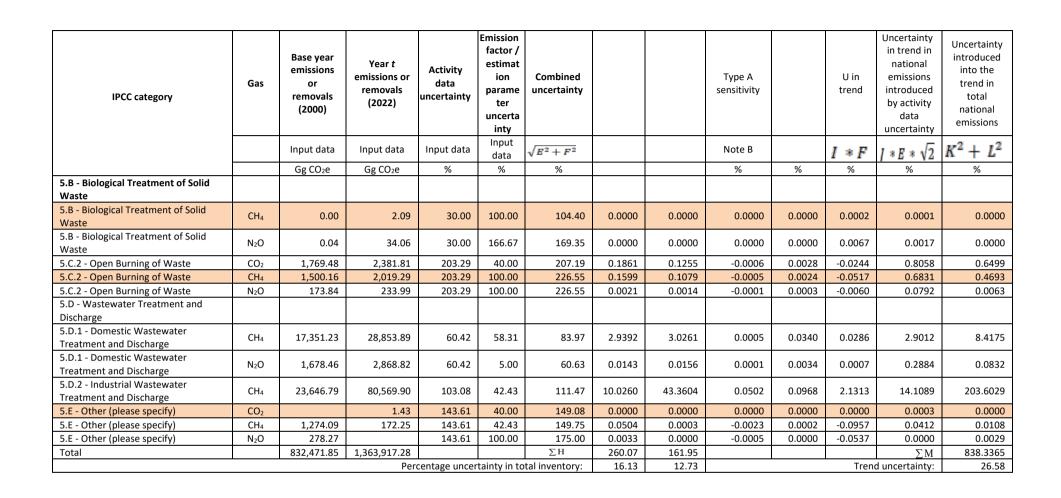


IPCC category	Gas	Base year emissions or removals (2000)	Year t emissions or removals (2022)	Activity data uncertainty	Emission factor / estimat ion parame ter uncerta inty	Combined uncertainty			Type A sensitivity		U in trend	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data Gg CO₂e	Input data Gg CO₂e	Input data	data %	$\sqrt{E^2 + F^2}$			Note B	%	<i>I ∗ F</i> %	$J*E*\sqrt{2}$	$K^2 + L^2$
1.A.3.d.ii - Domestic Water-borne		Gg CO2e	Gg CO2e	70	70	70			70	70	70	70	70
Navigation - Other Fossil Fuels	N ₂ O	0.01	0.00	5.00	5.00	7.07	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.B.1 - Fugitive Emissions from Fuels - Solid Fuels													
1.B.1.a.i.1 - Mining	CO_2	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.B.1.a.ii.1 - Mining	CH₄	433.58	3,182.97	5.00	300.00	300.04	0.0234	0.4702	0.0029	0.0037	0.8728	0.0265	0.7624
1.B.1.a.ii.2 - Post-mining seam gas emissions	CH ₄	144.53	1,060.99	5.00	300.00	300.04	0.0026	0.0522	0.0010	0.0012	0.2909	0.0088	0.0847
1.B.2.a.i - Venting	CO_2	148.01	63.93	5.00	75.00	75.17	0.0002	0.0000	-0.0002	0.0001	-0.0158	0.0005	0.0002
1.B.2.a.i - Venting	CH ₄	20,030.98	8,652.50	5.00	75.00	75.17	3.1390	0.2181	-0.0284	0.0102	-2.1331	0.0720	4.5554
1.B.2.a.i - Venting	N ₂ O			5.00		0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.B.2.a.ii - Flaring	CO_2	3,544.23	1,530.95	5.00	75.00	75.17	0.0983	0.0068	-0.0050	0.0018	-0.3775	0.0127	0.1427
1.B.2.a.ii - Flaring	CH ₄	495.02	213.83	5.00	75.00	75.17	0.0019	0.0001	-0.0007	0.0003	-0.0527	0.0018	0.0028
1.B.2.a.ii - Flaring	N_2O	13.25	5.72	5.00	75.00	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.B.2.a.iii.2 - Production and Upgrading	CO ₂	23.02	9.95	5.00	800.00	800.02	0.0005	0.0000	0.0000	0.0000	-0.0261	0.0001	0.0007
1.B.2.a.iii.2 - Production and Upgrading	CH ₄	5,065.31	2,187.99	5.00	800.00	800.02	22.7380	1.5795	-0.0072	0.0026	-5.7548	0.0182	33.1176
1.B.2.a.iii.2 - Production and Upgrading	N ₂ O			5.00		0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.B.2.a.iii.3 - Transport	CO ₂	35.99	15.55	5.00	200.00	200.06	0.0001	0.0000	-0.0001	0.0000	-0.0102	0.0001	0.0001
1.B.2.a.iii.3 - Transport	CH ₄	265.70	114.77	5.00	200.00	200.06	0.0039	0.0003	-0.0004	0.0001	-0.0755	0.0010	0.0057
1.B.2.a.iii.3 - Transport	N_2O	0.05	0.02	5.00	200.00	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.B.2.b.i - Venting	CO ₂	3,249.80	2,270.82	5.00	999.99	1,000.00	14.6237	2.6583	-0.0036	0.0027	-3.5950	0.0189	12.9244
1.B.2.b.i - Venting	CH ₄	100.09	69.94	5.00	999.99	0.00	0.0000	0.0000	-0.0001	0.0001	0.0000	0.0006	0.0000
1.B.2.b.ii - Flaring	CO_2	1,080.63	755.10	5.00	800.00	800.02	1.0349	0.1881	-0.0012	0.0009	-0.9564	0.0063	0.9147
1.B.2.b.ii - Flaring	CH ₄	447.57	312.74	5.00	800.00	800.02	0.1775	0.0323	-0.0005	0.0004	-0.3961	0.0026	0.1569
1.B.2.b.ii - Flaring	N_2O	2.63	1.84	5.00	999.99	1,000.00	0.0000	0.0000	0.0000	0.0000	-0.0029	0.0000	0.0000
1.B.2.b.iii.2 - Production	CO ₂	1.14	0.79	5.00	250.00	250.05	0.0000	0.0000	0.0000	0.0000	-0.0003	0.0000	0.0000
1.B.2.b.iii.2 - Production	CH ₄	864.38	603.99	5.00	250.00	250.05	0.0647	0.0118	-0.0010	0.0007	-0.2391	0.0050	0.0572
1.B.2.b.iii.3 - Processing	CO ₂	0.97	0.68	5.00	250.00	250.05	0.0000	0.0000	0.0000	0.0000	-0.0003	0.0000	0.0000
1.B.2.b.iii.3 - Processing	CH ₄	341.20	238.42	5.00	250.00	250.05	0.0101	0.0018	-0.0004	0.0003	-0.0944	0.0020	0.0089

