SOCIALIST REPUBLIC OF VIET NAM

MINISTRY OF NATURAL RESOURCES AND ENVIRONMENT

VIET NAM

Report on National GHG Inventory for 2016

HA NOI, 2020

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LIST OF ABBREVIATIONS

AD	Activity Data
AFOLU	Agriculture, Forestry and other Land Use
ALU	Agricultural and Land Use GHG Inventory
AR5	The 5th IPCC assessment report on climate change
BOD	Biochemical Oxygen Demand
BOF	Basic Oxygen Furnace
BUR	Biennial Updated Report
BTR	Biennial Transparency Report
COD	Chemical Oxygen Demand
COP	Conference of Parties
DCC	Department of Climate Change
DO	Diesel Oil
DOC	Degradable Organic Carbon
DOM	Dead organic matter
EAF	Electric Arc Furnace
EF	Emission Factor
ETF	Enhanced Transparency Framework
FAO	The Food and Agriculture Organization of the United Nations
FAOSTAT	FAO Statistics
FO	Fuel Oil
FOD	First Order Decay
GEF	Global Environment Facility
GHG	Greenhouse Gas
GPG	Good Practice Guidance
GPG 2000	The IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories
GPG 2003	The IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry
GSO	General Statistics Office
GWP	Global warming potential

HWP	Harvested Wood Products
IE	Institute of Energy
IP	Industrial Process
IPCC	Intergovernmental Panel on Climate Change
IPCC 1996 Revised	The Revised 1996 IPCC Guidelines for National Greenhouse Gas Greenhouse Gas Inventories
IPCC 2006	The 2006 IPCC Guidelines for National Greenhouse Gas Inventories
IPPU	Industrial Processes and Product Use
LKD	Lime kiln dust
LPG	Liquefied Petroleum Gas
LTO	Landing-Take Off Cycle
LULUCF	Land Use, Land Use Change and Forestry
MARD	Ministry of Agriculture and Rural Development
MOC	Ministry of Construction
MOH	Ministry of Health
MOIT	Ministry of Industry and Trade
MOT	Ministry of Transport
MONRE	Ministry of Natural Resources and Environment
MPI	Ministry of Planning and Investment
MRV	Measurement, Reporting and Verification
MSW	Municipal Solid Waste
NAMA	National Appropriate Mitigation Action
NC	National Communication
NDC	National Determined Contribution
NGO	Non-government Organization
NIR	National Inventory Report
ODS	Ozone Depleting Substances
OHF	Open Hearth Furnace
OPC	Ordinary Portland Cement
PA	Paris Agreement
PCB	Portland Cement Blended

PM	Prime Minister
PPC	People's Committee
QA	Quality Assurance
QC	Quality Control
SWD	Solid Waste Disposal
SWDS	Solid Waste Disposal Sites
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
VEA	Viet Nam Environment Administration

CHEMICAL FORMULA

C	Carbon
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2eq	Carbon dioxide equivalent
HFCs	Hydrofluorocarbons
NMVOC	Non-methane volatile organic compounds
NO_x	Nitrogen dioxide
N_2O	Nitrous oxide
SO_2	Sulfur dioxide

UNIT

^oC	Celsius degree
kg	Kilogram
kTOE	Kilotonne of oil equivalent
Mt	Million tonnes
kt	Thousand tonnes
t	Tonne
TJ	Tera joules

GLOSSARY

Accuracy	Inventory definition: Accuracy is a relative measure of the exactness of an emission or removal estimate. Estimates should be accurate in the sense that they are systematically neither over nor under true emissions or removals, as far as can be judged, and that uncertainties are reduced as far as practicable. Appropriate methodologies conforming to guidance on good practices should be used to promote accuracy in inventories. (FCCC/SBSTA/1999/6 Add. 1).
Activity data	Data on the magnitude of a human activity resulting in emissions or removals taking place during a given period of time. Data on energy use, metal production, land areas, management systems, lime and fertilizer use and waste arising are examples of activity data.
Anthropogenic	Man-made, resulting from human activities. In the IPCC Guidelines, anthropogenic emissions are distinguished from natural emissions. Many of the greenhouse gases are also emitted naturally. It is only the man-made increments over natural emissions which may be perturbing natural balances. In GPG-LULUCF, all emissions and removals of managed lands are seen as anthropogenic.
Category	Categories are subdivisions of the four main sectors Energy; Industrial Processes and Product Use (IPPU); Agriculture; Forestry and Land Use (AFOLU); and Waste. Categories may be further divided into subcategories.
Comparability	Comparability means that estimates of emissions and removals reported by countries in inventories should be comparable among countries. For this purpose, countries should use agreed methodologies and formats for estimating and reporting inventories.
Completeness	Completeness means that an inventory covers all sources and sinks and gases included in the IPCC Guidelines for the full geographic coverage in addition to other existing relevant source/sink categories which are specific to individual countries (and therefore may not be included in the IPCC Guidelines).
Consistency	Inventory definition: Consistency means that an inventory should be internally consistent in all its elements over a period of years. An inventory is consistent if the same methodologies are used for the base and all subsequent years and if consistent data sets are used to estimate emissions or removals from sources or sinks. Under certain circumstances referred to in paragraphs 10 and 11 of FCCC/SBSTA/1999/6 Add.1, an inventory using different methodologies for different years can be considered to be consistent if it has been recalculated in a transparent manner taking into account any good practices.
Emission factor	A coefficient that quantifies the emissions or removals of a gas per unit activity. Emission factors are often based on a sample of measurement data, averaged to develop a representative rate of emission for a given activity level under a given set of operating conditions.

Expert judgment	A carefully considered, well-documented qualitative or quantitative judgment made in the absence of unequivocal observational evidence by a person or persons who have a demonstrable expertise in the given field.
Good Practice	Good Practice is a set of procedures intended to ensure that greenhouse gas inventories are accurate in the sense that they are systematically neither over- nor underestimates so far as can be judged, and that uncertainties are reduced so far as possible. Good Practice covers choice of estimation methods appropriate to national circumstances, quality assurance and quality control at the national level, quantification of uncertainties and data archiving and reporting to promote transparency.
Key category	A key category is one that is prioritized within the national inventory system because its estimate has a significant influence on a country's total inventory of greenhouse gases in terms of the absolute level of emissions and removals, the trend in emissions and removals, or uncertainty in emissions or removals. Whenever the term key category is used, it includes both source and sink categories.
Transparency	Transparency means that the assumptions and methodologies used for an inventory should be clearly explained to facilitate replication and assessment of the inventory by users of the reported information. The transparency of inventories is fundamental to the success of the process for the communication and consideration of information.

PREFACE

Pursuant to Decision 2/CP.17 dated 15 March 2012 of the 17th session of the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC), the Ministry of Natural Resources and Environment (MONRE) - the Viet Nam national focal point for the implementation of the UNFCCC, the Kyoto Protocol and the Paris Agreement, took lead and coordinated with relevant ministries, departments and agencies to develop and complete the third Biennial Updated Report (BUR3) of Viet Nam to the UNFCCC and the Technical Report on national greenhouse gas (GHG) inventories for 2016 (NIR 2016).

The NIR 2016, developed according to the guidelines of the Intergovernmental Panel on Climate Change (IPCC), includes six chapters and four annexes with technical information on activity data (AD), emission factors (EFs) and emission/remove results of GHG inventory in 2016, including: energy; industrial processes and product use (IPPU); agriculture, forestry and other land use (AFOLU) and waste. In addition, the recalculation of GHG inventories for 2010 and 2014 was also carried out to ensure inventory principles are accurate, comparable, complete, consistent and transparent. The NIR 2016 marks an important step forward in improving transparency of national GHG inventory reports. Therefore, Viet Nam can gradually respond to the requirements of the enhanced transparency framework (ETF) of the UNFCCC to prepare for the implementation of the provisions of the 2020 Law on Environmental Protection. In particular, the contents on GHG emission reduction and the implementation of GHG emission reduction targets in the updated National Determined Contribution (NDC) of Viet Nam in 2020. In addition, the report also demonstrates the Government’s contributions to responding to climate change as well as to the country’s development, actively participates with the international community in the implementation of the goals of the UNFCCC and the Paris Agreement in the complex and challenging context of the COVID-19 pandemic.

MONRE wishes to thank the ministries, departments, localities and agencies for their active supports as well as of domestic and international experts and scientists for their valuable contributions; international organisations, notably the Global Environment Facility (GEF), the United Nations Environment Programme (UNEP) for financing support for the development of the Report.

MONRE hopes that the NIR 2016 is one of the supporting tools for state management and the policy-making process to effectively respond to climate change, and is also a useful reference for public service research and information dissemination.

EXECUTIVE SUMMARY

General Information

The GHG inventory is an important part of the BUR as well as the National Communications (NC) to the UNFCCC. The purpose of a national GHG inventory is to estimate the country's total GHG emissions/removals and to identify key GHG emission sources and sinks. On that basis, it is possible to develop and evaluate GHG emission reduction solutions suitable to national conditions to contribute to the implementation of the UNFCCC, the Paris Agreement and Viet Nam's updated NDC in 2020 as well as strategies and policies on climate change responses, green growth and low-carbon economic development, contributing to efforts to cope with global climate change.

Viet Nam has implemented national GHG inventories for the inventory years of 1994 (INC), 2000 (SNC), 2010 (BUR1), 2013 (BUR2) and 2014 (TNC) for five sectors, including energy; industrial processes (IP); agriculture, land use, land use change and forestry (LULUCF); and waste.

Under the framework of the BUR3 project, Viet Nam conducted a national GHG inventory for year 2016 and recalculated the national GHG inventory for year 2010 and 2014 among sectors: energy, IPPU, AFOLU and waste. In previous time, the implementation of national GHG inventories was in accordance with the revised 1996 IPCC Guidelines. Currently, despite not being required by international regulations, the 2016 national GHG inventories were conducted based on IPCC 2006 Guidelines. This is also a preparatory step for the mandatory implementation of BTR from 2024 onwards.

Implementation of national GHG inventory for 2016

The institutional arrangements for the 2016 national GHG inventor are in accordance with the national GHG inventory system specified under the Prime Minister Decision No.2359/2015/QD-TTg dated December 22, 2015 (Figure 1.1).

The Department of Climate Change (DCC) under MONRE is responsible for GHG inventory development; lead and coordinate with relevant agencies in the GHG inventory implementation system and compile technical reports.

The General Statistics Office (GSO) under Ministry of Planning and Investment (MPI) collects/controls data from the focal points including the Ministry of Industry and Trade (MOIT), the Ministry of Transport (MOT), the Ministry of Agriculture and Rural Development (MARD), the Ministry of Construction (MOC) and the People's Committees (PPCs) of provinces/cities, then provide AD and related information to the DCC-MONRE for implementing GHG inventory. Moreover, other relevant information and data are collected from agencies and organizations outside of the national GHG inventory system.

The results of national GHG inventory in Viet Nam are published, updated, archived and administered on the information system on Viet Nam's GHG national inventory at the website of the DCC-MONRE.

Methodology for national GHG inventory for 2016

The national GHG inventory for 2016 was conducted following the IPCC guidelines, including: the 2006 IPCC Guidelines for national GHG inventories (IPCC 2006 Guidelines); the 2019 refinement to the 2006 IPPC Guidelines; the Revised 1996 IPCC Guidelines for national GHG inventories (IPCC 1996 Revised); the IPCC Good practice guidance and uncertainty management in national GHG inventories (GPG 2000); the IPCC Good practice guidance for land use, land-use change and forestry (GPG 2003).

In addition, the emission of AFOLU was calculated with the agricultural and land use GHG inventory (ALU) software developed by the Colorado State University and based on the 2006 IPCC guidelines.

Categories are considered in the 2016 national GHG inventory are: (1) energy, (2) IPPU, (3) AFOLU, and (4) waste.

AD and related information are collected and aggregated from national statistics, government agencies, central and local organizations. Also, a part of them is obtained from scientific documents and reports of international cooperation projects. The approach of collecting, aggregating and processing AD is top-down. However, since the national data is not categorized fully following the IPCC classification, the AD for some sub-sectors in energy and IPPU are based on bottom-up approach.

The majority of EFs, parameters and conversion factors used in national GHG inventories were default values of IPCC 2006 Guidelines. In addition, some in-country specific EFs, parameters and conversion factors were also used.

Global warming potential

The global warming potential (GWP) value for 100 years were applied to 2016 GHG national inventory and recalculated for 2010 and 2014 according to the fifth IPCC Assessment report on climate change (AR5) published in 2014.

Results of national GHG inventory for 2016

Total GHG emissions/removals in 2016 in Viet Nam was 316,734.96 thousand tCO_2eq. Among which, the energy sector accounted for biggest share of 65% while IPPU takes second, 14.6%. The third biggest sector went to AFOLU, 13.9%, followed by the waste sector, 6.5%, as detailed in Table 1.

Table 1 GHG emissions/removals for 2016

IPCC Code	Sector	CO_2	CH_4	N_2O	HFCs	Total	Ratio
		$ktCO_2eq$					%
Total net emissions		**191,651.08**	**106,838.29**	**18,222.26**	**23.32**	**316,734.96**	**100**
1	Energy	182,291.22	22,345.35	1,195.63		205,832.20	65.0
2	IPPU	46,047.20		24.12	23.32	46,094.64	14.6
3	AFOLU	-37,489.34	66,544.64	15,014.44		44,069.74	13.9
4	Waste	802.00	17,948.30	1,988.07		20,738.38	6.5

Note: *Negative value (-) shows the GHG removal of sinks*

Energy sector: Total GHG emissions in 2016 were 205,832.20 $ktCO_2eq$, accounting for 65.0% of total national emissions. Of which, the largest emissions came from energy industry, 91,004.80 $ktCO_2eq$, equivalent to 44.2% of the sector total emissions.

IPPU sector: Total GHG emissions in 2016 were 46,094.64 $ktCO_2eq$, accounting for 14.6% of total national emissions. Of which, the largest emission came from the cement production, 36,773.00 $ktCO_2eq$, equivalent to 79.8% of the sector total emissions.

AFOLU sector: Total GHG emissions/removals in 2016 were 44,069.74 $ktCO_2eq$, accounting for 13.9% of total national emissions. Of which, the largest removal of -54,657.78 $ktCO_2eq$ came from the forest land and the largest emission of 49,693.02 $ktCO_2eq$ came from the rice cultivation.

Waste sector: Total GHG emissions in 2016 were 20,738.38 $ktCO_2eq$, accounting for 6.5% of total national emissions. Of which, the largest emission of 10,438.86 $ktCO_2eq$ came from the managed solid waste disposal, accounting for 50.3% of the sector total emissions.