IPCC category	Gas	Base year emissions or removals (2000)	Year t emissions or removals (2022)	Activity data uncertainty	Emission factor / estimat ion parame ter uncerta inty	Combined uncertainty			Type A sensitivity		U in trend	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data	$\sqrt{E^2+F^2}$			Note B		I * F	$J*E*\sqrt{2}$	$K^2 + L^2$
		Gg CO₂e	Gg CO₂e	%	%	%			%	%	%	%	%
1.B.2.b.iii.4 - Transmission and Storage	CO ₂	0.07	0.05	5.00	250.00	250.05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.B.2.b.iii.4 - Transmission and Storage	CH₄	377.60	263.85	5.00	250.00	250.05	0.0123	0.0022	-0.0004	0.0003	-0.1044	0.0022	0.0109
1.B.2.b.iii.5 - Distribution	CO ₂	4.14	2.90	5.00	500.00	500.02	0.0000	0.0000	0.0000	0.0000	-0.0023	0.0000	0.0000
1.B.2.b.iii.5 - Distribution	CH₄	2,502.15	1,748.39	5.00	500.00	500.02	2.1675	0.3940	-0.0028	0.0021	-1.3840	0.0145	1.9157
2 - Industrial Processes and Product Use													
2.A.1 - Cement production	CO ₂	16,174.11	28,876.76	2.00	5.00	5.39	0.0105	0.0125	0.0028	0.0340	0.0139	0.0961	0.0094
2.A.2 - Lime production	CO ₂	3,688.15	112.55	10.00	2.00	10.20	0.0020	0.0000	-0.0070	0.0001	-0.0140	0.0019	0.0002
2.A.3 - Glass Production	CO ₂	245.31	45.58	10.00	10.00	14.14	0.0000	0.0000	-0.0004	0.0001	-0.0042	0.0008	0.0000
2.A.4 - Other Process Uses of Carbonates	CO ₂	8,415.69	2,445.14	17.32	17.32	24.49	0.0588	0.0018	-0.0134	0.0029	-0.2312	0.0705	0.0584
2.B.1 - Ammonia Production	CO ₂	6,139.06	6,846.42	10.00	6.00	11.66	0.0071	0.0033	-0.0038	0.0081	-0.0227	0.1139	0.0135
2.B.2 - Nitric Acid Production	N ₂ O	127.59	865.45	2.00	10.00	10.20	0.0000	0.0000	0.0008	0.0010	0.0077	0.0029	0.0001
2.B.5 - Carbide Production	CO ₂	24.47	26.25	10.00	10.00	14.14	0.0000	0.0000	0.0000	0.0000	-0.0002	0.0004	0.0000
2.B.8 - Petrochemical and Carbon Black Production	CO ₂	1,825.63	2,494.13	22.36	22.36	31.62	0.0046	0.0032	-0.0006	0.0029	-0.0131	0.0928	0.0088
2.B.8 - Petrochemical and Carbon Black Production	CH ₄	93.75	102.84	22.36	22.36	31.62	0.0000	0.0000	-0.0001	0.0001	-0.0013	0.0038	0.0000
2.C.1 - Iron and Steel Production	CO ₂	1,301.76	10,303.58	10.00	10.00	14.14	0.0005	0.0109	0.0096	0.0121	0.0961	0.1715	0.0386
2.C.1 - Iron and Steel Production	CH ₄	37.96	0.00	10.00	10.00	14.14	0.0000	0.0000	-0.0001	0.0000	-0.0007	0.0000	0.0000
2.C.3 - Aluminum production	CO ₂	384.00	447.32	2.00	5.00	5.39	0.0000	0.0000	-0.0002	0.0005	-0.0011	0.0015	0.0000
2.C.3 - Aluminum production	CF4	254.59	55.61	2.00	5.00	5.39	0.0000	0.0000	-0.0004	0.0001	-0.0021	0.0002	0.0000
2.C.3 - Aluminum production	C2F6	26.64	0.00	2.00	5.00	5.39	0.0000	0.0000	-0.0001	0.0000	-0.0003	0.0000	0.0000
2.C.5 - Lead Production	CO ₂	19.05	118.83	10.00	10.00	14.14	0.0000	0.0000	0.0001	0.0001	0.0010	0.0020	0.0000
2.C.6 - Zinc Production	CO ₂	123.62	111.64	10.00	10.00	14.14	0.0000	0.0000	-0.0001	0.0001	-0.0011	0.0019	0.0000
2.D - Non-Energy Products from Fuels and Solvent Use	CO ₂	831.33	4,358.07	14.14	14.14	20.00	0.0004	0.0039	0.0035	0.0051	0.0498	0.1025	0.0130
2.H - Other	CO ₂	92.25	151.46	14.14	2.83	14.42	0.0000	0.0000	0.0000	0.0002	0.0000	0.0036	0.0000
3.A. Enteric Fermentation													
3.A.1.a.i. Mature dairy cattle	CH ₄	499.51	870.62	20.00	20.00	28.28	0.0003	0.0003	0.0001	0.0010	0.0012	0.0290	0.0008
3.A.1.a.ii. Other mature cattle	CH ₄	15,207.36	26,103.76	20.00	20.00	28.28	0.2562	0.2810	0.0014	0.0307	0.0278	0.8688	0.7556

IPCC category	Gas	Base year emissions or removals (2000)	Year t emissions or removals (2022)	Activity data uncertainty	Emission factor / estimat ion parame ter uncerta inty	Combined uncertainty $\sqrt{E^2 + F^2}$			Type A sensitivity		U in trend	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions $K^2 + L^2$
		6-60-	C= CO =	. 0/	data	-			0/	0/	%		%
2 A 2 Chaon	CH ₄	Gg CO₂e 820.87	Gg CO₂e 1,781.05	% 20.00	% 20.00	% 28.28	0.0007	0.0013	% 0.0005	% 0.0021	0.0103	% 0.0593	0.0036
3.A.2. Sheep 3.A.3. Swine	CH ₄	1,856.64	2,381.62	20.00	20.00	28.28	0.0007	0.0013	-0.0008	0.0021	-0.0156	0.0593	0.0036
3.A.4.a. Buffalo	CH ₄	4,592.19	2,332.37	20.00	20.00	28.28	0.0038	0.0023	-0.0061	0.0028	-0.0136	0.0793	0.0063
3.A.4.d. Goats	CH ₄	1,388.28	2,184.22	20.00	20.00	28.28	0.00234	0.0022	-0.0001	0.0027	-0.1222	0.0770	0.0053
3.A.4.e. Horses	CH ₄	1,116.06	1,067.23	20.00	20.00	28.28	0.0021	0.0020	-0.0001	0.0028	-0.0021	0.0727	0.0033
3.B. Manure Management	CH ₄	1,110.00	1,007.23	20.00	20.00	20.20	0.0014	0.0003	-0.0003	0.0013	-0.0173	0.0333	0.0010
3.B.1.a.i. Mature dairy cattle	CH ₄	10.03	17.48	20.00	20.00	28.28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000
3.B.1.a.ii. Other mature cattle	CH ₄	469.78	806.39	20.00	20.00	28.28	0.0002	0.0003	0.0000	0.0009	0.0009	0.0268	0.0007
3.A.2. Sheep	CH ₄	10.22	22.33	20.00	20.00	28.28	0.0000	0.0000	0.0000	0.0000	0.0001	0.0007	0.0000
3.A.3. Swine	CH ₄	899.95	1,223.09	20.00	20.00	28.28	0.0009	0.0006	-0.0003	0.0014	-0.0059	0.0407	0.0017
3.A.4.a. Buffalo	CH ₄	141.86	72.05	20.00	20.00	28.28	0.0000	0.0000	-0.0002	0.0001	-0.0038	0.0024	0.0000
3.A.4.d. Goats	CH₄	9.61	14.87	20.00	20.00	28.28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000
3.A.4.e. Horses	CH ₄	25.29	24.18	20.00	20.00	28.28	0.0000	0.0000	0.0000	0.0000	-0.0004	0.0008	0.0000
3.A.4.g. Poultry	CH ₄	97.10	350.16	20.00	20.00	28.28	0.0000	0.0001	0.0002	0.0004	0.0045	0.0117	0.0002
3.B.1.a.i. Mature dairy cattle	N ₂ O												
3.B.1.a.ii. Other mature cattle	N ₂ O	3,761.49	6,456.68	20.00	79.06	81.55	0.1303	0.1429	0.0003	0.0076	0.0272	0.2149	0.0469
3.A.2. Sheep	N ₂ O	501.97	1,083.42	20.00	79.06	81.55	0.0023	0.0040	0.0003	0.0013	0.0243	0.0361	0.0019
3.A.3. Swine	N ₂ O	341.69	438.31	20.00	79.06	81.55	0.0011	0.0007	-0.0001	0.0005	-0.0113	0.0146	0.0003
3.A.4.a. Buffalo	N ₂ O	1,146.74	581.32	20.00	79.06	81.55	0.0121	0.0012	-0.0015	0.0007	-0.1208	0.0193	0.0150
3.A.4.d. Goats	N ₂ O	996.64	1,558.72	20.00	79.06	81.55	0.0091	0.0083	-0.0001	0.0018	-0.0069	0.0519	0.0027
3.A.4.e. Horses	N ₂ O	236.21	225.87	20.00	79.06	81.55	0.0005	0.0002	-0.0002	0.0003	-0.0150	0.0075	0.0003
3.A.4.g. Poultry	N ₂ O	173.22	727.48	20.00	79.06	81.55	0.0003	0.0018	0.0005	0.0009	0.0413	0.0242	0.0023
3.B.5. Indirect N₂O emissions	N ₂ O	978.31	1,890.49	20.00	140.48	141.90	0.0267	0.0371	0.0003	0.0022	0.0475	0.0629	0.0062
3.C. Rice Cultivation	CH ₄												
3.C.1.a. Continuously flooded	CH₄	40,845.02	36,942.72	20.00	39.42	44.20	4.5137	1.3747	-0.0353	0.0435	-1.3908	1.2295	3.4462
3.C.2.b. Drought-prone	CH ₄	5,397.99	9,898.87	20.00	40.71	45.36	0.0830	0.1039	0.0012	0.0116	0.0504	0.3295	0.1111
3.D.Agriculture Soil													
3.D.1.a. Inorganic N fertilizers	N ₂ O	4,773.71	6,246.10	20.00	67.20	70.11	0.1551	0.0989	-0.0019	0.0073	-0.1247	0.2079	0.0588
3.D.1.b. Organic N fertilizers	N ₂ O	1,989.87	3,390.89	20.00	67.20	70.11	0.0270	0.0291	0.0002	0.0040	0.0103	0.1129	0.0128
3.D.1.c. Urine and dung deposited by grazing animals	N ₂ O	1,612.07	2,767.15	20.00	75.66	78.26	0.0220	0.0242	0.0001	0.0033	0.0111	0.0921	0.0086
3.D.1.d. Crop residues	N ₂ O	160.90	175.02	20.00	67.20	70.11	0.0002	0.0001	-0.0001	0.0002	-0.0070	0.0058	0.0001

3.D.1.f. Cultivation of organic soils (i.e. histosols) 3.D.2. Indirect N ₂ O Emissions from	Input data Gg CO ₂ e 8,149.85	Input data Gg CO ₂ e	Input data								by activity data uncertainty	national emissions
(i.e. histosols) N2 Indirect N2O Emissions from		Gg CO26		Input data	$\sqrt{E^2+F^2}$			Note B		I * F	$J*E*\sqrt{2}$	$K^2 + L^2$
(i.e. histosols) N2 Indirect N2O Emissions from	8,149.85	Ug COZE	%	%	%			%	%	%	%	%
3 D 2 Indirect NoO Emissions from		11,738.28	12.00	53.75	55.07	0.2789	0.2154	-0.0019	0.0138	-0.1024	0.2344	0.0654
managed soils N ₂	4,435.23	5,828.66	20.00	143.54	144.92	0.5721	0.3678	-0.0017	0.0069	-0.2432	0.1940	0.0968
3.E.1. Prescribed burning of savannahs CH	4 195.10	103.38	12.00	60.32	61.50	0.0002	0.0000	-0.0003	0.0001	-0.0154	0.0021	0.0002
3.E-2. Prescribed burning of savannahs	118.51	52.81	12.00	66.14	67.22	0.0001	0.0000	-0.0002	0.0001	-0.0110	0.0011	0.0001
3.F.1. Field burning of agricultural residues	4 1.45	0.98	12.00	70.71	71.72	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0000	0.0000
3.F.2. Field burning of agricultural N2 residues	1.25	0.85	12.00	70.71	71.72	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0000	0.0000
3.G.2. Liming CC	2 791.63	2,159.22	20.00	50.00	53.85	0.0025	0.0070	0.0010	0.0025	0.0507	0.0719	0.0077
3.H. Urea application CC	2 3,435.33	4,047.21	20.00	50.00	53.85	0.0474	0.0245	-0.0019	0.0048	-0.0931	0.1347	0.0268
4. Land Use, Land-use Change and Forestry												
4.A.1. Forest land remaining forest land	2 -209,511.58	-262,231.05	42.77	23.16	48.64	143.792 0	83.8657	0.0957	0.3086	2.2165	18.6652	353.3013
4.A.2. Land converted to forest land CO	-6,866.96	-4,510.48	7.49	11.38	13.62	0.0121	0.0019	0.0079	0.0053	0.0903	0.0562	0.0113
4.B.1. Cropland remaining cropland CC		364,677.31	2.45	3.09	3.94	2.7168	1.0656	-0.2550	0.4291	-0.7884	1.4847	2.8258
4.B.2. Land converted to cropland CC		47,581.58	3.35	76.74	76.81	34.8187	6.8864	-0.0699	0.0560	-5.3607	0.2654	28.8072
4.C.1. Grassland remaining grassland CC		91,638.95	2.45	8.83	9.17	0.4285	0.3638	-0.0092	0.1078	-0.0813	0.3731	0.1458
4.C.2. Land converted to grassland CC		-5,539.89	1.04	28.19	28.21	2.8031	0.0126	-0.1037	0.0065	-2.9241	0.0096	8.5505
4.D.2. Wetlands remaining wetlands CO		19.60	2.45	8.83	9.17	0.0000	0.0000	0.0000	0.0000	0.0002	0.0001	0.0000
4.D.1. Land converted to wetlands CC		1.66	1.04	28.19	28.21	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
4.E.2. Land converted to settlements CO		1,994.71	2.35	0.08	2.35	0.0000	0.0000	0.0009	0.0023	0.0001	0.0078	0.0001
4.F.2. Land converted to other land CO		64,283.00	1.04	28.19	28.21	0.2647	1.6954	0.0457	0.0756	1.2897	0.1110	1.6755
4.C.1.d. Biomass Burning Ch		2,552.09	13.30	71.19	72.42	0.0413	0.0176	-0.0016	0.0030	-0.1135	0.0565	0.0161
4.C.1.d. Biomass Burning N ₂	790.73	500.30	13.30	27.77	30.79	0.0008	0.0001	-0.0009	0.0006	-0.0260	0.0111	0.0008
5.A - Solid Waste Disposal		22.55	26.65	20.4:	47.1-	0.0005	0.000	0.0055	0.000-	0.0000	0.0055	0.005
5.A.1 - Managed Waste Disposal Sites 5.A.2 - Unmanaged Waste Disposal Sites CH		33.08 21,691.46	36.06 46.90	30.41 35.00	47.17 58.52	0.0000 0.6598	0.0000 0.8662	0.0000	0.0000	0.0000	0.0000 1.7283	3.0003



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Table A2 - 2 Uncertainty estimated GHG without LULUCF

IPCC category	Gas	Base year emissions or removals (2000)	Year t emissions or removals (2022)	Activity data uncertainty	Emission factor / estimation parameter uncertainty	Combined uncertainty	Contribution to variance by category in year base year	Contribution to variance by category in year t $\frac{(G*D)^2}{(\sum D)^2}$	Type A sensitivity	Type B sensitivity $\left \frac{D}{\sum C} \right $	U in trend in national emissions introduced by emission factor/ estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data	$\sqrt{E^2+F^2}$	$(G * C)^2$		Note B		I * F	$J * E * \sqrt{2}$	$K^2 + L^2$
		Gg CO₂e	Gg CO₂e	%	%	%	$(\Sigma C)^2$		%	%	%	%	%
1.A - Fuel Combustion Activities							\ - -/						
1.A.1.a.i - Electricity Generation - Solid Fuels	CO ₂	32,523.74	252,062.16	5.00	12.46	13.43	0.7187	9.6074	0.3553	0.4894	4.4270	3.4604	31.5726
1.A.1.a.i - Electricity Generation - Solid Fuels	CH ₄	0.34	2.62	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000
1.A.1.a.i - Electricity Generation - Solid Fuels	N ₂ O	0.51	3.93	5.00	222.22	222.28	0.0000	0.0000	0.0000	0.0000	0.0012	0.0001	0.0000
1.A.1.a.i - Electricity Generation - Other Fossil Fuels	CO ₂	29,606.77	43,524.03	5.00	4.56	6.77	0.1513	0.0728	-0.0373	0.0845	-0.1702	0.5975	0.3860
1.A.1.a.i - Electricity Generation - Other Fossil Fuels	CH ₄	0.86	0.93	5.00	233.33	233.38	0.0000	0.0000	0.0000	0.0000	-0.0004	0.0000	0.0000
1.A.1.a.i - Electricity Generation - Other Fossil Fuels	N ₂ O	0.15	0.12	5.00	275.00	275.05	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0000	0.0000
1.A.1.a.i - Electricity Generation - Biomass - solid	CH ₄	0.00		5.00	222.22	222.28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.1.a.i - Electricity Generation - Biomass - solid	N ₂ O	0.00		5.00	275.00	275.05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.1.a.i - Electricity Generation - Biomass - liquid	CH ₄		0.02	5.00	300.00	300.04	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.1.a.i - Electricity Generation - Biomass - liquid	N ₂ O		0.00	5.00	412.50	412.53	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.1.b - Petroleum Refining - Other Fossil Fuels	CO ₂	12,005.01	8,530.22	5.00	4.11	6.47	0.0228	0.0026	-0.0328	0.0166	-0.1350	0.1171	0.0319
1.A.1.b - Petroleum Refining - Other Fossil Fuels	CH ₄	0.29	0.22	5.00	233.33	233.38	0.0000	0.0000	0.0000	0.0000	-0.0002	0.0000	0.0000
1.A.1.b - Petroleum Refining - Other Fossil Fuels	N ₂ O	0.04	0.03	5.00	275.00	275.05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.1.c.i - Manufacture of Solid Fuels - Solid Fuels	CO ₂	174.49		5.00	12.46	13.43	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.1.c.i - Manufacture of Solid Fuels - Solid Fuels	CH ₄	0.03		5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