Key category analysis in 2016 and uncertainty assessments

The analysis of key emissions/removals was done based on IPCC 2006 Guidelines to identify the largest emissions that accumulate to 95% of total national net emissions. Viet Nam has 42 key emission/removal categories in 2016, which contribute to 95.1% of total 158 GHG emission sources/sinks. In particular, the largest source went to the electricity generation (1A1ai), occupying 20.6% of overall emission.

The uncertainties of selected AD, EFs, parameters and conversion factors were default values or a value within the default range according to IPCC 1996 Revised, GPG 2000, GPG 2003 and IPCC 2006 Guidelines. The uncertainty assessment helps improve next inventory years. The emission/removal uncertainties in the sector of energy, IPPU, AFOLU and waste were 5.6%, 26.9%, 100.2% and 20.3%, respectively.

Recalculation of previous national GHG inventories

In the framework of developing BUR3, recalculation of the national GHG inventories for 2010 and 2014 was conducted including updating AD according to national statistics as well as EFs and some parameters, conversion factors were applied in the 2016 national GHG inventories to ensure principles of the GHG inventory such as transparency, accuracy, completeness, comparability, consistency.

In accordance with the IPCC 2006 Guidelines, EFs and AD, conversion factors, updated parameters and updated IPCC GWP values (AR5, 2014), the recalculated results of Viet Nam's net GHG emissions for 2010 increased by 7% compared to those reported in the BUR1 with the biggest difference in IPPU, increasing by 22.1%, followed by waste, increasing by 15.8%. Similarly, recalculated results of the net GHG emissions for 2014 fell by 1.9% compared to those given in NC3, in which the most significant difference was a decrease of 13.8% in AFOLU. In the meantime, values of recalculated emissions for IPPU did not vary much from the published results.

The comparison of all the recalculated results of GHG emissions/removals for 2010 and the 2014 proves that total 2016 net emissions increased by 13.7% against 2014 and 19.9% against 2010. The direct cause was an increase of 17.3% and 19.0% of GHG emissions in the energy and IPPU sectors compared to 2014, respectively; an increase of 35.5% and 78.4% of GHG emissions in the energy and the IPPU sectors in 2016 compared to 2010. In AFOLU sector, net emissions in 2016 decreased by 2.1% and 35.9% compared to 2014 and 2010, respectively. In the waste sector, GHG emissions in 2016 increased by 7.0% and 16.7% compared to 2014 and 2010, respectively.

CHAPTER 1
INTRODUCTION

1.1 Legal basis for national GHG inventory

Viet Nam joined officially and ratified the UNFCCC in 1992 and 1994, respectively; signed and ratified the Kyoto Protocol in 1998 and 2002; approved the Doha Amendment and Supplement later on; participated in and approved the Paris Agreement in 2015 and April 2016. The Paris Agreement is the first global framework legally binding the responsibilities of all Parties to it for climate change mitigation, adaptation for sustainable development. MONRE was assigned as the national focal point for the implementation of the UNFCCC, the Kyoto Protocol, and the Paris Agreement. The preparation of NCs, BURs including Viet Nam's national GHG inventory to the UNFCCC is done within the framework of the implementation of the UNFCCC, the Kyoto Protocol and the Paris Agreement. Functions and tasks related to the GHG inventory of MONRE are specified in the following documents:

- The Law on Environmental Protection No.55/2014/QH13 dated June 23, 2014 which regulates MONRE shall lead and coordinate with relevant ministries and agencies to implement national GHG inventories as well as develop national reports on national GHG emissions management consistent with international treaties to which Viet Nam is a member according to Clause 2, Article 41, Chapter IV. On November 17, 2020, the Law on Environmental Protection No.72/2020/QH14 was passed by the National Assembly and will come into effect from January 1, 2021, stipulating that the MONRE is in charge of periodical developing the national GHG inventory reports every two years according to clause 4b, Article 91, Chapter VII.

- The Decrees No.25/2008/ND-CP dated March 4, 2008, No.19/2010/ND-CP dated March 5, 2010, No. 89/2010/ND-CP dated August 16, 2010, No.21/2013/ND-CP dated March 4, 2013 and No.36/2017/ND-CP dated April 4, 2017 by the Government to assign MONRE's functions, tasks, powers and organisational structure;

- The Decision No.47/2007/QD-TTg dated April 6, 2007 by the Prime Minister approving the Action plan to implement the Kyoto Protocol of the UNFCCC;

- The Decision No.43/2010/QD-TTg dated June 2, 2010 by the Prime Minister promulgating the National statistical indicator system and the Circular No.02/2011/TT-BKHDT dated January 10, 2011 of MPI regulating the content of the National statistical indicator system; the list and content of the system of statistical indicators at the provincial, district and commune levels;

- The Decision No.2139/QD-TTg dated December 5, 2011 by the Prime Minister on approval of the National strategy on climate change;

- The Decision No.1393/QD-TTg dated September 25, 2012 by the Prime Minister on approval the National green growth strategy;

- The Decision No.1775/QD-TTg dated November 21, 2012 by the Prime Minister on approval of the project on management of GHG emissions; management of carbon credit business activities to the global market;

- The Decision No.2359/2015/QD-TTg dated December 22, 2015 by the Prime Minister on the development of national inventory system has clearly defined the functions and tasks of relevant stakeholders in the making of national reports, including the content of GHG inventory. Since the 2013 national GHG inventory, the implementation of the national GHG inventory has been implemented in accordance with the Decision.

1.2 Implementation of national GHG inventory for 2016

The Viet Nam national GHG inventory are conducted in a centralised model. MONRE takes lead and cooperate with other related ministries and agencies in developing NCs and BURs including GHG inventory and submit to the UNFCCC.

The institutional arrangements of 2016 national GHG inventor were in accordance with the national GHG inventory system specified under the Prime Minister's Decision No.2359/2015/QD-TTg dated December 22, 2015 (Figure 1.1).

The DCC under MONRE is responsible for developing GHG inventory plan; chairing and cooperation with related agencies in the GHG inventory system as well as compiling the technical report.

GSO under MPI collects/controls the quality of data from other focal points including MOIT, MOT, MARD, MOC and the People's Committees of provinces/cities, then provide AD and related information to the DCC-MONRE for implementing GHG inventory. Moreover, other relevant information and data are collected from agencies and organisations outside of the national GHG inventory system.

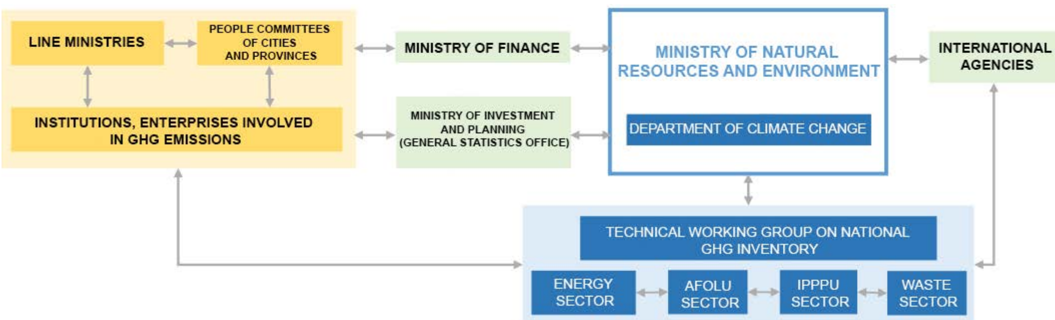

Figure 1.1. Institutional arrangements of national GHG inventory system.

The results of national GHG inventories in Viet Nam are published, updated, archived and administered on the Viet Nam's GHG national inventory information system at the website of the DCC-MONRE.

1.3 Methodology for national GHG inventory for 2016

1.3.1 Methods

The national GHG inventory is carried out following the IPCC guidelines, including IPCC 2006 Guidelines, the 2019 Refinement to the 2006 IPPC Guidelines, IPCC 2003, IPCC 2000, IPCC 1996 Revised.

Guidelines for classification of sub-sectors, the application of decision trees, constants, conversion factors and EFs were prioritised according to the IPCC 2006 Guidelines and the 2019 Refinement to the IPPC 2006 Guidelines used in this technical report. The IPCC 2000 and IPCC 2003 were used in case a few of EFs, parameters and conversion factors could not be found in the IPCC 2006 Guidelines or the 2019 Refinement to the IPPC 2006 Guidelines.

In addition, the emissions of AFOLU were calculated with the ALU software developed by the Colorado State University and based on the IPCC 2006 Guidelines.

Sectors are considered in the 2016 national GHG inventory are:

1. Energy;
2. IPPU;
3. AFOLU; and
4. Waste.

Compared to reporting guidance under IPCC 1996 Revised, the sub-sectors in the four above mentioned sectors reported under the IPCC 2006 Guidelines barely changed. The main changes went to the difference in the IPCC classification code and reporting order in the list of emission/removal sources among the sectors.

1.3.2 AD and EFs

AD and related information were collected and aggregated from national statistics, government agencies, central and local organisations. Also, a part of them was obtained from scientific documents and reports of international cooperation projects.

The approach of collecting, aggregating and processing AD was top-down. However, since the national data has not been categorised fully following the IPCC classification, AD for some sub-sectors in energy and IPPU were based on bottom-up approach.

The majority of EFs, parameters and conversion factors used in national GHG inventories were default values of the 2006 IPCC Guidelines. In addition, some in-country specific EFs, parameters and conversion factors are also used. A summary of AD, EFs, parameters and conversion factors in national GHG inventories is presented in Table 1.1.

Table 1.1 Methods and data sources used for national GHG inventory

1 Energy sector	
Tier	Tier 1, Tier 2 (1B1a)
AD	Viet Nam energy balance sheet 2016, the Institute of Energy, MOIT, 2020.
EFs	- CH_4 dispersion coefficient in pit coal mining in Viet Nam, MOIT; and - IPCC 2006 default values.
Other parameters	- Energy conversion coefficient of coal, oil, gas and biomass, the Institute of Energy, MOIT, 2020; - Ratio of surface and underground coal mining according to energy experts; and - IPCC 2006 default values.
2 IPPU sector	
Tier	Tier 1
AD	- Statistical yearbook 2018, GSO, 2019; - Statistical yearbook 2017 of the Steel Industry, the World Steel Association, 2017; - Reporting on production and import of urea fertiliser, The Plant Protection Department, MARD, 2020; - The Cement industry report 2016, the Viet Nam Cement Association, 2016; - Technical report on input data for GHG emission reduction by improving production processes of building materials manufacturing, MOC, 2016; - Report on HFCs consumption in Viet Nam by sectors in the period of 2011-2017, DCC, MONRE, 2018; - Report on updating data for nitric acid production, Viet Nam Chemicals Agency, MOIT, 2020; - Report on assessment and GHGs inventory in the production of building materials (cement, glass, tiles, fired bricks, sanitary ware) and proposal on appropriate management solutions, the Viet Nam Institute for Building Materials, MOC, 2019.
EFs	IPCC 2006 default values; and EFs of SO_2, NO_x, CO and NMVOC in steel production based on the IPCC 1996 Revised.
Other parameters	- The rate of clinker in cement, Final project report of 'the NAMA readiness programme for the Viet Nam cement sector', MOC, 2016; and - IPCC 2006 default values.
3 AFOLU sector	
Tier	Tier 1, Tier 2 (3A2), Tier 3 (3B1)
AD	- Statistical yearbook 2018, GSO, 2019; - Statistical yearbook of the agriculture and rural development in 2018; - Reporting on production and import of urea fertilisers, the Plant Protection Department, MARD; - The Report on state of forest data 2016, the Forest Protection Department, MARD, 2017; and - The Surface coating matrix 2006-2016, the National Remote Sensing Department, MONRE, 2020.

EFs	- Country -specific EF for rice cultivation and manure management; and - IPCC 2006 default values.
Other parameters	- The percentage of manure handled using manure system in livestock, the Department of Livestock Production, MARD, 2015; - The percentage of burning straw in the field, Summary report on assessment of current status and proposing solutions for waste management in the field of farming, the Institute of Agricultural Environment, MARD, 2018; - Growth parameters of biomass, aboveground biomass of forest types and the biomass conversion and expansion factors applicable to wood removals (BCEFr) used by forestry experts, the Forest Inventory and Planning Institute, MARD, 2020; and - IPCC GPG 2000, 2006 and 2019 default values.
4 Waste sector	
Tier	Tier 1, Tier 2 (4A)
AD	- Statistical yearbook 2018, GSO, 2019; - National environment status report 2017, MONRE, 2017; and - Environment Status Report 2006-2010; 2011-2015, the People's Committees of 63 provinces and cities.
EFs	- IPCC 2006 default values
Other parameters	- Average rate of municipal solid waste generation (kg/cap/day) and average rate of solid waste management at landfills, Viet Nam Environmental Monitor 2004 - Solid Waste, MONRE, 2004; - Average rate of rural solid waste generation (kg/cap/day), National Environment Report 2011 - Solid waste, MONRE, 2011; - Rate of wastewater treatment by type of treatment and discharge pathway or system, the National environment status report 2017, MONRE, 2017; and - IPCC 2006 default value.

1.3.3 GWP values

GWP values for 100 years are applied to the national GHG inventory for 2016 and recalculated for 2010 and 2014 according to the AR5 published in 2014. Details are presented in Table 1.2.

Table 1.2 GWP values applied to national GHG inventory for 2016 and recalculation for 2010 and 2014

Gas		GWP	Source
CO_2		1	AR5, IPCC, 2014
CH_4		28	
N_2O		265	
HFCs	HFC-125	3.170	
	HFC-227ea	3.350	
	HFC-23	12.400	

1.4 Key category analysis for emissions/removals of 2016

The analysis of key emission/removal categories was done based on Tier 1 approach, according to formula 4.1, page 4.14, Chapter 4, Volume 1, IPCC 2006 Guidelines to identify the largest emissions accumulating to 95% of total national net emissions. Viet Nam had 42 key emission and removal categories in 2016, contributing to 95.1% of total 158 GHG emission sources/sinks. In particular, the largest source came from electricity generation (1A1ai), occupying 20.3% of overall emission. The detailed analysis of 2016 key emission/ removal categories is summarised in Table 1.3.

Table 1.3 Key emission/removal categories for 2016

No	IPCC Code	Category	Gas	Emissions/ removals	Contribution level	Cumulative total
				$ktCO_2eq$	%	
1	1A1ai	Energy industries: Electricity generation	CO_2	88,482.75	20.6	20.6
2	3C7	Rice cultivations	CH_4	49,693.02	11.6	32.1
3	3B1a	Forest land remaining forest land	CO_2	-42,704.93	9.9	42.1
4	2A1	Mineral industry: Cement production	CO_2	36,773.00	8.6	50.6
5	1A3b	Transport: Road transportation	CO_2	29,860.73	6.9	57.6
6	1A2f	Manufacturing industries and construction: Non-metallic minerals	CO_2	14,402.77	3.3	60.9
7	1B2a	Fugitive emissions from oil	CH_4	14,270.02	3.3	64.2
8	3B1bii	Grassland converted to forest land	CO_2	-11,030.95	2.6	66.8
9	4A	Solid waste disposal	CH_4	10,438.86	2.4	69.2
10	1A2a	Manufacturing industries and construction: Iron and steel	CO_2	8,757.59	2.0	71.3
11	1A4c	Other sectors: agriculture, foresty and fishing farm	CO_2	8,235.91	1.9	73.2
12	3C4	Direct N_2O emissions from managed soils	N_2O	7,754.11	1.8	75.0
13	1A4b	Other sectors: residential	CO_2	6,994.11	1.6	76.6
14	3A1aii	Enteric fermentation: non-dairy cattle	CH_4	6,861.05	1.6	78.2
15	3B2bi	Forest land converted to cropland	CO_2	5,623.33	1.3	79.5
16	3B6bi	Forest land converted to other land	CO_2	5,335.51	1.2	80.7

No	IPCC Code	Category	Gas	Emissions/ removals	Contribution level	Cumulative total
				$ktCO_2eq$	%	
17	4D1	Domestic wastewater treatment and discharge	CH_4	4,805.66	1.1	81.9
18	3A1b	Enteric fermentation: Buffalo	CH_4	3,879.89	0.9	82.8
19	2C1	Metal industry: Iron and steel production	CO_2	3,858.22	0.9	83.7
20	2A2	Mineral industry: Lime production	CO_2	3,825.00	0.9	84.6
21	1B2b	Fugitive emissions from natural gas	CH_4	3,777.10	0.9	85.4
22	3C5	Indirect N2O emissions from managed soils	N_2O	3,752.55	0.9	86.3
23	1A2l	Manufacturing industries and construction: Textile and leather	CO_2	3,352.31	0.8	87.1
24	1A3d	Transport: Water borne navigations	CO_2	2,963.01	0.7	87.8
25	1B1ai	Fugitive emissions from coal: Underground mines	CH_4	2,652.99	0.6	88.4
26	1A2k	Manufacturing industries and construction: construction	CO_2	2,571.69	0.6	89.0
27	1A2c	Manufacturing industries and construction: Chemicals and petroleum refining	CO_2	2,286.29	0.5	89.5
28	4D2	Industrial wastewater treatment and discharge	CH_4	2,257.05	0.5	90.0
29	1A3a	Transport: Civil aviation	CO_2	2,246.01	0.5	90.6
30	1A4a	Other sectors: commercial/ institutional	CO_2	2,088.03	0.5	91.0
31	1A1b	Fuel combustion for petroleum refining	CO_2	2,008.90	0.5	91.5
32	4D1	Domestic wastewater treatment and discharge	N_2O	1,886.55	0.4	92.0
33	1A2m	Manufacturing Industries and Construction: Non-specified Industry	CO_2	1,734.14	0.4	92.4
34	1A2i	Manufacturing industries and construction: Mining (excluding fuels) and quarrying	CO_2	1,683.71	0.4	92.8

No	IPCC Code	Category	Gas	Emissions/ removals	Contribution level	Cumulative total
				$ktCO_2eq$	%	
35	1A2e	Manufacturing industries and construction: Food processing, beverages and tobacco	CO_2	1,629.60	0.4	93.1
36	3C3	Emission from urea fertilisation	CO_2	1,436.11	0.3	93.5
37	3B6bii	Cropland converted to other land	CO_2	1,350.75	0.3	93.8
38	2B1	Chemical industry: Ammonia production	CO_2	1,271.78	0.3	94.1
39	3C1b	Emissions from biomass burning in croplands	CH_4	1,244.59	0.3	94.4
40	3B3bi	Forest land converted to grassland	CO_2	1,168.70	0.3	94.6
41	3A2h	Manure management: Swine	CH_4	1,034.78	0.2	94.9
42	3B2a	Cropland remaining cropland	CO_2	-1,026.04	0.2	95.1

Note: *Negative values (-) shows the GHG absorption of sinks.*

Among 42 key categories of GHG emissions/removals, 28 sources were of CO_2, 11 of CH_4 and three of N_2O. The numbers of key categories is summarised in Table 1.4.

Table 1.4 Statistics on number of major GHG emissions/removals for 2016

IPCC Code	Sector	CO_2	CH_4	N_2O	Total
Total key categories		**28**	**11**	**3**	**42**
1	Energy	16	3	0	19
2	IPPU	4	0	0	4
3	AFOLU	8	5	2	15
4	Waste	0	3	1	4

In comparison with the results of the key catogory analysis for 2014 with 39 sources including LULUCF, the 2016 inventory results had three more key categories due to an increase of one source in each sector of energy, AFOLU and waste whereas the IPPU sector experienced no changes. Furthermore, the contribution of key categories in 2016 was different from those of 2014 by gases, specifically:

- The energy sector had an increase of one source due to an increase of two CO_2 categories and a loss of one CH_4 category.

- The IPPU sector witnessed no changes.

- The AFOLU sector had increase of three CO_2 categories and reduction of two NO_2 while the CH4 categories stayed unchanged.

- The waste sector saw an increase of one CH_4 category while others remained unchanged.

1.5 Uncertainty assessments of 2016 national greenhouse gas inventory

The uncertainty assessments for the 2016 national GHG inventory was conducted using Tier 1 approach, Equations 3.1 and 3.2 page 3.28, Chapter 3, Volume 1, the IPCC 2006 Guidelines.

The uncertainty value is the combination value of method error, statistical error and standard deviation of used value. The uncertainties of the used AD, EFs, parameters and conversion factors are default values or one value in a default range according to the revised 1996 IPCC Guidelines, GPG 2000, GPG 2003 and the IPCC 2006 Guidelines. Some of the uncertainties for AD, parameters and EFs have been applied according to statistical expert judgments.

The uncertainty assessments will contribute to next GHG inventory cycle. Results of the uncertainty assessments for 158 GHG emissions/removals of GHGs are combined values of uncertainties of respective AD and EFs. Uncertainty assessment results of the sectors are presented in Table 1.5.

Table 1.5 Results of uncertainty assessments for 2016 national GHG inventory

IPCC Code	Sector	Emissions/Removals	Uncertainty
		$ktCO_2eq$	%
1	Energy	205,832.20	5.6
2	IPPU	46,094.64	26.9
3	AFOLU	44,069.74	100.2
4	Waste	20,738.38	20.3

1.6 Quality control and Quality assurance

1.6.1 Quality control

Quality control (QC) for the 2016 national GHG inventory includes i) AD and EFs; ii) Results of emission/removal calculation; iii) Key category analysis, uncertainty assessment and other related issues. QC results are synthesised in Table 1.6.

Table 1.6 QC results for 2016 national GHG inventory

Scope	Activities	Results
AD	Check AD sources and criteria for selecting AD	AD are used clearly to ensure reliability. Information and AD published in the national statistical yearbooks have been prioritised, followed by AD obtained from state management, central and local agencies and organisations; some research papers at home and abroad.
AD EFs and parameters	Check the assumptions used due to the lack of AD.	The assumptions based on expert judgments have been found most appropriate for the current data status.
	Check the process of inputting AD and measure units into spreadsheets and inventory tools.	No errors have been found during the process of inputting AD and measure units into spreadsheets and inventory tools.
	Check the consistency of AD among sectors.	AD among sectors has been inspected to ensure consistency.
	Check the parameters, conversion factors and country-specific EFs used.	The selected values have been appropriate and transparent based on reliable sources as well as have ensured consistency across sectors.
Calculated results	Check the EFs and parameters using IPCC default value.	The selected values have been accurate, consistent and suitable with the IPCC GPG.
	Check methodology for calculating emissions/removals.	Fully complied with the methodology of the IPCC 2006 Guidelines.
Other contents	Check inventory results of sectors for 2016 and recalculated results for the years of 2010 and 2014.	The applied calculation formulas, GWP values according to the IPCC guidelines have been found correct.
	Check the completeness, accuracy and consistency according to the IPCC categorisation.	The emissions/removals have been calculated correctly. Such notations as NA, NO, IE and NE have been unanimous according to the IPCC 2006 Guidelines.
	Check the results of key category analysis and the uncertainty assessment.	The used method as well as formula for key categories analysis and uncertainty assessment have been precisely applied according to the IPCC guidelines.
Other contents	Check the reporting results according to IPCC 2006 guidelines and templates.	The displayed tables and graphs have been accurate, consistent and conformable to the IPCC 2006 Guidelines templates.

1.6.2 Quality assurance

Quality assurance (QA) of the national GHG inventory for 2016, including activities in the national GHG inventory system is shown in Figure 1.1 was conducted by agency/experts not directly involved in the inventory compilation. QA activities were conducted from the preparation of GHG inventory until completion of final report.

QA activities include inspecting and assessing the quality of input data as well as the appropriateness of the GHG inventory methodology to make sure that inventory results are the best-estimated emissions/removals under the current scientific background with the existing data. Moreover, QA also supports QC activities.

The process of coordinating and supervising QA activities has seen regular, continuous and close collaboration among related state management agencies, research institutions, NGOs and sectoral experts. Under the consultation procedure for the 2016 inventory in terms of EFs, AD, parameters and conversion factors, applied methods, results, eight workshops, consulting meetings were organised on GHG inventory in the AFOLU and waste sectors; five, in the energy and IPPU sectors together with other technical discussions among GHG inventory compilation groups and sector experts. Comments and inputs from those technical seminars, meetings were well-received, acquired and supplemented in the 2016 National Inventory Report (NIR 2016) as well as sectoral inventory reports.

The NIR 2016 was sent to line ministries and agencies involved in the making of BUR3 for official consultation. Feedbacks and inputs were accommodated in NIR 2016.

1.7 Improvements of 2016 national GHG inventory

Under the framework of the BUR3 project, Viet Nam conducted a national GHG inventory for 2016 and recalculated the national GHG inventory for the years of 2010 and 2014 among four sectors, including energy, IPPU, AFOLU and waste. In previous time, the implementation of national GHG inventories had been conducted in accordance with the IPCC 1996 Revised. Currently, despite not being required by international regulations, the 2016 national GHG inventory was conducted in accordance with IPCC 2006 Guidelines.

Some improvements of the 2016 national GHG inventory are presented for each sector in Chapters 3, 4, 5 and 6 of this Report.

CHAPTER 2

GHG EMISSION TRENDS

2.1 Summary of GHG emissions and removals for 2016

The total GHG emissions/removals of Viet Nam for 2016 was 316,734.96 ktCO_2eq. Of which, the energy sector was the biggest contributor, accouting for 65% of emissions, followed by the IPPU sector, 14.6%. The third biggest contributor went to AFOLU, 13.9% and lastly the waste sector, 6.5%, as detailed in Table 2.1 and Figure 2.1.

Table 2.1 GHG emissions/removals for 2016

IPCC Code	Sector	CO_2	CH_4	N_2O	HFCs	Total
		ktCO_2eq				
Total net emissions		**191,651.08**	**106,838.29**	**18,222.26**	**23.32**	**316,734.96**
1	Energy	182,291.22	22,345.35	1,195.63		205,832.20
2	IPPU	46,047.20		24.12	23.32	46,094.64
3	AFOLU	-37,489.34	66,544.64	15,014.44		44,069.74
4	Waste	802.00	17,948.30	1,988.07		20,738.38

Note: *Negative values (-) shows the GHG absorption of sinks.*

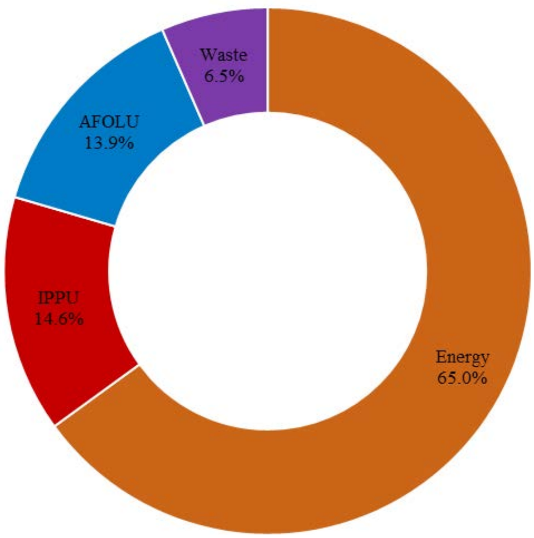

Figure 2.1 Ratio of GHG emissions by sector in 2016.

2.2 Synthesise GHG emission/removal trends

2.2.1 GHG emission/removal trends by sector

Viet Nam has implemented national GHG inventories for five sectors namely energy, industrial processes (IP), agriculture, LULUCF and waste for such years of 1994, 2000, 2010, 2013 and 2014. All results are presented in Table 2.2.

Table 2.2 Published GHG emissions/removals of Viet Nam

IPCC 1996	Sector	1994	2000	2010	2013	2014
		$ktCO_2eq$				
Total net emission		**103,839.30**	**150,899.73**	**246,830.65**	**259,024.10**	**283,965.53**
1	Energy	25,637.09	52,773.46	141,170.79	151,402.52	171.621,08
2	IP	3,807.19	10,005.72	21,172.01	31,767.38	38.619,79*
4	Agriculture	52,450.00	65,090.65	88,354.77	89,407.82	89.751,80
5	LULUCF	19,380.00	15,104.72	-19,218.59	-34,239.83	-37.540,18
6	Waste	2,565.02	7,925.18	15,351.67	20,686.21	21.513,04

Note: *Negative values (-) shows the GHG absorption of sinks* ** Results are calculated for IPPU*

Source: INC, MONRE, 2000; SNC, MONRE, 2010 BUR1, MONRE, 2014
BUR2, MONRE, 2017; TNC, MONRE, 2019

2.2.2 Comparison of net GHG emission proportion by gaseous type

The proportion of net GHG emissions from CO_2 in 2016 tended to have increased while CH_4 dropped sharply and N_2O showed an unknown trend compared to the previous inventory years. The proportion of CO_2 emissions in 1994 accounts for 39.1% of the total national GHG emissions and increased to 61.2% in 2016. CH_4 emissions in 1994 accounted for 50.7% of the national total net GHG emissions but reduced to 33.1% in 2016. The proportion of N_2O emissions in the national total net emissions in 1994 was 10.2% and declined to 5.7% in 2016; the 2016 results tended to have gone down slightly compared to the results of 6.1% calculated for 2014.