IPCC category	Gas	Base year emissions or removals (2000)	Year t emissions or removals (2022)	Activity data uncertainty	Emission factor / estimation parameter uncertainty	Combined uncertainty	Contribution to variance by category in year base year	Contribution to variance by category in year t $\frac{(G*D)^2}{(\sum D)^2}$	Type A sensitivity	Type B sensitivity $\left \frac{D}{\sum C} \right $	U in trend in national emissions introduced by emission factor/ estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data				Note B		I * F] * E * √2	$K^2 + L^2$
		Gg CO₂e	Gg CO₂e	%	%	%			%	%	%	%	%
1.A.1.c.i - Manufacture of Solid Fuels - Solid Fuels	N ₂ O	0.36		5.00	222.22	222.28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.a - Iron and Steel - Solid Fuels	CO ₂		94,805.62	5.00	12.46	13.43	0.0000	1.3591	0.0000	0.1841	0.0000	1.3015	1.6939
1.A.2.a - Iron and Steel - Solid Fuels	CH ₄		10.02	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
1.A.2.a - Iron and Steel - Solid Fuels	N ₂ O		1.50	5.00	222.22	222.28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.a - Iron and Steel - Other Fossil Fuels	CO ₂		1,091.09	5.00	5.73	7.60	0.0000	0.0001	0.0000	0.0021	0.0000	0.0150	0.0002
1.A.2.a - Iron and Steel - Other Fossil Fuels	CH ₄		0.02	5.00	233.33	233.38	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.a - Iron and Steel - Other Fossil Fuels	N ₂ O		0.00	5.00	108.33	108.45	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.c - Chemicals - Solid Fuels	CO ₂		6,019.62	5.00	12.46	13.43	0.0000	0.0055	0.0000	0.0117	0.0000	0.0826	0.0068
1.A.2.c - Chemicals - Solid Fuels	CH ₄		0.64	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.c - Chemicals - Solid Fuels	N ₂ O		0.10	5.00	222.22	222.28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.c - Chemicals - Other Fossil Fuels	CO ₂		4,749.59	5.00	5.70	7.58	0.0000	0.0011	0.0000	0.0092	0.0000	0.0652	0.0043
1.A.2.c - Chemicals - Other Fossil Fuels	CH ₄		0.08	5.00	233.33	233.38	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.c - Chemicals - Other Fossil Fuels	N ₂ O		0.01	5.00	108.33	108.45	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.d - Pulp, Paper and Print - Solid Fuels	CO ₂		12,096.68	5.00	12.46	13.43	0.0000	0.0221	0.0000	0.0235	0.0000	0.1661	0.0276
1.A.2.d - Pulp, Paper and Print - Solid Fuels	CH ₄		1.28	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.d - Pulp, Paper and Print - Solid Fuels	N ₂ O		0.19	5.00	222.22	222.28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.d - Pulp, Paper and Print - Other Fossil Fuels	CO ₂		1,752.75	5.00	5.66	7.55	0.0000	0.0001	0.0000	0.0034	0.0000	0.0241	0.0006
1.A.2.d - Pulp, Paper and Print - Other Fossil Fuels	CH ₄		0.03	5.00	233.33	233.38	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.d - Pulp, Paper and Print - Other Fossil Fuels	N ₂ O		0.00	5.00	108.33	108.45	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.e - Food Processing, Beverages and Tobacco - Solid Fuels	CO ₂			5.00	12.46	13.43	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

IPCC category	Gas	Base year emissions or removals (2000)	Year t emissions or removals (2022)	Activity data uncertainty	Emission factor / estimation parameter uncertainty	Combined uncertainty	Contribution to variance by category in year base year	Contribution to variance by category in year t $\frac{(G*D)^2}{(\sum D)^2}$	Type A sensitivity	Type B sensitivity $\left \frac{D}{\sum C} \right $	U in trend in national emissions introduced by emission factor/ estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data				Note B		I * F] * E * √2	$K^2 + L^2$
		Gg CO₂e	Gg CO₂e	%	%	%			%	%	%	%	%
1.A.2.e - Food Processing, Beverages and Tobacco - Other Fossil Fuels	CO ₂		14,600.01	5.00	5.73	7.60	0.0000	0.0103	0.0000	0.0283	0.0000	0.2004	0.0402
1.A.2.e - Food Processing, Beverages and Tobacco - Other Fossil Fuels	CH ₄		0.25	5.00	233.33	233.38	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.e - Food Processing, Beverages and Tobacco - Other Fossil Fuels	N ₂ O		0.03	5.00	108.33	108.45	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.f - Non-Metallic Minerals - Solid Fuels	CO ₂		41,295.33	5.00	12.46	13.43	0.0000	0.2579	0.0000	0.0802	0.0000	0.5669	0.3214
1.A.2.f - Non-Metallic Minerals - Solid Fuels	CH ₄		4.37	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
1.A.2.f - Non-Metallic Minerals - Solid Fuels	N ₂ O		0.65	5.00	222.22	222.28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.f - Non-Metallic Minerals - Other Fossil Fuels	CO ₂		2,542.33	5.00	5.65	7.54	0.0000	0.0003	0.0000	0.0049	0.0000	0.0349	0.0012
1.A.2.f - Non-Metallic Minerals - Other Fossil Fuels	CH ₄		0.05	5.00	233.33	233.38	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.f - Non-Metallic Minerals - Other Fossil Fuels	N ₂ O		0.00	5.00	108.33	108.45	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.a - Commercial/Institutional - Other Fossil Fuels	CO ₂	3,426.03	1,794.45	5.00	3.90	6.34	0.0018	0.0001	-0.0106	0.0035	-0.0414	0.0246	0.0023
1.A.4.a - Commercial/Institutional - Other Fossil Fuels	CH ₄	0.42	0.19	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	-0.0003	0.0000	0.0000
1.A.4.a - Commercial/Institutional - Other Fossil Fuels	N₂O	0.02	0.01	5.00	275.00	275.05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.a - Commercial/Institutional - Biomass - solid	CH₄	2.56	2.29	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	-0.0012	0.0000	0.0000
1.A.4.a - Commercial/Institutional - Biomass - solid	N ₂ O	0.03	0.03	5.00	250.00	250.05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.a - Commercial/Institutional - Biomass - liquid	CH ₄		0.01	5.00	275.00	275.05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.a - Commercial/Institutional - Biomass - liquid	N₂O		0.00	5.00	412.50	412.53	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.b - Residential - Solid Fuels	CO ₂	48.90		5.00	12.46	13.43	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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		Input data	Input data	Input data	Input data				Note B		I * F] * E * √2	$K^2 + L^2$
		Gg CO₂e	Gg CO₂e	%	%	%			%	%	%	%	%
1.A.4.b - Residential - Solid Fuels	CH ₄	0.16		5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.b - Residential - Solid Fuels	N ₂ O	0.00		5.00	222.22	222.28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.b - Residential - Other Fossil Fuels	CO ₂	23,965.50	28,098.85	5.00	5.94	7.76	0.1305	0.0399	-0.0441	0.0546	-0.2617	0.3857	0.2173
1.A.4.b - Residential - Other Fossil Fuels	CH ₄	3.22	2.22	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	-0.0018	0.0000	0.0000
1.A.4.b - Residential - Other Fossil Fuels	N ₂ O	0.21	0.42	5.00	275.00	275.05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.b - Residential - Biomass - solid	CH ₄	367.61	29.97	5.00	200.00	200.06	0.0204	0.0000	-0.0015	0.0001	-0.2909	0.0004	0.0846
1.A.4.b - Residential - Biomass - solid	N ₂ O	4.90	0.40	5.00	250.00	250.05	0.0000	0.0000	0.0000	0.0000	-0.0048	0.0000	0.0000
1.A.4.b - Residential - Biomass - gas	CH ₄		0.01	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.b - Residential - Biomass - gas	N ₂ O		0.00	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.c.i - Stationary - Other Fossil Fuels	CO ₂	11,296.62	3,866.20	5.00	1.32	5.17	0.0129	0.0003	-0.0390	0.0075	-0.0514	0.0531	0.0055
1.A.4.c.i - Stationary - Other Fossil Fuels	CH ₄	1.54	0.52	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	-0.0011	0.0000	0.0000
1.A.4.c.i - Stationary - Other Fossil Fuels	N ₂ O	0.09	0.03	5.00	275.00	275.05	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0000	0.0000
1.A.4.c.i - Stationary - Biomass - liquid	CH ₄		0.13	5.00	275.00	275.05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.4.c.i - Stationary - Biomass - liquid	N ₂ O		0.01	5.00	412.50	412.53	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.1.c.ii - Other Energy Industries - Other Fossil Fuels	CO ₂	9,561.43	10,276.87	5.00	5.73	7.60	0.0199	0.0051	-0.0194	0.0200	-0.1111	0.1411	0.0323
1.A.1.c.ii - Other Energy Industries - Other Fossil Fuels	CH ₄	0.17	0.18	5.00	233.33	233.38	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0000	0.0000
1.A.1.c.ii - Other Energy Industries - Other Fossil Fuels	N ₂ O	0.02	0.02	5.00	275.00	275.05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.m - Non-specified Industry - Solid Fuels	CO ₂	20,443.06	12,228.41	5.00	12.46	13.43	0.2839	0.0226	-0.0604	0.0237	-0.7521	0.1679	0.5939
1.A.2.m - Non-specified Industry - Solid Fuels	CH₄	2.13	1.27	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	-0.0013	0.0000	0.0000