HFCs have witnessed a quite small proportion (<1%) since the first GHG inventory in 2013. As a result, in 2016, HFCs only accounted for 0.01%, lower than 2014 (0.03%). The comparison of net GHG emissions by gaseous type over the period 1994-2016 is shown in detail in Figure 2.2.

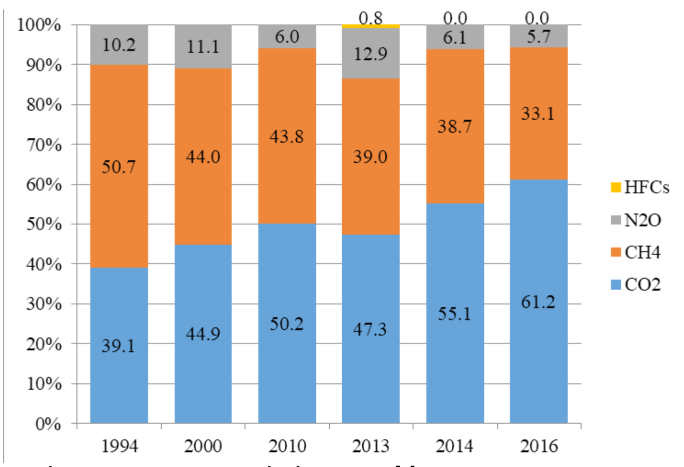

Figure 2.2 GHG emission trend by gaseous type.

2.3 Recalculation of national GHG inventories for 2010 and 2014

In the framework of developing BUR3, recalculation was conducted for the 2010 and 2014 national GHG inventories.

In accordance with IPCC 2006 Guidelines, EFs and AD, conversion factors, updated parameters and new IPCC GWP values (AR5, 2014), the recalculated results of net GHG emissions in 2010 increased by 7% compared to those reported in BUR1 with biggest difference in IPPU increasing by 22.1%, followed by waste, going up by 15.8%. The main reason was the use of new GWP values of the IPCC, especially the GWP values for CH_4 and N_2O and the constants and conversion factors applied under IPCC 2006 Guidelines, the recalculated results for the year 2010 are shown in Table 2.3 and detailed in Annexes 3-1a, 3-2a, 3-3a and 3-4a.

Table 2.3 Recalculation of GHG emissions/removals for 2010

2006 IPCC Code	Sector	CO_2	CH_4	N_2O	HFCs	Total net emissions	Difference
		$ktCO_2eq$					*%*
Total net emissions		**132,641.81**	**115,801.48**	**15,856.10**	**NE**	**264,210.67**	**7.0**
1	Energy	125,514.57	25,075.17	1,289.33		151,879.06	7.6
2	IPPU	25,844.05		NE	NE	25,844.05	22.1
3	AFOLU	-19,499.85	75,258.07	12,952.60		68,710.82	0.6*
4	Waste	694.48	15,468.18	1,614.08		17,776.73	15.8

Note: *Negative values (-) shows the GHG absorption of sinks.*

**: The recalculation results are lower than the published results.*

Similarly, recalculated results of Viet Nam's net GHG emissions in 2014 falls by 1.9% compared to NC3 in which the most significant difference is due to a decrease of 13.8% in AFOLU. In the meantime, values of IPPU does not vary much from the published results. Table 2.4 shows the recalculation results in 2014. The main reason for the change of recalculation result in 2014 was the same as explaination for recalculation result in 2010. The recalculated results for the year 2014 are shown in Table 2.4 and details in the Annexes 3-1b, 3-2b, 3-3b and 3-4b.

Table 2.4 Recalculation of GHG emissions/removals for 2014

2006 IPCC Code	Sector	CO_2	CH_4	N_2O	HFCs	Total net emissions	Difference
		$ktCO_2eq$					*%*
Total net emissions		**151,930.72**	**109,842.95**	**16,791.01**	**95.01**	**278,659.70**	**1.9***

1	Energy	148,435.33	25,784.95	1,319.91		175,540.20	2.3
2	IPPU	38,637.70		NE	95.01	38,732.71	0.3
3	AFOLU	-35,936.97	67,304.63	13,630.26		44,997.92	13.8*
4	Waste	794.66	16,753.37	1,840.84		19,388.87	9.9*

Note: *Negative values (-) shows the GHG absorption of sinks.*

**: The recalculation results are lower than the published results.*

The comparison of all the recalculated results of GHG emissions/removals for 2010 and 2014 and 2016 shows that total 2016 net emissions increased by 38,075.26 ktCO_2eq, or 13.7%, against those of 2014 and 52,524.29 ktCO_2eq, or 19.9% in proportion compared to 2010, specifically:

Energy: the 2016 emissions increased by 30.292.00 ktCO_2eq, or 17.3%, against those of 2014 and by 53,953.14 ktCO_2eq, or 35.5%, versus those of 2010;

IPPU: the 2016 net emissions has a rise of 7,361.93 ktCO_2eq, or 19.0% versus those of 2014 and 20,250.59 thousand tonnes CO_2eq, or 78.4%, versus those of 2010;

AFOLU: the 2016 emissions declined by 928.18 ktCO_2eq, or 2.1%, versus those of 2014 and 24,641.08 ktCO_2eq, or 35.9%, versus those of 2010;

Waste: total 2016 net emissions went up by 1,349.51 ktCO_2eq, or 13.7%, versus those of 2014 and 2,961.64 ktCO_2eq, or 19.9%, versus those of 2010.

The calculation results are presented in Table 2.5 and Figure 2.3.

Table 2.5 National GHG inventory results for 2010, 2014 and 2016

2006 IPCC	Sector	2010	2014	2016
		ktCO_2eq		
Total net emissions		**264,210.67**	**278,659.70**	**316,734.96**
1	Energy	151,879.06	175,540.20	205,832.20
2	IPPU	25,844.05	38,732.71	46,094.64
3	AFOLU	68,710.81	44,997.92	44,069.74
4	Waste	17,776.74	19,388.87	20,738.38

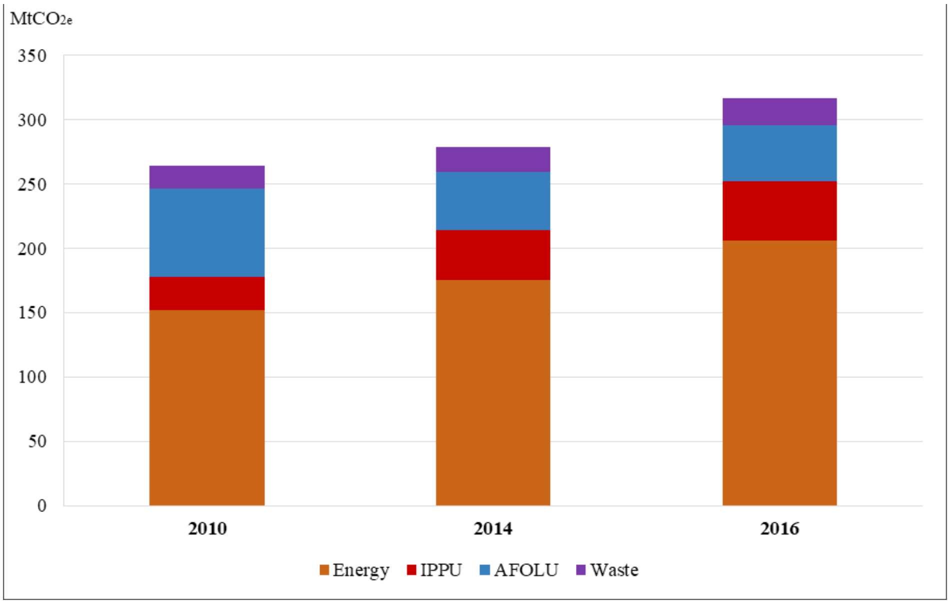

Figure 2.3 Comparing results of national GHG inventories for 2010*, 2014* and 2016

**: Recalculation results*

CHAPTER 3
ENERGY

3.1 Introduction

In the energy sector, GHGs are estimated in two forms, namely fuel combustion emissions (CO_2, CH_4, N_2O), and fugitive emissions released of fuels (CO_2, CH_4, N_2O). In 2016, total emissions in energy were 205,832.20 $ktCO_2eq$, of which, CO_2 emission from fuel combustion was the largest source with the amount of 180,767.38 $ktCO_2eq$. The second largest source was CH4 emissions from fugitive emissions with 21,053.83 $ktCO_2eq$. The GHG emissions in energy in 2016 are presented in Table 3.1. Details of the summary are presented in Annex 2-1.

Table 3.1 GHG emissions in energy sector for 2016

IPCC Code	Category	CO_2	CH_4	N_2O	Total	Proportion
		$ktCO_2eq$				*%*
1	**Energy**	**182,291.22**	**22,345.35**	**1,195.63**	**205,832.20**	**100**
1A	Fuel combustion activities	180,767.38	1,291.51	1,192.57	183,251.46	89.0
1A1	Energy industries	90,554.60	86.56	364.64	91,004.80	44.2
1A2	Manufacturing industries and construction	37,701.55	233.95	312.61	38,248.11	18.6
1A3	Transport	35,193.17	277.38	424.77	35,845.32	17.4
1A4	Other sectors	17,318.05	744.63	90.55	18,153.23	8.8
1B	Fugitive emissions from fuels	1,523.84	21,053.83	3.06	22,580.74	11.0
1B1	Solid fuels		3,006.72		3,006.72	1.5
1B2	Oil and natural gas	1,523.84	18,047.12	3.06	19,574.02	9.5

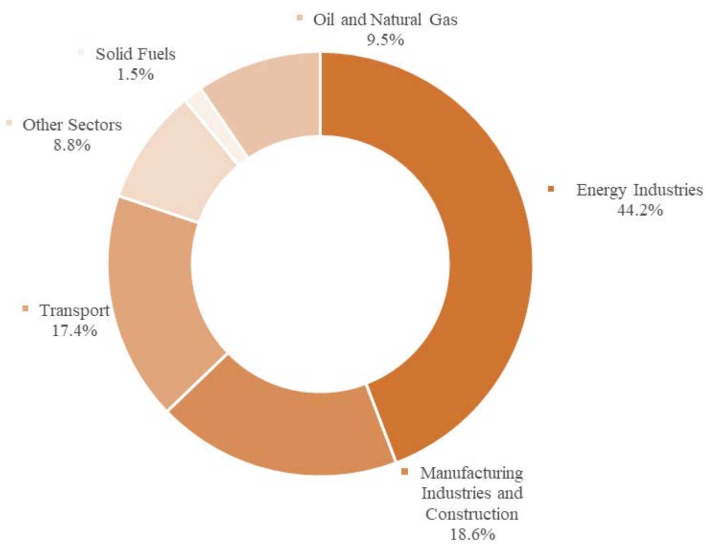

Figure 3.1 Ratio of GHG emissions in Energy for 2016.

3.2 Description of emission sources

CO_2 emissions are the result of intentional carbon oxidation in fuel combustion. Under complete combustion, the total carbon in the fuel is converted into CO_2. CH_4 is released in small amounts from the fuel combustion due to incomplete combustion of hydrogen carbon. The generation of CH_4 depends on the temperature in the boiler, furnace or stove. N_2O is formed through NO combustion reaction with volatile Nitrogen-containing components in the fuels. The lower the combustion temperature, the higher the amount of N_2O is emitted.

3.2.1 Fuel combustion (1A)

3.2.1.1 Energy industries (1A1)

The energy industries comprise activities of energy production and conversion, including power plants, petroleum refining factories and gas processing, etc. Power plants for internal operations are also included in the source.

a. Methodology

Since Viet Nam has not currently had measurements of factories as well as data related to combustion technology, Tier 1 approach method is applied to estimate GHG emissions according to equation 2.1, page 2.11, Chapter 2, volume 2, the IPCC 2006 Guidelines.

b. AD

Fuel consumption for the energy industries comprises the consumption of coal, diesel oil, gasoline, natural gas and non-commercial energy used in electricity generation, petrochemical refining, gas processing and charcoal. These figures are synthesised from the Energy balance table in 2016 of the Institute of Energy (IE), MOIT, 2020, as presented in Table 3.2.

Table 3.2 Fuel consumption in Energy industries

2016	Antraxit coal	Sub-bitum coal	Crude oil	Diesel oil	Gasoline	Natural gas	Bio-mass	Char-coal
	kTOE							
Electricity generation	16,811.5	169.9		41.8	200.2	7,591.5	1,069.7	
Petrochemical refinery			654.6					
Gas processing plant						26.8		
Charcoal plant								453.58

c. EFs

Viet Nam has not currently had country specific EFs for fuel consumption in the energy industries, thus, the default values in the Table 2.2, pages 2.16-2.17, Chapter 2, Volume 2, the IPCC 2006 Guidelines was used as detailed in Table 3.3.

Table 3.3 Default EFs applied to Energy industries

GHG	Antraxit coal	Sub-bitum coal	Crude oil	Diesel oil	Gasoline	Natural gas	Bio-mass	Char-coal
	Kg/TJ							
CO_2	98,300	96,100	73,300	74,100	77,400	56,100	100,000	
CH_4	1	1	3	3	3	1	30	200
N_2O	1.5	1.5	0.6	0.6	0.6	0.1	4	4

d. Results of emissions

GHG emissions in Energy industries (1A1) are shown in Table 3.4.

Table 3.4 GHG emissions in Energy industries for 2016

IPCC Code	Category	CO_2	CH_4	N_2O	Total
		kt			*$ktCO_2eq$*
1A1	Energy industries	90,554.60	3.06	1.38	91,004.80
1A1a	Electricity and heat production	88,482.75	2.40	1.28	88,890.15
1A1ai	Electricity generation	88,482.75	2.40	1.28	88,890.15
1A1b	Petroleum refining	2,008.90	0.08	0.02	2,015.56
1A1c	Manufacture of solid fuels and other energy industries	62.95	0.57	0.08	99.09
1A1ci	Manufacture of solid fuels		0.57	0.08	36.08
1A1cii	Gas extraction	62.95	0.00	0.00	63.01

3.2.1.2 Manufacturing industries and construction (1A2)

The manufacturing industries and construction comprise such activities as iron and steel production; chemicals and petroleum refining; cement and construction materials; food processing, beverages and tobacco; textile and leather; pulp, paper and print and other activities; Mining (excluding fuels) and quarrying, transport equipment, machinery, wood and wood products, construction, other typical activities). Energy inputs for these industries are coal, oil products, natural gas and non-commercial energy.

a. Methodology

Since Viet Nam has not currently had measurements of factories as well as data related to combustion technologies, the Tier 1 approach method was applied to estimate GHG emissions according to Equation 2.1, page 2.11, Chapter 2, Section 2, the IPCC 2006 Guidelines.

b. AD

Data on fuel consumption used in the manufacturing industries and construction sector (1A2) based on fuel type and industry are synthesised from the 2016 Energy balance table of the IE, MOIT, 2020 as detailed in Table 3.5.

Table 3.5 Fuel consumption in Manufacturing industries and construction

Subsector	Antraxit coal	Diesel oil	Gasoline	LPG	Natural gas	Biomass
	kTOE					
Total	**7,392.58**	**1,753.11**	**42.72**	**214.19**	**479.15**	**3,985.24**
Iron and steel	1,942.76	69.85	7.82	39.83	176.40	
Chemicals and petroleum refining	429.56	59.80	2.11	12.67	124.45	
Pulp, paper and print	161.58	25.21	3.63	1.43	2.12	
Food processing, beverages and tobacco	325.96	64.84	9.95	12.49	9.18	1,306.61
Non-metallic minerals	3,260.62	151.72	14.22	44.94	147.94	399.90
Transport equipment	1.90	24.30	0.15	34.18	4.66	
Machinery	1.24	24.53	0.63	52.12	10.67	
Mining (excluding fuels) and quarrying	74.67	442.98	0.65			
Wood and wood products	0.46	25.21	0.03	0.68	0.00	980.19
Construction	16.57	805.41		1.38	0.47	
Textile and leather	777.16	40.21	3.41	4.14	3.02	1,298.54
Non-specified industry	400.10	19.04	0.12	10.40	0.23	

c. EFs

Currently, Viet Nam has not had country specific EFs for fuel consumption, thus, the default values in Table 2.3, page 2.18-19, Chapter 2, Volume 2, the IPCC 2006 Guidelines were used as detailed in Table 3.6.

Table 3.6 Default EFs applied to Manufacturing industries and construction

GHG	Antraxit coal	Diesel oil	Gasoline	LPG	Natural gas	Biomass
	Kg/TJ					
CO_2	98,300.0	74,100.0	77,400.0	63,100.0	56,100.0	
CH_4	10.0	3.0	3.0	1.0	1.0	30.0
N_2O	1.5	0.6	0.6	0.1	0.1	4.0

d. Results of emissions

GHG emissions from the Manufacturing industries and construction category are shown in Table 3.7.

Table 3.7 GHG emissions in Manufacturing industries and construction for 2016

IPCC Code	Category	CO_2	CH_4	N_2O	Total
		kt			$ktCO_2eq$
1A2	Manufacturing industries and construction	37,701.55	8.36	1.18	38,248.11
1A2a	Iron and steel	1,683.71	0.09	0.02	1,690.34
1A2c	Chemicals and petroleum refining	1,629.60	1.79	0.24	1,743.59
1A2d	Pulp, paper and print	3,352.31	1.96	0.27	3,478.11
1A2e	Food processing, beverages and tobacco	82.01	1.23	0.16	160.25
1A2f	Non-metallic minerals	760.45	0.07	0.01	765.32
1A2g	Transport equipment	2,286.29	0.19	0.03	2,299.42
1A2h	Machinery	14,402.77	1.90	0.28	14,529.20
1A2i	Mining (excluding fuels) and quarrying	8,757.59	0.83	0.12	8,813.98
1A2j	Wood and wood products	246.51	0.01	0.00	246.94
1A2k	Construction	194.48	0.01	0.00	194.88
1A2l	Textile and leather	1,734.14	0.17	0.03	1,745.71
1A2m	Non-specified industry	2,571.69	0.11	0.02	2,580.36

3.2.1.3 Transport (1A3)

Transport comprises the following activities:

- Civil aviation: transportation activities in the civil aviation industry include international and domestic aviation;

- Road transportation: road transportation activities of road vehicles such as cars, motorcycles...;

- Railways: the transportation of railway vehicles;

- Water borne navigation: activities in the water borne navigation include international and domestic water borne navigation; and

- Other transportation activities, such as gas pipeline transport, off-road vehicles and fishing... However, Viet Nam cannot collect operational data; therefor, this sub-sector has not been counted.

Fuel emissions emitted from international transport including water borne navigation and civil aviation operations were reported separately in the 'Memorandum' section and were not included in the total national emissions. However, 2016 operational data of fuel consumption for the international aviation and water borne navigation has not been collected so fuel consumption has not been calculated yet.

a. Methodology

According to the IPCC 2006 Guidelines, transport emissions comprise those from the road, railway, civil aviation and water borne navigation transport activities:

- Civil aviation: Applying Tier 1 approach since Viet Nam does not have general data on the number of Landing-take off (LTO) times of each aircraft.

- Road transportation: Apply the first-order method to calculate the CO_2 emissions since Viet Nam has data on fuel consumption for road transportation, but has not had a country specific EF. For non-CO_2 emissions, the Tier 1 approach method is also applied since no complete fuel consumption data has been recorded for each vehicle.

- Railways: Applying the first-order method as no data has been recorded on locomotives, EF and fuel consumption for each type of locomotive.

- Water borne navigation: Applying the first-order method as Viet Nam only has fuel consumption data by fuel type and has no data on country specific carbon content and country specific EF for CO_2, CH_4 and N_2O.

Emissions calculation formulas for transport include:

Equation 3.6.1, page 3.59, Chapter 3, Volume 2, the IPCC 2006 Guidelines for the civil aviation subsector;

Equation 3.2.1, page 3.12, Chapter 3, Volume 2, the IPCC 2006 Guidelines for the road transportation subsector;

Equation 3.2.3, page 3.13, Chapter 3, Volume 2, the IPCC 2006 Guidelines for the road transportation subsector;

Equation 3.4.1, page 3.41, Chapter 3, Volume 2, the IPCC 2006 Guidelines for the railways subsector; and

Equation 3.5.1, page 3.47, Chapter 3, Volume 2, the IPCC 2006 Guidelines for the water borne navigation subsector.

b. AD

Operation data for the transport sector is the amount of fuel for domestic civil aviation, road transportation, railways, domestic water borne navigation, compiled from the 2016 Energy balance table of the IE, MOIT, 2020, as detailed in Table 3.8.

Table 3.8 Fuel consumption in Transport

Category	Gasoline	Aircraft gasoline	Diesel oil	Fuel oil	Natural gas	Ethanol
	kTOE					
Domestic civil aviation		750.28				
Road transportaion	5,203.16		4,745.04		18.27	5,203.16
Railways			39.78			
Domestic water borne navigation			727.26	218.09		

c. EFs

Viet Nam has not currently had any country specific EFs for fuel consumption for the energy industry, so default values in Table 3.2.1, page 3.16; Table 3.2.2, page 3.21; Table 3.4.1, page 3.43; Table 3.5.2, page 3.50; Table 3.5.3, page 3.50; Table 3.6.4, page 3.64 and Table 3.6.5, page 3.64 of Chapter 3, Volume 2, IPCC 2006 Guidelines were used as detailed in Table 3.9.

Table 3.9 Default EFs applied to Transport

GHG	Gasoline	Aircraft gasoline	Diesel oil	Fuel oil	Natural gas
	Kg/TJ				
CO_2	69,300.0	71,500.0	74,100.0	77,400.0	56,100.0
CH_4	33.0	0.5	3.9 (road) 4.2 (railways)	7.0	92.0
N_2O	3.2	2.0	3.9 (road) 28.6 (railways)	2.0	3.0

d. Results of emissions

3.2.1.4.2 GHG emissions in the Transport sector (1A3) are shown in Table 3.10.

Table 3.10 GHG emissions from Transport sector for 2016

IPCC Code	Category	CO_2	CH4	N_2O	Total
		kt			*ktCO$_2$eq*
1A3	Transport	35,193.17	8.12	1.60	35,845.32
1A3a	Civil aviation	2,246.01	0.02	0.06	2,263.10
1A3b	Road transportation	29,860.73	8.03	1.47	30,476.34
1A3c	Railways	123.41	0.01	0.05	136.23
1A3d	Water borne navigations	2,963.01	0.06	0.02	2,969.64

3.2.1.4 Other sectors (1A4)

GHG emissions in other sectors in Viet Nam including Trade and services (1A4a), Civil (1A4b) and Agriculture, forestry and fisheries (1A4c), as shown in Table 3.11.

Table 3.11 GHG emissions in Other sectors for 2016

IPCC Code	Category	CO_2	CH_4	N_2O	Total
		kt			*ktCO$_2$eq*
1A4	Other Sectors	17,318.05	26.59	0.34	18,153.23
1A4a	Commercial/institusional	2,088.03	0.37	0.01	2,102.14
1A4b	Residential	6,994.11	21.10	0.21	7,639.64
1A4c	Agriculture, foresty and fishing farm	8,235.91	5.13	0.12	8,411.45

3.2.1.4.1 Commercial/institutional (1A4a)

GHG emissions from fuel combustion activities in commercial/institutional sector include: Wholesale and retail businesses, medical facilities, social and educational organizations, and central and local government organisations (eg, military bases, prisons, office buildings).

a. Methodology

Since Viet Nam has not currently had information on baseline measurements as well as data related to combustion technologies, the Tier 1 approach method was used to estimate the emissions using Equation 2.1, page 2.11, Chapter 2, Volume 2, the IPCC 2006 Guidelines.

b. AD

Fuel consumption data in the Commercial/institutional sector was synthesised from the Energy balance table in 2016, the IE, MOIT, 2020, as detailed in Table 3.12.

Table 3.12 Fuel consumption in Commercial/institutional

2016	Diesel oil	LPG	Charcoal
	kTOE		
Commercial/Institutional	510.60	190.75	13.80

c. EFs

Currently, Viet Nam has not had data on carbon content and country specific EFs for fuel consumption, thus the default values in Table 2.4, page 2.20, Chapter 2, Volume 2, the IPCC 2006 Guidelines was used to calculate GHGs emissions as detailed in Table 3.13.

Table 3.13 Default EFs applied to Commercial/institutional sector

GHG	Diesel Oil	LPG	Charcoal
	Kg/TJ		
CO_2	74,100.0	63,100.0	
CH_4	10.0	5.0	200.0
N_2O	0.6	0.1	1.0

d. Results of emissions

GHG emissions in category commercial/institutional (1A4a) are reported in Table 3.11.

3.2.1.4.2 Residential (1A4b)

Residential GHG emissions include the emissions from fuel compustion activities for such as lighting, heating and other appliances in everyday life.

a. Methodology

Since Viet Nam has not currently had measurements of factories as well as data related to combustion technologies, the Tier 1 approach method was used to estimate the emissions according to Equation 2.1, page 2.11, Chapter 2, Volume 2, the IPCC 2006 Guidelines.

b. AD

Fuel consumption data in the residential sector is taken from the Energy balance table 2016, the IE, MOIT, 2020 as detailed in Table 3.14.

Table 3.14 Fuel consumption in residential

2016	Antraxit coal	Diesel oil	LPG	Biomass	Charcoal
	kTOE				
Residential	702.0	39.1	1,505.1	913.6	56.6

c. EFs

Viet Nam has not currently had data on carbon content and country specific EFs for fuel consumption, thus the default values shown in Table 2.5, page 2.22, Chapter 2, Volume 2, the IPCC 2006 Guidelines were used as detailed in Table 3.15.

Table 3.15 Default EFs applied to residential

GHG	Antraxit coal	Diesel oil	LPG	Biomass	Charcoal
	Kg/TJ				
CO_2	98,300.0	71,900.0	63,100.0	100,000.0	
CH_4	300.0	10.0	5.0	300.0	200.0
N_2O	1.5	0.6	0.1	4.0	1.0

d. Results of emissions

GHG emissions from residential (1A4b) are reported in Table 3.11.

3.2.1.4.3 Agriculture, forestry and fishing farms (1A4c)

GHG emissions from this category include GHGs emitted from the fuel combustion for agriculture, forestry, fishing and aquaculture activities, such as food processing, timber and aquaculture.

a. Methodology

Since Viet Nam has not currently had measurements of factories as well as data related to combustion technologies, the Tier 1 approach method is used to calculate emissions according to Equation 2.1, page 2.11, Chapter 2, Volume 2, the IPCC 2006 Guidelines.

b. AD

Fuel consumption data in agriculture, forestry and fishing farms is taken from the Energy balance table 2016, the IE, MOIT, 2020 as detailed in Table 3.16.

Table 3.16 Fuel consumption in Agriculture, forestry and fishing farms

2016	Gasoline	Diesel oil	Fuel oil	Biomass
	kTOE			
Agriculture, forestry and fishing farms	639.96	1,708.71	332.65	318.76

c. EFs

Currently, Viet Nam has not had data on carbon content and country specific EFs for fuel consumption, so the default values shown in Table 2.5, page 2.22, Chapter 2, Volume 2, the IPCC 2006 Guidelines were used as shown in Table 3.17.

Table 3.17 Default EFs applied to Agriculture, forestry and fishing farms

GHG	Gasoline	Diesel oil	Fuel oil	Biomass
	Kg/TJ			
CO_2	69,300.0	74,100.0	77,400.0	
CH_4	10.0	10.0	10.0	300.0
N_2O	0.6	0.6	0.6	4.0

d. Results of emissions

GHG emissions from agriculture, forestry and fishing farms (1A4c) are reported in Table 3.11.

3.2.1.5 Non-Specified (1A5)

As data is not available, emissions from non-specified (1A5) are not taken into account.

Comparison reference approach with the sectoral approach

The reference approach to estimate CO_2 emissions from fuel combustion activities using a top-down approach on the basis of national energy statistics for production, import, export and reserves changes. The difference in CO_2 emissions between the reference approach and the sectoral approach in 2016 is 1.9%. The difference in energy consumption and CO_2 emissions can be seen as energy loss and carbon imbalance in the Energy balance table 2016, the IE, MOIT, 2020 as shown in Table 3.18.

Table 3.18 Comparison of CO_2 emissions in 2016 between sectoral approach and referenced approach

	Method		Difference
	Sectoral approach	Reference approach	
	kt		*%*
CO_2 Emissions	184,534.87	188,191.30	1.9

3.2.2 Fugitive emissions (1B)

The geological characteristics of the coal seams can generate CH_4 and CO_2. Fugitive emissions are calculated as the amount of GHG emissions leaked from oil and gas facilities, except emissions from fuel combustion. The oil and natural gas systems include all the necessary facilities to produce, collect, process or refine and deliver natural gas and petroleum products to the market.

Fugitive emissions are intentional or unintentional GHG emissions that can occur during the extraction, processing and distribution of fossil fuels to the final consumers. Fugitive emissions occur from the extraction, treatment, storage and transportation of coal, oil and natural gas.

3.2.2.1 Solid Fuels (1B1)

Coal mining and handling (1B1a)

For coal mining, the geological process that produces coals also releases CH_4, and some of that remains in coal seams until they are mined. In general, the deeper coal seams underground, the more CH_4 containing than that of surface coal seams. As a result, most of the GHG emissions are emitted from underground coal seams. Emissions are also from open coal seams and post-mining activities.