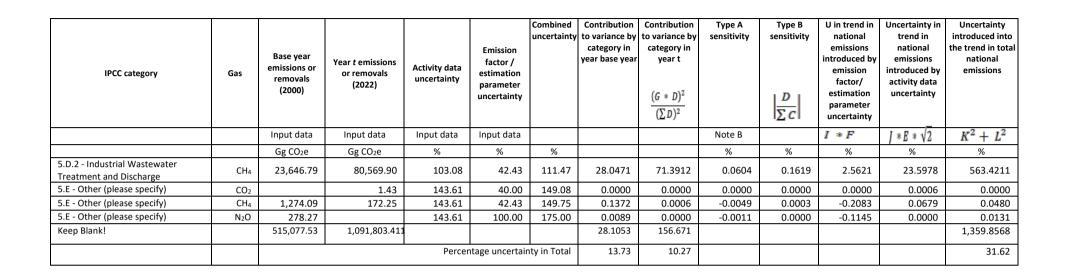
IPCC category	Gas	Base year emissions or removals (2000)	Year t emissions or removals (2022)	Activity data uncertainty	Emission factor / estimation parameter uncertainty	Combined uncertainty	Contribution to variance by category in year base year	category in	Type A sensitivity	Type B sensitivity $\left \frac{D}{\sum C} \right $	U in trend in national emissions introduced by emission factor/ estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data				Note B		I * F] * E * √2	$K^2 + L^2$
		Gg CO₂e	Gg CO₂e	%	%	%			%	%	%	%	%
1.A.2.m - Non-specified Industry - Solid Fuels	N ₂ O	0.32	0.19	5.00	222.22	222.28	0.0000	0.0000	0.0000	0.0000	-0.0002	0.0000	0.0000
1.A.2.m - Non-specified Industry - Other Fossil Fuels	CO ₂	51,221.77	13,431.35	5.00	1.62	5.26	0.2732	0.0042	-0.1845	0.0261	-0.2989	0.1844	0.1234
1.A.2.m - Non-specified Industry - Other Fossil Fuels	CH ₄	1.74	0.52	5.00	233.33	233.38	0.0000	0.0000	0.0000	0.0000	-0.0014	0.0000	0.0000
1.A.2.m - Non-specified Industry - Other Fossil Fuels	N ₂ O	0.32	0.10	5.00	108.33	108.45	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0000	0.0000
1.A.2.m - Non-specified Industry - Biomass - solid	CH ₄	10.39	10.24	5.00	222.22	222.28	0.0000	0.0000	0.0000	0.0000	-0.0051	0.0001	0.0000
1.A.2.m - Non-specified Industry - Biomass - solid	N ₂ O	1.39	1.37	5.00	275.00	275.05	0.0000	0.0000	0.0000	0.0000	-0.0008	0.0000	0.0000
1.A.2.m - Non-specified Industry - Biomass - liquid	CH ₄		0.08	5.00	300.00	300.04	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.2.m - Non-specified Industry - Biomass - liquid	N ₂ O		0.02	5.00	412.50	412.53	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.3.a.ii - Domestic Aviation - Liquid Fuels	CO ₂	2,982.63	8,315.45	5.00	0.89	5.08	0.0009	0.0015	0.0039	0.0161	0.0034	0.1142	0.0130
1.A.3.a.ii - Domestic Aviation - Liquid Fuels	CH ₄	0.02	0.06	5.00	100.00	100.12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.3.a.ii - Domestic Aviation - Liquid Fuels	N ₂ O	0.08	0.23	5.00	150.00	150.08	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.3.b.i - Cars - Other Fossil Fuels	CO ₂	53,663.20	145,306.81	5.00	1.98	5.38	0.3139	0.5123	0.0612	0.2821	0.1212	1.9948	3.9939
1.A.3.b.i - Cars - Other Fossil Fuels	CH ₄	14.87	43.69	5.00	5.00	7.07	0.0000	0.0000	0.0000	0.0001	0.0001	0.0006	0.0000
1.A.3.b.i - Cars - Other Fossil Fuels	N ₂ O	2.65	7.14	5.00	5.00	7.07	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
1.A.3.b.i - Cars - Biomass - liquid	CH ₄		1.00	5.00	302.56	302.60	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.3.b.i - Cars - Biomass - liquid	N ₂ O		0.20	5.00	200.00	200.06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.3.c - Railways - Other Fossil Fuels	CO ₂	620.68	1,178.46	5.00	1.21	5.14	0.0000	0.0000	-0.0003	0.0023	-0.0003	0.0162	0.0003
1.A.3.c - Railways - Other Fossil Fuels	CH ₄	0.04	0.07	5.00	5.00	7.07	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.3.c - Railways - Other Fossil Fuels	N ₂ O	0.24	0.46	5.00	5.00	7.07	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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		Input data	Input data	Input data	Input data				Note B		I * F] * E * √2	$K^2 + L^2$
		Gg CO₂e	Gg CO₂e	%	%	%			%	%	%	%	%
1.A.3.d.ii - Domestic Water-borne Navigation - Other Fossil Fuels	CO ₂	375.21	154.83	5.00	1.52	5.23	0.0000	0.0000	-0.0012	0.0003	-0.0019	0.0021	0.0000
1.A.3.d.ii - Domestic Water-borne Navigation - Other Fossil Fuels	CH ₄	0.03	0.01	5.00	5.00	7.07	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.A.3.d.ii - Domestic Water-borne Navigation - Other Fossil Fuels	N ₂ O	0.01	0.00	5.00	5.00	7.07	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.B.1 - Fugitive Emissions from Fuels - Solid Fuels													
1.B.1.a.i.1 - Mining	CO ₂	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.B.1.a.ii.1 - Mining	CH ₄	433.58	3,182.97	5.00	300.00	300.04	0.0638	0.7651	0.0044	0.0062	1.3186	0.0437	1.7406
1.B.1.a.ii.2 - Post-mining seam gas emissions	CH ₄	144.53	1,060.99	5.00	300.00	300.04	0.0071	0.0850	0.0015	0.0021	0.4395	0.0146	0.1934
1.B.2.a.i - Venting	CO ₂	148.01	63.93	5.00	75.00	75.17	0.0005	0.0000	-0.0005	0.0001	-0.0364	0.0009	0.0013
1.B.2.a.i - Venting	CH ₄	20,030.98	8,652.50	5.00	75.00	75.17	8.5449	0.3548	-0.0656	0.0168	-4.9207	0.1188	24.2272
1.B.2.a.i - Venting	N ₂ O			5.00		0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.B.2.a.ii - Flaring	CO ₂	3,544.23	1,530.95	5.00	75.00	75.17	0.2675	0.0111	-0.0116	0.0030	-0.8709	0.0210	0.7590
1.B.2.a.ii - Flaring	CH ₄	495.02	213.83	5.00	75.00	75.17	0.0052	0.0002	-0.0016	0.0004	-0.1216	0.0029	0.0148
1.B.2.a.ii - Flaring	N ₂ O	13.25	5.72	5.00	75.00	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
1.B.2.a.iii.2 - Production and Upgrading	CO ₂	23.02	9.95	5.00	800.00	800.02	0.0013	0.0001	-0.0001	0.0000	-0.0603	0.0001	0.0036
1.B.2.a.iii.2 - Production and Upgrading	CH ₄	5,065.31	2,187.99	5.00	800.00	800.02	61.8962	2.5704	-0.0166	0.0042	-13.2765	0.0300	176.2668
1.B.2.a.iii.2 - Production and Upgrading	N ₂ O			5.00		0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.B.2.a.iii.3 - Transport	CO ₂	35.99	15.55	5.00	200.00	200.06	0.0002	0.0000	-0.0001	0.0000	-0.0236	0.0002	0.0006
1.B.2.a.iii.3 - Transport	CH ₄	265.70	114.77	5.00	200.00	200.06	0.0107	0.0004	-0.0009	0.0002	-0.1741	0.0016	0.0303
1.B.2.a.iii.3 - Transport	N ₂ O	0.05	0.02	5.00	200.00	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.B.2.b.i - Venting	CO ₂	3,249.80	2,270.82	5.00	999.99	1,000.0 0	39.8080	4.3259	-0.0090	0.0044	-8.9645	0.0312	80.3629
1.B.2.b.i - Venting	CH ₄	100.09	69.94	5.00	999.99	0.00	0.0000	0.0000	-0.0003	0.0001	0.0000	0.0010	0.0000
1.B.2.b.ii - Flaring	CO ₂	1,080.63	755.10	5.00	800.00	800.02	2.8171	0.3061	-0.0030	0.0015	-2.3848	0.0104	5.6875
1.B.2.b.ii - Flaring	CH ₄	447.57	312.74	5.00	800.00	800.02	0.4833	0.0525	-0.0012	0.0006	-0.9878	0.0043	0.9757
1.B.2.b.ii - Flaring	N ₂ O	2.63	1.84	5.00	999.99	1,000.0 0	0.0000	0.0000	0.0000	0.0000	-0.0073	0.0000	0.0001
1.B.2.b.iii.2 - Production	CO ₂	1.14	0.79	5.00	250.00	250.05	0.0000	0.0000	0.0000	0.0000	-0.0008	0.0000	0.0000