GHG emissions from coal mining and handling are reported in Table 3.19.

Table 3.19 GHG emissions from coal mining for 2016

IPCC Code	Category	CO_2	CH_4	N_2O	Total
			kt		*$ktCO_2eq$*
1B1a	**Coal mining**		**94.76**		**2,653.34**
1B1ai	Underground mines		94.75		2,652.99
1B1aii	Surface mines		0.01		0.35

i. Underground Mining (1B1ai)

a. Methodology

According to the IPCC 2006 Guidelines, a Tier 1 approach method is used to calculate CH_4 emissions for underground coal mining. The formulas include: Equation 4.1.1, page 4.9; Equation 4.1.3, page 4.11; and Equation 4.1.4, page 4.12, Chapter 4, Volume 2, the IPCC 2006 Guidelines.

b. AD

According to data from the Energy balance table 2016, the IE, MOIT, 2020, domestic coal production in 2016 reached about 37 million tonnes, but the figure has not been separated into underground and surface coal mines. According to expert adjustments, the percentage of surface coal mining in Viet Nam was 40% and underground coal mining, 60%. Details of coal mining production for each type are shown in Table 3.20.

Table 3.20 Domestic coal mining production

Year 2016	Underground coal mining	Surface coal mining
	thousand tonnes	
Domestic production	22,626.74	15,084.49

c. EFs

The default EFs applied are the country specific EFs and default values according to the IPCC 2006 Guidelines for the emission calculation:

CH_4 EF for underground coal mining: 3.8m^3/tonne (MOIT, 2014); and

Post-mining CH_4 EF: 2.5m^3/tonne (page 4.12, Chapter 4, Volume 2, the IPCC 2006 Guidelines).

d. Results of emissions

GHG emissions from underground coal mining (1B1ai) are reported in Table 3.19.

ii. Surface coal mining (1B1aii)

a. Methodology

According to the IPCC 2006 Guidelines, the Tier 1 approach was used to calculate CH_4 emissions for surface coal mining. The formulas used included: Equation 4.1.6, page 4.17; Equation 4.1.7, page 4.18 and Equation 4.1.8, page 4.19, Chapter 4, Volume 2, the IPCC 2006 Guidelines.

b. AD

The surface coal mining production data is shown in Table 3.22.

c. EFs

Default EFs used according to IPCC 2006 guidelines included:

- The CH_4 EF for surface coal mining: 1.2m^3/tonne (page 4.18, Chapter 4, Volume 2, the IPCC 2006 Guidelines); and

- The CH4 EF for post-mining: 0.1m^3/tonne (page 4.19, Chapter 4, Volume 2, the IPCC 2006 Guidelines).

d. Results of emissions

GHG emissions from surface coal mining (1B1aii) are reported in Table 3.19.

3.2.2.2 Oil and natural gas (1B2)

CH_4 emissions from oil and natural gas include the emissions during normal operations, for example, the emissions from steam venting and combustion in oil and natural gas producing, frequent leaks or emissions from ventilatonne; emissions during repair and maintenance; emissions due to problems and malfunctions in the system operations. The emissions from oil and natural gas in 2016 are shown in Table 3.21.

Table 3.21 GHG emissions from oil and natural gas for 2016

IPCC Code	Category	CO_2	CH_4	N_2O	Total
		kt			*ktCO₂eq*
1B2	Oil and natural gas	1,523.84	644.54	0.01	19,574.02
1B2a	Oil	767.48	509.64	0.01	15,040.39
1B2b	Natural gas	756.36	134.90	0.00	4,533.63

3.2.2.2.1 Oil (1B2a)

a. Methodology

According to the IPCC 2006 Guidelines, the Tier 1 approach was used to calculate GHG emissions for crude oil production and transportation since Viet Nam has not had actual measurement data and country specific EFs, as well as data on associated gas treatment, applying Equation 4.2.1, page 4.41, Chapter 4, Volume 2, the IPCC 2006 Guidelines.

According to IPCC 2006 Guidelines, the Tier 1 method was used to calculate the GHG emissions for crude oil refining and further subdivided into the different parts as Viet Nam has not had actual measure data and country specific EFs, equation 4.2.1, page 4.41, Chapter 4, Volume 2, the IPCC 2006 Guidelines.

b. AD

According to the Energy balance table 2016, the IE, MOIT, 2020, the amount of crude oil produced domestically in 2016 was 14,860.00 tonnes.

c. EFs

The default EFs in IPCC 2006 were used to calculate the amount of emissions as Viet Nam has not had country specific EFs. Since the default EFs in Table 4.2.5, pages 4.55 to 4.62, Chapter 4, Volume 2, the IPCC 2006 Guidelines were determined to an extent and no expert suggestions were available, the mean values were chosen as the EFs as detailed in Table 3.22.

Table 3.22 Default EFs applied to oil and natural gas production

Emission source	Unit	CO_2 EF	Mean value	CH_4 EF	Mean value	N_2O EF	Mean value
		thousand tonnes/10^3m^3		*thousand tonnes CH_4*		*thousand tonnes N_2O*	
Oil							
Oil production/ Venting	thousand tonnes /103m³ total Oil production	1.8E-03 to 2,5 E-03	0.00215	8.7E-03 to 1.2E-02	0.01035	NA	NA
Oil production/ Flaring	thousand tonnes /103m³ total Oil production	3.4E-02 to 4,7E-02	0.0405	2.1E-05 to 2.9E-05	0.000025	5.4E-07 to 7.4E-07	0.00000064
Oil production/ Fugitive	thousand tonnes /103m³ total Oil production	2.8E-04 to 4.7E-03	0.00249	2.2E-03 to 3.7E-02	0.0196	NA	NA
Natural gas							
Gas proccessing/ Venting CO_2	thousand tonnes /106m³ total gas input	4E-02 to 9.5E-02	0.0675	NA	NA	NA	NA
Gas proccessing/ Flaring	thousand tonnes /106m³ total gas production	3E-03 to 4.1E-03	0.00355	2E-06 to 2.8E-06	0.0000024	3.3E-08 to 4.5E-08	0.000000039
Gas production/Flaring	thousand tonnes /106m_3 total gas production	1.2E-03 to 1.6E-03	0.0014	7.6E-07 to 1E-06	0.00000088	2.1E-08 to 2.9E-08	0.000000025
Gas production/ Fugitive	thousand tonnes /106m³ total gas production	1.4E-05 to 1.8E-04	0.000097	3.8E-04 to 2.4E-02	0.01219	NA	NA
Gas proccessing/ Fugitive	thousand tonnes /106m³ total gas input	1.5E-04 to 3.5E-04	0.00025	4.8E-04 to 1.1E-03	0.00079	NA	NA

d. Results of emissions

Emissions from oil (1B2a) are reported in Table 3.21.

3.2.2.2.2 Natural gas (1B2b)

a. Methodology

According to the IPCC 2006 Guidelines, the Tier 1 approach was used to calculate the GHG emissions for the natural gas since Viet Nam has not had actual measure data and country specific EFs, applying Equation 4.2.1, page 4.41 and Equation 4.2.2, page 4.41, Chapter 4, Volume 2, the IPCC 2006 Guidelines.

b. AD

Based on the Energy balance table 2016, the IE, MOIT, the volume of natural gas domestically produced was 10,390.00x106 m3.

c. EFs

Default EFs for calculating emissions from natural gas are shown in Table 3.2.

d. Results of emissions

GHG emissions from natural gas are reported in Table 3.21.

Other emissions from energy production (1B3)

Since the data on these activities has not been collected yet, the emissions from other energy production have not been taken into account.

3.2.3 Carbon dioxide transport and storage (1C)

Since the data of CO_2 production, transport and storage has not been available in Viet Nam, no 2016 national GHG inventories were conducted in the subsectors of 1C1, 1C2 and 1C3.

3.3 Conclusions and Recommendations

3.3.1 Improvements compared to previous inventories

- Use the methodology under IPCC 2006 Guidelines: more detailed subcategories, applying default EFs in the IPCC 2006 Guidelines.

- The consistency of operational data under the same kTOE facilitates calculation, avoids confusion, and unifies the data between energy data compilers and data providers.

- For each subsector:

+ 1A1. Energy industry: the emission estimate for the new subcategory '1A1ci. Producing charcoal'; fuel consumption figures for petrochemical refining and gas processing were more reasonably selected.

+ 1A2. Manufacturing industries and construction: Fuel consumption figures were more detailed and complete.

+ 1A3. Transport: Updated two new fuel types including ethanol and natural gas used in transport.

3.3.2 Difficulties, shortcomings and recommendations

- Gathering information and data on fuel combustion in petrochemical refining: this data has currently been calculated as the mean value in the range recommended by the IPCC 2006 Guidelines while Viet Nam could estimate the data, and at present the figure has not been shown in the Energy balance table 2016.

- Gathering information and data on fuel combustion in gas processing: the data has presently been assumed to be estimated.

- It is necessary to collect fuel consumption data in the non-ferrous metal manufacturing subsector.

- It is essential to collect fuel consumption figures for international water borne navigation and international civil aviation.

- It is necessary to collect sufficient data to be able to estimate the emissions using an accurate source model for oil and natural gas.

- Formulate the country specific EFs, give priority to coal combustion.

CHAPTER 4

INDUSTRIAL PROCESSES AND PRODUCT USE

4.1 Introduction

GHG emissions are produced from a wide variety of industrial activities not related to the energy sector. The main emission sources are from IPPU that chemically or physically transform materials. GHG emissions in IPPU for 2016 were calculated for existing IP in Viet Nam including the production of cement, lime, glass, ammonia, nitric acid (N_2O), iron and steel and the use of fire protection. Total 2016 GHG emissions in IPPU were 46,094.64 $ktCO_2eq$. Of which, the largest emissions came from the cement production, 36,773.00 $ktCO_2eq$, accounting for 79.8% of the total as shown in Table 4.1 and Figure 4.1. Details of the summary are given in Annex 2-2.

Table 4.1 GHG emissions in IPPU sector for 2016

IPCC Code	Category	CO_2	CH_4	N_2O	HFCs	Total	Proportion
		$ktCO_2eq$					*%*
2	**IPPU**	**46,047.20**		**184.46**	**23.32**	**46,094.64**	**100**
2A	Mineral industry	40,917.20				40,917.20	88.8
2A1	Cement production	36,773.00				36,773.00	79.8
2A2	Lime production	3,825.00				3,825.00	8.3
2A3	Glass production	319.20				319.20	0.7
2B	Chemical industry	1,271.78		184.46		1,295.90	2.8
2B1	Ammonia production	1,271.78				1,271.78	2.8
2B2	Nitric acid production			24.12		24.12	0.1
2C	Metal industry	3,858.22				3,858.22	8.4
2C1	Iron and steel production	3,858.22				3,858.22	8.4
2F	Product uses as substitutes for ozone depleting substances				23.32	23.32	0.1
2F3	Fire protection				23.32	23.32	0.1

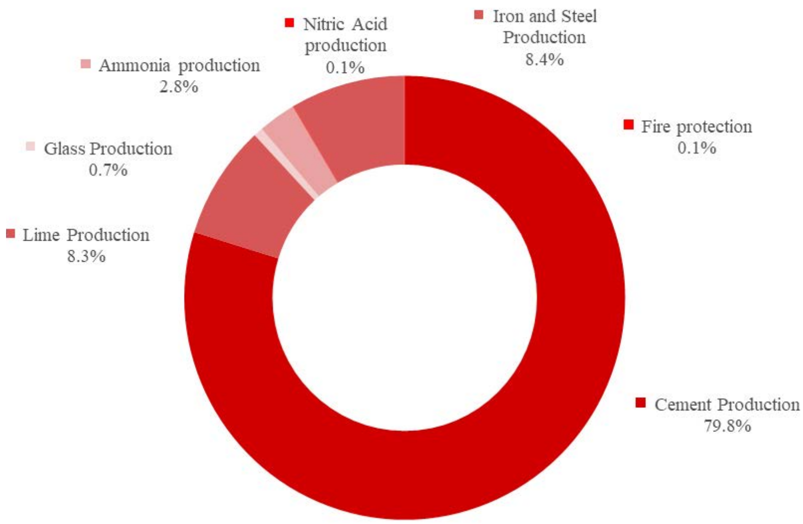

Figure 4.1 Propotion of GHG emissions of IPPU for 2016.

4.2 Description of emission sources

4.2.1 Mineral industry (2A)

4.2.1.1 Cement production (2A1)

In the cement production, CO_2 is generated during the production of clinker. During the production of clinker, limestone, 95% composition of which is calcium carbonate ($CaCO_3$), is heated, or calcined, to produce lime (CaO) and CO_2 as a by-product. The CaO then reacts with silica (SiO_2), alumina (Al_2O_3) and iron oxide (Fe_2O_3) in the raw materials to make the clinker minerals (mainly calcium silicates) and this reaction does not produce additional CO_2.

Although CH_4 and N_2O have emissions in the cement production process, according to the current research results, they only account for a very small amount compared to CO_2, so the calculation for these two GHGs can be ignored.

a. Methodology

Since no statistical data for domestically produced clinker and country specific EFs are available, the Tier 1 approach was used to calculate the emissions, according to Equation 2.1, page 2.8, Chapter 2, Volume 3, the IPCC 2006 Guidelines.

b. AD

As no statistics on clinker production in Viet Nam in 2016 have been available, the clinker production was estimated from domestic cement production and imported and exported clinker volumes. Data on cement production in 2016 was reported in the Viet Nam Statistical yearbook 2019, GSO. However, the Viet Nam Statistical yearbook does not provide data on imported and exported clinker volumes. Therefore, the AD on imported and exported cement and clinker production was taken from the 'Cement industry report 2016' of the Viet Nam Cement Association, 2017 as detailed in Table 4.2.

Table 4.2 Cement produced in Viet Nam and imported and exported clinker volumes

Production	2016 *Thousand tonnes*	Source
Cement	74,457	Viet Nam Statistical yearbook 2019, GSO
Imported clinker	0	Cement industry report 2016, the Viet Nam Cement Association, 2017
Exported clinker	8,918	

The average percentage of clinker in cement produced in Viet Nam was estimated at about 83% based on the data of MOC in 2016. The statistics were taken from the project namely 'Preparing to the readiness of NAMA for the cement production sector in Viet Nam', detailed in Table 4.3.