IPCC category	Gas	Base year emissions or removals (2000)	Year t emissions or removals (2022)	Activity data uncertainty	Emission factor / estimation parameter uncertainty	Combined uncertainty	Contribution to variance by category in year base year	Contribution to variance by category in year t $\frac{(G*D)^2}{(\sum D)^2}$	Type A sensitivity	Type B sensitivity $\left \frac{D}{\sum C} \right $	U in trend in national emissions introduced by emission factor/ estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data				Note B		I * F	J * E * √2	$K^2 + L^2$
		Gg CO₂e	Gg CO₂e	%	%	%			%	%	%	%	%
1.B.2.b.iii.2 - Production	CH ₄	864.38	603.99	5.00	250.00	250.05	0.1761	0.0191	-0.0024	0.0012	-0.5961	0.0083	0.3554
1.B.2.b.iii.3 - Processing	CO ₂	0.97	0.68	5.00	250.00	250.05	0.0000	0.0000	0.0000	0.0000	-0.0007	0.0000	0.0000
1.B.2.b.iii.3 - Processing	CH ₄	341.20	238.42	5.00	250.00	250.05	0.0274	0.0030	-0.0009	0.0005	-0.2353	0.0033	0.0554
1.B.2.b.iii.4 - Transmission and Storage	CO ₂	0.07	0.05	5.00	250.00	250.05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.B.2.b.iii.4 - Transmission and Storage	CH ₄	377.60	263.85	5.00	250.00	250.05	0.0336	0.0037	-0.0010	0.0005	-0.2604	0.0036	0.0678
1.B.2.b.iii.5 - Distribution	CO ₂	4.14	2.90	5.00	500.00	500.02	0.0000	0.0000	0.0000	0.0000	-0.0057	0.0000	0.0000
1.B.2.b.iii.5 - Distribution	CH ₄	2,502.15	1,748.39	5.00	500.00	500.02	5.9002	0.6412	-0.0069	0.0034	-3.4511	0.0240	11.9110
2 - Industrial Processes and													
Product Use													
2.A.1 - Cement production	CO ₂	16,174.11	28,876.76	2.00	5.00	5.39	0.0286	0.0203	-0.0105	0.0561	-0.0525	0.1586	0.0279
2.A.2 - Lime production	CO ₂	3,688.15	112.55	10.00	2.00	10.20	0.0053	0.0000	-0.0150	0.0002	-0.0299	0.0031	0.0009
2.A.3 - Glass Production	CO ₂	245.31	45.58	10.00	10.00	14.14	0.0000	0.0000	-0.0009	0.0001	-0.0092	0.0013	0.0001
2.A.4 - Other Process Uses of Carbonates	CO ₂	8,415.69	2,445.14	17.32	17.32	24.49	0.1602	0.0030	-0.0299	0.0047	-0.5175	0.1163	0.2814
2.B.1 - Ammonia Production	CO ₂	6,139.06	6,846.42	10.00	6.00	11.66	0.0193	0.0053	-0.0120	0.0133	-0.0718	0.1880	0.0405
2.B.2 - Nitric Acid Production	N ₂ O	127.59	865.45	2.00	10.00	10.20	0.0000	0.0001	0.0012	0.0017	0.0116	0.0048	0.0002
2.B.5 - Carbide Production	CO ₂	24.47	26.25	10.00	10.00	14.14	0.0000	0.0000	0.0000	0.0001	-0.0005	0.0007	0.0000
2.B.8 - Petrochemical and Carbon Black Production	CO ₂	1,825.63	2,494.13	22.36	22.36	31.62	0.0126	0.0052	-0.0027	0.0048	-0.0597	0.1531	0.0270
2.B.8 - Petrochemical and Carbon Black Production	CH ₄	93.75	102.84	22.36	22.36	31.62	0.0000	0.0000	-0.0002	0.0002	-0.0042	0.0063	0.0001
2.C.1 - Iron and Steel Production	CO ₂	1,301.76	10,303.58	10.00	10.00	14.14	0.0013	0.0178	0.0146	0.0200	0.1465	0.2829	0.1015
2.C.1 - Iron and Steel Production	CH ₄	37.96	0.00	10.00	10.00	14.14	0.0000	0.0000	-0.0002	0.0000	-0.0016	0.0000	0.0000
2.C.3 - Aluminum production	CO ₂	384.00	447.32	2.00	5.00	5.39	0.0000	0.0000	-0.0007	0.0009	-0.0036	0.0025	0.0000
2.C.3 - Aluminum production	CF4	254.59	55.61	2.00	5.00	5.39	0.0000	0.0000	-0.0009	0.0001	-0.0047	0.0003	0.0000
2.C.3 - Aluminum production	C2F6	26.64	0.00	2.00	5.00	5.39	0.0000	0.0000	-0.0001	0.0000	-0.0005	0.0000	0.0000
2.C.5 - Lead Production	CO ₂	19.05	118.83	10.00	10.00	14.14	0.0000	0.0000	0.0002	0.0002	0.0015	0.0033	0.0000
2.C.6 - Zinc Production	CO ₂	123.62	111.64	10.00	10.00	14.14	0.0000	0.0000	-0.0003	0.0002	-0.0029	0.0031	0.0000
2.D - Non-Energy Products from Fuels and Solvent Use	CO ₂	831.33	4,358.07	14.14	14.14	20.00	0.0010	0.0064	0.0050	0.0085	0.0713	0.1692	0.0337
2.H - Other	CO ₂	92.25	151.46	14.14	2.83	14.42	0.0000	0.0000	-0.0001	0.0003	-0.0002	0.0059	0.0000
3.A. Enteric Fermentation													

IPCC category	Gas	Base year emissions or removals (2000)	Year t emissions or removals (2022)	Activity data uncertainty	Emission factor / estimation parameter uncertainty	Combined uncertainty	Contribution to variance by category in year base year	Contribution to variance by category in year t $\frac{(G*D)^2}{(\sum D)^2}$	Type A sensitivity	Type B sensitivity $\left \frac{D}{\sum C} \right $	U in trend in national emissions introduced by emission factor/ estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data				Note B		I * F	J * E * √2	$K^2 + L^2$
		Gg CO₂e	Gg CO₂e	%	%	%			%	%	%	%	%
3.A.1.a.i. Mature dairy cattle	CH ₄	499.51	870.62	20.00	20.00	28.28	0.0008	0.0005	-0.0004	0.0017	-0.0073	0.0478	0.0023
3.A.1.a.ii. Other mature cattle	CH ₄	15,207.36	26,103.76	20.00	20.00	28.28	0.6974	0.4573	-0.0119	0.0507	-0.2380	1.4334	2.1114
3.A.2. Sheep	CH ₄	820.87	1,781.05	20.00	20.00	28.28	0.0020	0.0021	0.0001	0.0035	0.0016	0.0978	0.0096
3.A.3. Babi	CH ₄	1,856.64	2,381.62	20.00	20.00	28.28	0.0104	0.0038	-0.0030	0.0046	-0.0603	0.1308	0.0207
3.A.4.a. Buffalo	CH ₄	4,592.19	2,332.37	20.00	20.00	28.28	0.0636	0.0037	-0.0144	0.0045	-0.2874	0.1281	0.0990
3.A.4.d. Goat	CH ₄	1,388.28	2,184.22	20.00	20.00	28.28	0.0058	0.0032	-0.0015	0.0042	-0.0295	0.1199	0.0153
3.A.4.e. Kuda	CH ₄	1,116.06	1,067.23	20.00	20.00	28.28	0.0038	0.0008	-0.0025	0.0021	-0.0504	0.0586	0.0060
3.B.C. Manure Management	CH ₄												
3.B.1.a.i. Mature dairy cattle	CH ₄	10.03	17.48	20.00	20.00	28.28	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0010	0.0000
3.B.1.a.ii. Other mature cattle	CH₄	469.78	806.39	20.00	20.00	28.28	0.0007	0.0004	-0.0004	0.0016	-0.0074	0.0443	0.0020
3.A.2. Sheep	CH ₄	10.22	22.33	20.00	20.00	28.28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0000
3.A.3. Swine	CH ₄	899.95	1,223.09	20.00	20.00	28.28	0.0024	0.0010	-0.0013	0.0024	-0.0266	0.0672	0.0052
3.A.4.a. Buffalo	CH ₄	141.86	72.05	20.00	20.00	28.28	0.0001	0.0000	-0.0004	0.0001	-0.0089	0.0040	0.0001
3.A.4.d. Goats	CH ₄	9.61	14.87	20.00	20.00	28.28	0.0000	0.0000	0.0000	0.0000	-0.0002	0.0008	0.0000
3.A.4.e. Horses	CH ₄	25.29	24.18	20.00	20.00	28.28	0.0000	0.0000	-0.0001	0.0000	-0.0011	0.0013	0.0000
3.A.4.g. Poultry	CH ₄	97.10	350.16	20.00	20.00	28.28	0.0000	0.0001	0.0003	0.0007	0.0056	0.0192	0.0004
3.B.1.a.i. Mature dairy cattle	N ₂ O												
3.B.1.a.ii. Other mature cattle	N ₂ O	3,761.49	6,456.68	20.00	79.06	81.55	0.3547	0.2326	-0.0029	0.0125	-0.2328	0.3546	0.1799
3.A.2. Sheep	N ₂ O	501.97	1,083.42	20.00	79.06	81.55	0.0063	0.0065	0.0000	0.0021	0.0030	0.0595	0.0035
3.A.3. Swine	N ₂ O	341.69	438.31	20.00	79.06	81.55	0.0029	0.0011	-0.0006	0.0009	-0.0439	0.0241	0.0025
3.A.4.a. Buffalo	N ₂ O	1,146.74	581.32	20.00	79.06	81.55	0.0330	0.0019	-0.0036	0.0011	-0.2839	0.0319	0.0816
3.A.4.d. Goats	N ₂ O	996.64	1,558.72	20.00	79.06	81.55	0.0249	0.0136	-0.0011	0.0030	-0.0850	0.0856	0.0146
3.A.4.e. Horses	N ₂ O	236.21	225.87	20.00	79.06	81.55	0.0014	0.0003	-0.0005	0.0004	-0.0422	0.0124	0.0019
3.A.4.g. Poultry	N ₂ O	173.22	727.48	20.00	79.06	81.55	0.0008	0.0030	0.0007	0.0014	0.0553	0.0399	0.0047
3.B.5. Indirect N ₂ O emissions	N ₂ O	978.31	1,890.49	20.00	140.48	141.90	0.0726	0.0604	-0.0004	0.0037	-0.0500	0.1038	0.0133
3.C. Rice Cultivation	CH ₄												
3.C.1.a. Continuously flooded	CH ₄	40,845.02	36,942.72	20.00	39.42	44.20	12.2869	2.2371	-0.0963	0.0717	-3.7957	2.0286	18.5229
3.C.2.b. Drought-prone	CH ₄	5,397.99	9,898.87	20.00	40.71	45.36	0.2260	0.1691	-0.0030	0.0192	-0.1220	0.5436	0.3103
3.D. Agriculture Soil													
3.D.1.a. Inorganic N fertilizers	N ₂ O	4,773.71	6,246.10	20.00	67.20	70.11	0.4223	0.1609	-0.0075	0.0121	-0.5052	0.3430	0.3729
3.D.1.b. Organic N fertilizers	N ₂ O	1,989.87	3,390.89	20.00	67.20	70.11	0.0734	0.0474	-0.0016	0.0066	-0.1079	0.1862	0.0463
3.D.1.c. Urine and dung deposited by grazing animals	N ₂ O	1,612.07	2,767.15	20.00	75.66	78.26	0.0600	0.0393	-0.0013	0.0054	-0.0955	0.1520	0.0322

IPCC category	Gas	Base year emissions or removals (2000)	Year t emissions or removals (2022)	Activity data uncertainty	Emission factor / estimation parameter uncertainty	Combined uncertainty	Contribution to variance by category in year base year	Contribution to variance by category in year t $\frac{(G*D)^2}{(\sum D)^2}$	Type A sensitivity	Type B sensitivity $\left \frac{D}{\sum C} \right $	U in trend in national emissions introduced by emission factor/ estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data				Note B		I * F	$J*E*\sqrt{2}$	$K^2 + L^2$
		Gg CO₂e	Gg CO₂e	%	%	%			%	%	%	%	%
3.D.1.d. Crop residues	N ₂ O	160.90	175.02	20.00	67.20	70.11	0.0005	0.0001	-0.0003	0.0003	-0.0217	0.0096	0.0006
3.D.1.f. Cultivation of organic soils (i.e. histosols)	N ₂ O	8,149.85	11,738.28	12.00	53.75	55.07	0.7593	0.3506	-0.0107	0.0228	-0.5777	0.3867	0.4833
3.D.2. Indirect N ₂ O Emissions from managed soils	N ₂ O	4,435.23	5,828.66	20.00	143.54	144.92	1.5573	0.5986	-0.0069	0.0113	-0.9955	0.3201	1.0935
3.E.1.Prescribed burning of savannahs	CH ₄	195.10	103.38	12.00	60.32	61.50	0.0005	0.0000	-0.0006	0.0002	-0.0363	0.0034	0.0013
3.E.2. Prescribed burning of savannahs	N ₂ O	118.51	52.81	12.00	66.14	67.22	0.0002	0.0000	-0.0004	0.0001	-0.0255	0.0017	0.0007
3.F.1. Field burning of agricultural residues	CH ₄	1.45	0.98	12.00	70.71	71.72	0.0000	0.0000	0.0000	0.0000	-0.0003	0.0000	0.0000
3.F.2. Field burning of agricultural residues	N₂O	1.25	0.85	12.00	70.71	71.72	0.0000	0.0000	0.0000	0.0000	-0.0002	0.0000	0.0000
3.G.2. Liming	CO ₂	791.63	2,159.22	20.00	50.00	53.85	0.0069	0.0113	0.0009	0.0042	0.0467	0.1186	0.0162
3.H. Urea Application	CO ₂	3,435.33	4,047.21	20.00	50.00	53.85	0.1290	0.0398	-0.0063	0.0079	-0.3140	0.2222	0.1480
5.A - Solid Waste Disposal													
5.A.1 - Managed Waste Disposal Sites	CH ₄		33.08	36.06	30.41	47.17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5.A.2 - Unmanaged Waste Disposal Sites	CH ₄	11,555.21	21,691.46	46.90	35.00	58.52	1.8458	1.4261	-0.0060	0.0436	-0.2099	2.8906	8.3996
5.B - Biological Treatment of Solid Waste													
5.B - Biological Treatment of Solid Waste	CH ₄	0.00	2.09	30.00	100.00	104.40	0.0000	0.0000	0.0000	0.0000	0.0004	0.0002	0.0000
5.B - Biological Treatment of Solid Waste	N ₂ O	0.04	34.06	30.00	166.67	169.35	0.0000	0.0000	0.0001	0.0001	0.0110	0.0028	0.0001
5.C.2 - Open Burning of Waste	CO ₂	1,769.48	2,381.81	203.29	40.00	207.19	0.5066	0.2043	-0.0027	0.0046	-0.1063	1.3294	1.7787
5.C.2 - Open Burning of Waste	CH ₄	1,500.16	2,019.29	203.29	100.00	226.55	0.4354	0.1756	-0.0023	0.0039	-0.2253	1.1271	1.3211
5.C.2 - Open Burning of Waste	N ₂ O	173.84	233.99	203.29	100.00	226.55	0.0058	0.0024	-0.0003	0.0005	-0.0261	0.1306	0.0177
5.D - Wastewater Treatment and Discharge													
5.D.1 - Domestic Wastewater Treatment and Discharge	CH ₄	17,351.23	28,853.89	60.42	58.31	83.97	8.0010	4.9243	-0.0154	0.0560	-0.8969	4.7866	23.7160
5.D.1 - Domestic Wastewater Treatment and Discharge	N ₂ O	1,678.46	2,868.82	60.42	5.00	60.63	0.0390	0.0254	-0.0013	0.0056	-0.0067	0.4759	0.2265





ANNEX 3: THE CO₂ REFERENCE APPROACH, AND COMPARISON WITH THE SECTORAL APPROACH

The Reference Approach is a method applied to energy supply as apparent consumption. Based on the reported fuel consumption, each fuel has a carbon content that was used to estimate GHG emissions. Table A3-1 compare fuel consumption and CO₂ emission between reference and sectoral approach in 2022. In 2022 the energy consumption difference between two approaches is 0.56% and the emissions difference is 1.42%.