Table 4.3 Average percentage of clinker in cement produced in Viet Nam

Cement production	Percentage of clinker in cement (Ccli)	Average percentage of clinker	Source
	%		
OPC	92 - 96	83	Project report 'Preparing to the readiness of NAMA for the cement production sector in Viet Nam', MOC, 2016
PCB 40	75 - 80		
PCB 30	60 - 65		

AD of the cement production is the volume of domestically produced clinker and the export volume in 2016. The total production was 70,717.31 thousand tonnes.

c. EFs

Since no country specific Efs have been available, the EF applied was 0.52 tCO_2/tonne clinker from IPCC 2006 default values, detailed in Table 4.4.

Table 4.4 Default EFs applied to cement production

Factor	Value	Source
Ratio Factor	0.786	The ratio of molecular mass between CO_2 and CaO
Content CaO/clinker	0.65	Page 2.11, Chapter 2, Volume 3, IPCC 2006 Guidelines
Correction factor CKD	1.02	Page 2.11, Chapter 2, Volume 3, IPCC 2006 Guidelines

CHAPTER 1 Introduction
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d. Results of emissions

CO_2 emissions in the cement production in 2016 were 36,733.00 thousand tonnes. Besides, the cement production also emits SO_2 with an EF of 0.3kgSO_2/tonne as the default value according to Section 2.3.3, page 2.7, Chapter 2, Volume 3, the IPCC 1996 Revised. Therefore, SO_2 emissions from the cement production in 2016 were 22.34 thousand tonnes.

4.2.1.2 Lime production (2A2)

Lime production produces calcium oxide (CaO or quicklime) through the thermal decomposition (calcination method) of $CaCO_3$ in the limestone, or through the decomposition of dolomite ($CaCO_3$.$MgCO_3$) to produce dolomite lime (CaO.MgO). To calculate GHG emissions from the lime production, it is necessary to determine the amount of CaO and CaO.MgO generated from the lime production.

a. Methodology

For Tier 2 and Tier 3, AD is required to have a clear distinction between lime production and lime kiln dust (LKD). Since no data have been available on LKD, the emissions from the lime production in 2016 were calculated using the Tier 1 approach method.

b. AD

The data on lime production in 2016 was 5.1 million tonnes obtained from the technical report on input data for GHG emission reduction based on improved technological processes in building material manufacturing, MOC, 2016.

As the AD on Viet Nam's lime production has not been separatedly reported by type of lime, the default value for the high Calcium/Lime lime ratio was 85/15 according to Section 2.3.1.2, page 2.22, Volume 3, the IPCC 2006 Guidelines and the mass of slaked lime was assumed to be zero according to the adjustment of the construction material experts.

c. EFs

The default EFs were used according to Table 2.4, page 2.22, Chapter 2, Volume 3, the IPCC 2006 Guidelines.

d. Results of emissions

CO_2 emissions from the lime production (2A2) in 2016 were 3,825.00 thousand tonnes.

4.2.1.3 Glass production (2A3)

Materials used to produce glass which are the main contributors to CO_2 emissions during melting are limestone ($CaCO_3$), dolomite $CaMg(CO_3)_2$ and soda (Na_2CO_3). These materials are mined as mineral carbonates for use in the glass industry, they contribute primary CO_2 production and should be included in the emission estimate. In the case of the carbonate materials produced through hydroxide carbonation, they will not release CO_2 emissions and should not be included in the emission estimate. There is a small amount of CO_2 emitted from the raw materials of glass namely barium carbonate ($BaCO_3$), ash ($3CaO_2P_2O_5 + XCaCO_3$), potassium carbonate (K_2CO_3) and strontium carbonate ($SrCO_3$). In addition, charcoal powder or some other organic materials can be added to create the conditions for the reducing reaction in the molten glass, and will combine with the available oxygen in the glass melt to produce CO_2.

a. Methodology

Since there is no data on the amount of carbonate used in the glass production, the emissions from glass production were calculated using the Tier 1 apprach and Equation 2.10, page 2.28, Chapter 2, Volume 3, the IPCC 2006 Guideliens.

b. AD

Data on the glass production in 2016 was 168 million m^2 collected from the technical report 'Input data for GHG emission reduction through improvement of technological processes in building material production', the Institute of Materials Construction Materials, MOC, 2016.

c. EFs

The default EF of IPCC 2006 Guidelines was used for the calculation with a value of 0.2kgCO_2/kg of the materials (quartz sand, feldspar, limestone,...). The converted amount of glass used was 10kg/m^2 according to the adjustment of construction material experts.

In addition, the construction glass production also releases emissions of organic compounds outside methane (NMVOC). The default EF of NMVOC from glass production was 0.0045 tonnes NMVOC/tonne of glass.

d. Results of emissions

CO_2 emission from the glass production in 2016 was 319.20 thousand tonnes and NMVOC emissions from glass production was 7.56 thousand tonnes.

4.2.1.4 Other process uses of carbonates (2A4) and other mineral industries (2A5)

4.2.1.4.1 Limestone and dolomite use

$CaCO_3$ and $CaMg(CO_3)_2$ are the main materials used in the metallurgic, glass, agriculture, construction and environmental remediation industries. In industry process, these materials are often heated at high temperatures, from which CO_2 is produced. However, due to the fact that the AD has not yet been collected, emissions from the use of $CaCO_3$ and $CaMg(CO_3)_2$ have not been estimated.

4.2.1.4.2 Sodium carbonate production and use

Sodium carbonate (Na_2CO_3) is used as a raw material for the glass, soap and detergent, pulp and paper, and water treatment industries. CO_2 can be produced during both the use and producing of Sodium Carbonate, depending on the technology used to produce it. In 2016, soda ash was not produced in Viet Nam and the data on the Na_2CO_3 production used in Viet Nam was not available, thus, the GHG emissions from this production were not estimated.

4.2.1.5 Use of carbonates in ceramics production

Ceramics include the production of bricks and roof tiles, vitrified clay pipes, refractory products, expanded clay products, wall and floor tiles, table and ornamental ware (household ceramics), sanitary ware, technical ceramics, and inorganic bonded abrasives. Emissions related to the ceramics manufacturing process are the results of calcination of carbonates in clay, as well as the addition of additives. In the case of traditional ceramics manufacturing, ceramics are dried and then enameled before being heated to high temperatures in a kiln, producing oxides and CO_2. After heated, some ceramics may undergo an additional treatment to achieve the desired quality. CO_2 releases from the process of heating raw materials (especially clay, shale, limestonnee and dolomite) and using limestonnee as auxiliary materials. Because the AD of ceramics industry has not been collected yet, the emissions from this process cannot be estimated.

4.2.1.6 Soda ash use

Soda ash is used in a variety of applications, including the manufacture of glass, soaps and detergents, flue gas desulfurization, chemicals, pulp and paper, and other popular consumer products. Soda ash production and consumption (including Na_2CO_3) CO_2 emissions. Emissions from the use of Soda ash are partially accounted for in the Glass process sub-sector (2A3), while emissions from the use of soda ash can also be accounted for in Other mineral industrial processes (2A5) and in other sub-sectors of Industrial processes and product use (2H). Similarly, when soda ash is used as input material sources of other industries such as chemicals, the emissions will be reported in that sub-sector. Since no data has been available on total soda ash production used in Viet Nam, emissions from the Other use of carbonates (2A4) sub-subsector were not calculated, except for the calculation in (2A3) sub-sector.

4.2.1.7 Other mineral industries (2A5)

Since the AD has not been collected yet, the emissions from other mineral industries could not be estimated.

4.2.2 Chemical industry (2B)

4.2.2.1 Ammonia production (2B1)

Ammonia (NH_3) is a major industrial chemical and the most important nitrogenous material produced. Ammonia gas is used directly in a variety of applications such as as a fertiliser, in heat treating, paper pulping, nitric acid and nitrates manufacture, nitric acid ester and nitro compound manufacture, explosives of various types, and as a refrigerant. Ammonia is produced by the reaction that changes the structure of natural gas or other fossil fuels that causes CO_2 emissions.

a. Methodology

GHG emissions from NH_3 production are calculated using the Tier 1 approach and based on Equation 3.1, page 3.12, Chapter 3, Volume 3, the IPCC 2006 Guidelines.

b. AD

Since no data on NH3 production has been available in the National Statistical yearbook, the data on NH_3 production in 2016 was collected directly from the fertilizer factories and urea ($(NH_2)_2CO$) production was collected from the Plant Protection Department, MARD, 2020, detailed in Tables 4.5 and 4.6.

Table 4.5 NH_3 and urea production in 2016

Production	Factory				Source
	Ha Bac	Ninh Binh	Phu My	Ca Mau	
	tonnes				
Urea	193,240	60,526	503,470	468,450	Data provided by the factories, 2020
The proportion of NH_3 in urea (%)	80	70	59	58	

Table 4.6 NH_3 and urea production by fuel type in 2016

Year	NH_3 produced from coals (partial oxidation)	NH_3 produced from natural gases (steam reforming)	Total Urea production	Urea produced from coals	Urea produced from natural gases	Source
	tonnes					
2016	253,766	971,920	2,218,894	412,180	1,806,714	Data provided by 4 factories, 2020

c. EFs

The default values of EFs for NH_3 production were used according to the IPCC 2006 Guidelines and the IPCC 1996 Revised, detailed in Tables 4.7, 4.8 and 4.9.

Table 4.7 Total fuel requirement by type of NH_3 production technology

Technology	Type of fuel	Fuel requirement *GJ/tonne NH_3*	Source
Partial oxidation	Coal	42.75	Table 3.1, page 3.15, Chapter 3, Volume 3, IPCC 2006 Guidelines
Reforming - natural gas	Natural gas	34.2	

Table 4.8 Carbon content factor (CCF) in fuels

Technology	Type of fuel	CCF *kg C/GJ*	COF	Source
Partial oxidation	Coal	26	1	Table 1.3, pages 1.21-22 and Table 1.4, pages 1.23-24, Chapter 1, Volume 2, IPCC 2006 Guidelines
Reforming - natural gas	Natural gas	15.3	1	

Table 4.9 GHG EFs from NH_3 Production

	NMVOC	CO	S_{02}	Source
	kg/tonne product			
EF	4.7	7.9	0.03	Table 2-6, page 2.17, Chapter 2, Volume 3, IPCC 1996 revised

d. Results of emissions

Emissions from NH_3 production are reported in Table 4.10.

Table 4.10 Emissions from NH_3 production in 2016

Year	CO_2 emissions		CO_2 used to produce urea	Emissions			
	NH_3 produced from coal	NH_3 produced from natural gas		CO_2	NMVOC	CO	SO_2
	kt						
2016	1,034.22	1,864.75	1,627.19	1,271.78	5.76	9.68	0.04

4.2.2.2 Nitric acid production (2B2)

During the production of nitric acid (HNO_3), nitrogen oxide (N_2O) is generated as an unintended by-product of the high temperature catalytic oxidation of NH_3.

a. Methodology

To calculate the GHG emissions from the production of HNO_3, the Tier 1 method is used, applying Equation 3.5, page 3.21, Chapter 3, Volume 3, the IPCC 2006 Guidelines.

b. AD

By November 2016, a new HNO_3 ammonium nitrate plant had operated in Viet Nam. Based on the data from the Viet Nam Coal and Mineral Group, in 2016, the HNO_3 production of the Z195 Factory was 25,000 tonnes/year and that of the MICCO Thai Binh Factory was 160,000 tonnes/year. However, according to the survey data from the Chemical Department, MOIT, 2020, the HNO_3 production amount of the two factories were 12,000 tonnes and 1,000 tonnes, respectively.

c. EFs

EF applied for medium pressure combustion plants during the HNO_3 production was selected as 7kg N_2O/ tonne HNO_3 according to Table 3.3, page 3.23, Chapter 3, Volume 3, the IPCC 2006 Guidelines.

d. Results of emissions

N_2O emissions in 2016 from the production of HNO_3 were 91 tonnes N_2O, or equivalent to 24.12 ktCO_2eq.

4.2.2.3 Other chemical industries (2B4, 2B5, 2B6, 2B7, 2B8, 2B9 và 2B10)

Due to the lack of AD, the GHG emissions from other chemical industries including category 2B4, 2B5, 2B6, 2B7, 2B8, 2B9 and 2B10 were not estimated.

4.2.3 Metal industry (2C)

4.2.3.1 Iron and steel production (2C1)

The production of iron and steel leads to emissions of CO_2, CH_4, and N_2O. Unrefined iron (Fe) is produced by reducing iron oxide ore mostly in blast-furnace, carbon in coke or charcoal is used as fuel and reducing agent. In most blast-furnace, the process is aided by the use of carbonate (limestone) streams. Iron and steel production generates mainly CO_2 emissions. N_2O emissions are are also emitted the process; however, the emissions are small and can be ignored during the calculation of GHG emissions. Besides, the IPCC 2006 Guidelines do not provide guidance on estimating N_2O emissions from the iron steel production.

a. Methodology

Based on the AD of the total crude iron and steel production in 2016, the Tier 1 approach was applied to calculate the CO_2 and CH_4 emissions, according to Equation 4.4, page 4.21, Chapter 4, Volume 3, the IPCC 2006 Guidelines.

b. AD

The total production of crude iron and steel produced in 2016 was 5,472 thousand tonnes according to the Viet Nam Statistical yearbook, GSO, 2019; however, no AD has been available on crude iron and steel production classified based on technology. Currently, Viet Nam has applied three technologies to produce iron and steel, including BOF, EAF and OHF. According to the recommendation of construction material experts and the World Steel Association's 2017 Steel Statistics, in 2016, the iron and steel production produced by BOF and by EAF were 2,343 thousand tonnes and 2,343 thousand tonnes, respectively. Meanwhile, the data of crude iron and steel production using OHF technology has not been collected.

c. EFs

Based on the AD from the Steel Industry Statistical yearbook, the World Steel Association, 2017, GHG EFs from the steel and iron production were selected as 1.46tCO_2/tonne with BOF technology and 0.08 tCO_2/tonne with EAF technology. The emissions of steel and iron production applied OHF technology could not be calculated due to the lack of AD. The details are in Table 4.11.

Table 4.11 Default EFs of SO_2, NOx, CO and NMVOC applied to iron and steel production

EF	SO_2	NO_x	CO	NMVOC	Source
	g/tonne steel produced				
Iron production: Blast furnace charging	2,000		1,330	100	Section 2.13.3.3, page 2.28-29, Chapter 2, Volume 3, IPCC 1996 revised
Iron production: Pig iron tapping	30	76	112	20	
Rolling mills	45	40	1	30	Table 2.2-14, Section 2.13.3.3, page 2.29, Chapter 2, Volume 3, IPCC 1996 Revised

d. Results of emissions

GHG emissions from iron and steel production are reported in Table 4.12.