Table A3 - 1 Comparison between reference and sectoral approaches in 2022

	Reference Ap	proach	Sectoral Ap	proach	Differen	ice
Fuel	Apparent Consumption* (TJ)	CO ₂ Emissions (kt)	Energy Consumption (TJ)	CO ₂ Emissions (kt)	Energy Consumption (%)	CO ₂ Emissions (%)
Aviation Gasoline	43	3	41	3	5.77	8.04
Crude Oil	1,932,499	141,717			100.00	100.00
Jet Kerosene	-90,581	-6,554	114,878	8,313	-105.56	-104.25
Other Bituminous Coal	-	-	1,630,204	154,217	-100.00	-100.00
Sub-Bituminous Coal	4,380,366	420,807	2,750,162	264,291	59.28	59.22
Diesel Oil	1,506	112	2,354	175	-36.00	-36.00
Fuel Oil	2,555	199	166,265	12,952	-98.46	-98.46
Gas	1,237,807	71,347	1,164,348	67,113	6.31	6.31
Gasoil CN 48	220,428	16,153	996,212	73,002	-77.87	-77.87
Gasoil CN 51	-	-	38,768	2,827	-100.00	-100.00
Gasoil CN 53	35,888	2,614	12,747	929	181.55	181.55
Gasoline RON 88	559,302	38,967	646	45	86,460.48	86,486.19
Gasoline RON 90	-	-	1,016,139	70,408	-100.00	-100.00
Gasoline RON 92	154,001	10,632	197,631	13,644	-22.08	-22.08
Gasoline RON 98	3,278	226	10,914	752	-69.96	-69.96
Kerosene	-	-	17,550	1,271	-100.00	-100.00
LNG	-	-	170,056	9,739	-100.00	-100.00
LPG	329,270	21,534	428,730	28,039	-23.20	-23.20
Total	8,766,362	717,757	8,717,644	707,721	0.56	1.42

Note: *excluding non-energy use and feedstocks

ANNEX 4: QA/QC PLAN

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A4.1. Application of QA/QC

The implementation of QC and QA in the GHGI is essential for maintaining the transparency, accuracy, consistency, comparability, completeness, and integrity of the national inventory. This consequently enhances confidence in the reported information. The 2006 IPCC Guidelines define QC as general checks conducted by the inventory compiling agency during the preparation of the inventory, whereas QA encompasses reviews and audits performed by external agencies not involved in the inventory compilation process.

Indonesia has established a QA/QC guideline through the Ministry of Environment and Forestry, detailed in Regulation of the Minister of Environment and Forestry Number 12 of 2024, reflecting a commitment to the continuous enhancement of inventory compilation. QC in this regulation is conducted by the Directorate of GHGI and MRV in collaboration with the Sectoral Responsible Ministries/Agencies, encompassing the following activities:

- Verifying the precision of data collection and computations;
- Employing established standard methodologies for the calculation of GHG emissions and removals or their quantification;
- A technical review of source/sink categories, AD, EFs, proxy parameters, and methodologies employed in the implementation of the GHGI.

Two activities remain unaddressed in the QC process.:

- Uncertainty estimation.
- Consistency in data and information storage and reporting (e.g., file and folder naming conventions, worksheet protection measures).

The QA process involves conducting data, methodology, and technical reviews in collaboration with the Ministry's Expert Team (MoEF Methodology Panel). An independent team has not yet conducted QA. Table A4-1 presents the current state of the QC process, beginning with the responsible parties in the sub-sector.

Table A4- 1 Existing Condition of GHGI QA/QC in Indonesia

Stages	Description of Stages	Existing Condition	Gap
Stage I	The sub-sector responsible parties conduct QC on AD and EFs, and report the output to the sector coordinator	 The sub-sector responsible parties report the AD and/or EFs to the Sector Coordinator or directly to the NGHGI Responsible Party. The data checking mechanism has been carried out by the sub-sector responsible parties on the available data. 	 The mechanism for filling data gaps and analyzing the uncertainty level of AD and EFs has not been carried out. Data submission is not accompanied by a statement that all data has undergone the QC process. QC analysis reports have not been prepared. The data archiving system, starting from inconsistent file naming, worksheet protection, and the lack of templates for data archiving, is not yet available.

Stages	Description of Stages	Existing Condition	Gap
Stage II	The Sector Coordinator validates the documents from the sub-sectors, to conduct further QA/QC on the data	The Sector Coordinator collects data from the Subsectors, or the Subsectors directly send the data to the NGHGI Responsible Party without going through the Sector Coordinator.	The mechanism for document validation by the Sub-Sector Coordinators, with QA on: data gaps, uncertainty levels, KCA, and checking the difference in emission values between years, has not been performed;
Stage III	The Sector Coordinator reports the emission level data and related QA/QC documents to the NGHGI Responsible Party	The Sector Coordinator reports the data (AD and EFs) to the NGHGI Responsible Party.	The Sector Coordinators have not compiled Sectoral QA/QC Reports, which also contain the validated GHGI data.
Stage IV	The NGHGI Responsible Party conducts QA/QC (cross-checking emission level data, report format), before reporting the NGHGI to the UNFCCC	 The NGHGI Responsible Party collects data from the Sector Coordinators, or directly from the Sub-Sector Coordinators. The NGHGI Responsible Party has conducted QC by checking for missing data, KCA, and uncertainty analysis. Based on the verification results, the NGHGI Responsible Party compiles the (verified) GHGI Report. 	 The NGHGI Responsible Party collects data from the Sector Coordinators or directly from the Sub-Sector Coordinators. The NGHGI Responsible Party has conducted QC by checking for missing data and performing KCA. Together with the MRV Team and Methodology Panel, they have verified the AD, EFs, and the results of the estimation of GHG emission levels and trends. Proper uncertainty analysis has not been carried out. Checks on uncertainty values and differences in emission values between years have not been performed. Verification by an independent audit team has not been conducted. Activity-specific QA/QC reports for each stage are not available. Checks for errors and/or differences in emission values have not been conducted.

A4.2. Plan of Improvements QA/QC

The QA/QC plan of improvement shown in Table A4-2 includes the following stages:

- Evaluating the techniques for addressing data gaps, including a checklist to determine if the data filling employs one of the following methods: overlap, surrogate data, interpolation, or extrapolation.
- Methods for uncertainty analysis.
- Evaluating methodologies for assessing variations in emissions across different years.
- Procedures for data archiving, including file and folder naming conventions, file protection measures, and related practices.
- Appointment of personnel responsible for the QA and QC process.

The appointment of personnel (name, institution, contact) is governed by the Indonesian QA/QC Guidelines, which stipulate the following:

- The GHGI Responsible Party oversees all elements of the GHGI program, encompassing cross-cutting QA/QC responsibilities.
- The QA/QC Coordinator is tasked with the execution of the QA/QC plan.



- The Sector Coordinator is tasked with the implementation of QA/QC procedures within their sector.
- The implementing unit is tasked with executing the QC procedures within its subsector.
- Expert reviewers evaluate the GHGI documents.

Table A4- 2 The QA/QC Plan of Improvements for the GHG Inventory

Stages	Description of Stages	Gap	Plan of Improvements
Stage I	The sub-sector responsible parties conduct QC on AD and EFs, and report the output to the sector coordinator.	 The mechanism for filling data gaps and analyzing the uncertainty level of AD and EFs has not been carried out. Data submissions are not accompanied by a statement that all data has undergone the QC process. QC analysis reports have not been produced. The data archiving system, starting from inconsistent naming conventions (no data archiving template available). 	Standardization of data archiving, starting from file numbering and naming, folder organization, etc.
Stage II	The Sector Coordinator validates the documents from the Sub-sectors, to conduct further QA/QC on the data.	The mechanism for document validation by the Sub-Sector Coordinators, with Quality Assurance on: data gaps, uncertainty levels, KCA, and checking the difference in emission values between years, has not been performed.	 Implementation of QA/QC by the Sector Coordinator, covering data gaps, uncertainty levels, KCA, and checking the difference in emission values between years.
Stage III	The Sector Coordinator reports the emission level data and related QA/QC documents to the NGHGI Responsible Party.	The Sector Coordinators have not compiled Sectoral QA/QC Reports, which also contain the validated GHGI data.	Reporting of Sectoral QA/QC by the Sector Coordinator.
Stage IV	The NGHGI Responsible Party conducts QA/QC (cross-checking emission level data, report format), before reporting the NGHGI to the UNFCCC.	 The NGHGI Responsible Party collects data from the Sector Coordinators or directly from the Sub-Sector Coordinators. The NGHGI Responsible Party has conducted QC by checking for missing data, performing KCA, and uncertainty analysis. Together with the MRV Team and Methodology Panel, they have verified the AD, EFs, and the results of the estimation of GHG emission levels and trends. Checks on uncertainty values and differences in emission values between years have not been performed. Verification by an independent audit team has not been conducted. Activity-specific QA/QC reports for each stage are not available. 	 Standardization of the reporting flow and timelines from the Sector Coordinators. Checking the uncertainty values and differences in emission values between years. Conducting verification by an independent audit team. Collecting and reporting QA/QC activities from the Sector Coordinators. Compiling a QA/QC Report for the NGHGI Report.



ANNEX 5: QA/QC ADDITIONAL INFORMATION TO BE CONSIDERED AS PART OF THE NID SUBMISSION (WHERE RELEVANT) OR OTHER USEFUL REFERENCE INFORMATION

This section will present supplementary information required for reporting, as relevant, including comprehensive methodological descriptions of source or sink categories and the national emissions balance.



ANNEX 6: COMMON REPORTING TABLES

This section presents the GHG Inventory worksheets from 2000 to 2022. The tables are generated by importing them into the 2006 IPCC software and subsequently processed by the LTFs software. For each year, the following tables will be provided: Sectoral Background, Sectoral Reporting, and Cross-Sectoral Summary/Tables.

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