Table 4.12 GHG emissions from iron and steel production for 2016

IPCC Code	CO_2	CH_4	N_2O	SO_2	NO_x	CO	NMVOC
	kt						
2C1	3,858.20	NE	NA	16.21	9.06	11.27	1.17

4.2.3.2 Primary aluminium production (2C3)

Primary aluminium is produced exclusively by the Hall-Heroult electrolytic process. In this process, electrolytic reduction cells differ in the form and configuration of the carbon anode and alumina feed system and belong to one of four technology types: Centre-worked prebake (CWPB)3, Side-worked prebake (SWPB), horizontal Stud Søderberg (HSS) and vertical Stud Søderberg (VSS).

The most significant process emissions are:

(i) CO_2 emissions from the consumption of carbon anodes in the reaction to convert aluminium oxide to aluminium metal;

(ii) Perfluorocarbons (PFCs) emissions of CF_4 and C_2F_6 during anode effects.

In Viet Nam, two factories producing Al_2O_3 include:

The project to produce aluminum oxide from bauxite ore in Tan Rai, Lam Dong province, which have been operating since 2013;

The project to produce aluminum oxide from bauxite ore in Nhan Co, Dac Nong province, which has been operating since 2014.

However, all the aluminum oxide production is exported overseas. Therefore, the process of producing aluminum from Al_2O_3 has not been done in Viet Nam and Al_2O_3 production emits almost zero emissions, according to the IPCC Guidelines.

Other metal production processes (2C4, 2C5 & 2C6) and metallurgical production (2C7)

Due to the lack of AD, GHG emissions from other metal production (2C4, 2C5 and 2C6) and Metallurgical production (2C7) could not be estimated.

4.2.4 Non-Energy products from fuels and solvent use (2D)

Due to the lack of AD, GHG emissions from Non-energy products from fuels and solvent use sub-sectors (2D1, 2D2, 2D3 & 2D4) were not estimated.

4.2.5 Electronics industry (2E)

Due to the lack of AD, the GHG emissions from electronics industry production sub-sectors (2E1, 2E2, 2E3, 2E4 & 2E5) were not estimated.

4.2.6 Product uses as substitutes for ozone depleting substances (2F)

Since 2010, the consumption of halons and CFCs must be completely phased out in developing countries including Viet Nam under the Montreal Protocol. In recent years, the consumption of HFCs and PFCs has steadily increased to replace ozone depleting substances (ODS).

HFCs, fully known as Hydroflourcarbons, are flour-containing solvents widely used in manufacture and as refrigerant in refrigeration equipment. Viet Nam has not produced HFCs yet, so the emissions are only formed by using these F-gases.

4.2.6.1 Refrigeration and air conditioning (2F1) and foam blowing agents (2F2)

Due to the lack of information and the collection of HFCs and the amount of used HFCs, the GHG emissions from refrigeration and air conditioning (2F1) and foam blowing agents (2F2) processes were not estimated.

4.2.6.2 Fire protection (2F3)

a. Methodology

The method for calculating F gas emissions is based on Equation 7.2A, page 7.14, Chapter 7, Volume 3, the IPCC 2006 Guidelines.

b. AD

AD is the volume of HFCs used. This volume was calculated from the import HFCs volume provided by the National Ozone Office, DCC, MONRE, 2020 as well as the recommendation of refrigerant experts. The volumes of HFCs imported in 2015, 2016 and 2017 are shown in Table 4.13.

Table 4.13 Volumes of HFCs imported from 2015 to 2017

TT	Sector	2015	2016	2017
		tonne		
Total HFCs consumption		**1,720**	**2,088**	**2,307**
1	Residential refrigeration	167.5	171.1	183.5
	HFC-134A	167.5	171.1	183.5
2	Commercial and industrial refrigeration	128.2	143.6	160.0
	HFC-134A	30.5	34.7	41.1
	HFC-404A	54.9	60.1	64.7

TT	Sector	2015	2016	2017
		tonne		
	HFC-407C	18.6	19.6	22.7
	HFC-410A	18.4	22.6	24.6
	HFC-507C	5.8	6.5	6.9
3	Transport refrigeration	17.6	21.2	24.4
	HFC-134A	4.8	6.8	7.4
	HFC-404A	7.2	7.4	9.0
	HFC-407C	5.6	7.0	8.0
4	Residential air conditioning	7.5	16.2	62.8
	HFC-410A	7.5	16.2	62.8
5	Stationary air conditioning	101.4	107.0	114.8
	HFC-134A	47.2	48.9	52.7
	HFC-404A	8.7	8.9	9.3
	HFC-407c	12.8	14.2	16.1
	HFC-410A	32.8	35.0	36.7
6	Car air conditioning	122.6	155.9	153.1
	HFC-134A	122.6	155.9	153.1
7	Fire suppression and explosion protection	6.9	5.4	6.6
	HFC-125	2.4	1.8	2.2
	HFC-23	0.1	0.4	0.4
	HFC-227EA	4.3	3.2	4.0
8	Glass production	-	-	14.6
	HFC-152A	-	-	14.6
9	Services	1,168	1.468	1,587

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The HFC gases used in fire protection are HFC125, HFC23 and HFC227ea with the volume of 2.13, 0.3 and 3.83 tonnes, respectively, used in 2016. This value was calculated from the average imported volume in 3 years of 2015, 2016 and 2017 and recommended by refrigerant experts. However, this value has not shown the HFCs left over from previous years. Actually, the emissions of HFCs in equipment can take place for many consecutive years.

c. EFs

Each HFC is a source of GHG emissions during use, the EF is the GWP value of the corresponding gas, detailed in Table 4.14.

Table 4.14 GWP100 factors of HFCs

HFCs	GWP100yr	Source
HFC-23	12,400	IPCC, AR5, 2014
HFC-125	3,170	
HFC-227ea	3,350	

d. Results of emissions

The GHG emissions from the use of the fire protection agent are reported in Table 4.15.

Table 4.15 Emissions of fire protection in 2016

IPCC Code	HFC-23	HFC-125	HFC-227ea	Total
	tCO_2eq			
2F3	3.72	6.76	12.84	23.32

4.2.6.3 Aerosols (2F4), solvents (2F5) and other applications (2F6)

Due to the lack of AD, the GHG emissions from aerosols (2F4), solvents (2F5) and other applications (2F6) could not be estimated.

4.2.7 Other product manufacture and use (2G)

Due to the lack of AD, the GHG emissions from the sub-sectors from 2G1 to 2G4 could not be estimated.

4.2.8 Other product manufacture and use (2H)

Due to the lack of AD, the GHG emissions from sub-sectors from 2H1 to 2H3 were not estimated.

4.3 Conclusions and Recommendations

4.3.1 Improvements compared to the previous inventory

- The 2016 GHG emissions inventory for IPPU has improved in comparision to the previous inventories in terms of data and methods. Country specific EFs of Viet Nam were applied in some categories including the cement production and construction glass. The AD on a number of sectors has been collected in details for each manifacture facility (ammonia production, nitric acid production).

- The import and export clinker data was used for GHG inventory for the cement production in 2016.

- GHG emissions were calculated and estimated for the ammonia production based on the AD on the fuel consumption during the manufacturing

4.3.2 Difficulties, shortcomings and recommendations

- Improvements can be made to AD on the presence of high calcium and dolomite. This information can be collected from the statistics of the Department of Building Materials, MOC or from the enterprise statistics of the GSO. GHG emissions can be calculated more accurately with country specific EF available for lthe lime production. Furthermore, information on the purity of lime and water is necessary to determine since it has presently been assumed to be zero.

- The quantity of HFCs applied to each HFCs in practice according to the use purpose has not been accurate statistically. When AD on the use of each type of HFCs in application is collected, the results of the emissions calculated will be more accurate.

- It is necessary to collect more detailed on the types and characteristics of glass such as the thickness and weight of each type of glass.

- Since the AD on total NH_3 and urea production has not been reported in the Statistical yearbook, the AD have to be combined the information from the Department of Plant Protection, MARD and collected from nitrogen fertiliser plants. Improving the uniformity of the AD will make the results more accurate.

- When the iron and steel production is classified by type and manufacture technology related to the fossil fuels used, the calculation will be much more accurate. At the same time, CH_4 emissions will also be calculated when the AD on iron and steel production classified by type is available.

CHAPTER 5

AGRICULTURE, FORESTRY AND OTHER LAND USE

5.1 Introduction

GHG emissions and removals in AFOLU sectors for the inventory year of 2016 were calculated following the IPCC 2016 Guidelines. Total GHG emissions from AFOLU in 2016 were 44,069.74 ktCO_2eq. Summary of emissions/removals are displayed in Table 5.1 and Figure 5.1. Details of the summary are given in Annex 2-3.

Table 5.1 Net GHG emissions in AFOLU for 2016

IPCC Code	Category	CO_2	CH_4	N_2O	Total Net Emissions
		ktCO_2eq			
3	**AFOLU**	**-37,489.34**	**66,544.64**	**15,014.44**	**44,069.74**
3A	Livestock		15,553.10	2,960.27	18,513.37
3A1	Enteric fermentation		12,421.74		12,421.74
3A2	Manure management		3,131.36	2,960.27	6,091.63
3B	Land	-39,491.24			-39,491.24
3B1	Forest land	-54,657.78			-54,657.78
3B2	Cropland	3,637.60			3,637.60
3B3	Glassland	1,383.64			1,383.64
3B4	Wetlands	1,046.90			1,046.90
3B5	Settlements	1,919.14			1,919.14
3B6	Other land	7,179.27			7,179.27
3C	Aggregate sources and non-CO_2 emissions sources on land	2,001.90	50,991.54	12,054.16	65,047.60
3C1	Emissions from biomass burning		1,298.52	325.61	1,624.13
3C2	Liming	565.79			565.79
3C3	Urea application	1,436.11			1,436.11
3C4	Direct N_2O emissions from managed soils			7,754.11	7,754.11
3C5	Indirect N_2O emissions from managed soils			3,752.55	3,752.55
3C6	Indirect N_2O emissions from manure management			221.90	221.90
3C7	Rice cultivations		49,693.02		49,693.02

Note: *Negative value (-) shows the GHG absorption of sinks.*

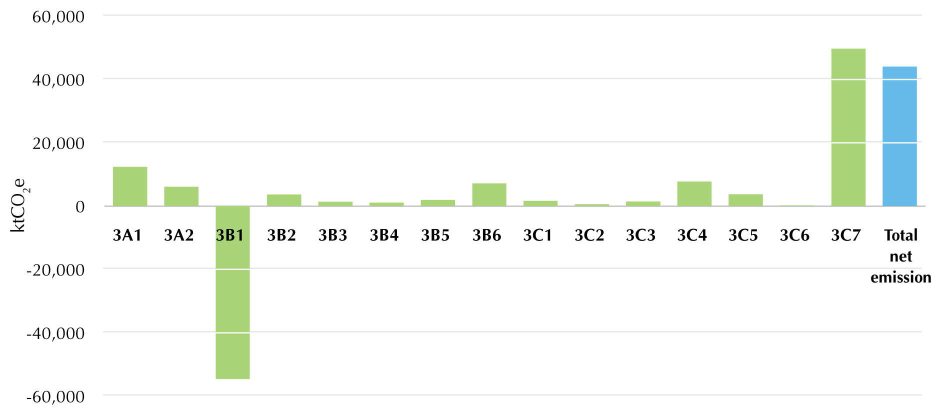

Figure 5.1 Net GHG emissions of AFOLU in 2016.

5.2 Description of emission sources

5.2.1 Livestock (3A)

5.2.1.1 Enteric fermentation (3A1)

Enteric fermentation is a digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption into the bloodstream. The main ruminant animals are cattle, buffalo, goats, sheep and camels. Pseudo-ruminant animals (e.g., horses, mules, and asses) and monogastric animals (i.e., animals with one stomach such as swine) have relatively lower methane emissions because much less methane-producing fermentation takes place in their digestive systems.

a. Methodology

Methane emissions from enteric fermentation were estimated by using Tier 1, Fomula 10.19 and 10.20, page 218, Chapter 4, the the IPCC 2006 Guidelines.

b. AD

The AD is livestock populations by each species. The number of dairy cows was taken from the 'Statistical yearbook of agriculture and rural development 2018' published in 2019 by MARD. The number of non-dairy cows was subtract of number of cows and number of dairy cows. Other livestock population numbers were taken from the Viet Nam Statistical yearbook 2018 by GSO and shown in Table 5.2.

Table 5.2 Livestock population in 2016

Animal Category	Quantity	Data source/Analysis of information (if available)
	head	
Daily cow	282,990	Statistical Yearbook of agriculture and rural development 2018, MARD, 2019
Non- Daily cow	5,213,567	Statistical yearbook 2018, GSO, 2019
Sheep	126,133	Statistical yearbook of agriculture and rural development 2018, MARD, 2019
Goats	2,021,003	
Horses	54,117	
Buffalo	2,519,411	Statistical yearbook 2018, GSO, 2019
Swine	29,075,315	
Poultry	361,721,000	

c. EFs

EFs applied to Enteric fermentation were the default values taken from the IPCC 2006 Guidelines, details in Table 5.3.

Table 5.3 EFs applied to Enteric fermentation

Animal category	EFs	Data source/Analysis of information (if available)
	$kgCH_4$/head/year	
Daily cow	68	Table 10.10, page 10.28, IPCC 2006 Guidelines (Asia)
Non-dairy cow	47	
Buffalo	55	Table 10.11, page 10.29, IPCC 2006 Guidelines (developing country)
Sheep	5	
Goats	5	
Horses	18	
Swine	1	

d. Results of emissions/removals

Total CH_4 emissions from Enteric fermentation for 2016 were 443.63 $ktCH_4$. The largest emissions went from the subsector of non-dairy cow (245.04 $ktCH_4$), and the second, the subsector of buffalo (138.57 $ktCH_4$). Results are reported in Table 5.4

Table 5.4 CH_4 emissions from enteric fermentation for 2016

Animal category	Emissions	
	$ktCH_4$	*$ktCO_2eq$*
Total	443.63	12,421.74
Daily cow	19.24	538.81
Non-dairy cow	245.04	6,861.05
Buffalo	138.57	3,879.89
Sheep	0.63	17.66
Goats	10.11	282.94
Horses	0.97	27.27
Swine	29.08	814.11

5.2.1.2 Manure management (3A2)

5.2.1.2.1 Methane emissions from Manure management

Methane is produced from the decomposition of manure under anaerobic conditions. These conditions often occur when large numbers of animals are raised in a confined area (e.g., dairy farms, beef feedlots, and swine and poultry farms) and where manure is typically stored in large piles or disposed of in lagoons, where oxygen is absent or present in very low concentration.

The portion of the manure that decomposes anaerobically depends on how the manure is managed. When manure is stored or treated as a liquid (e.g., in lagoons, ponds, tanks, or pits), it tends to decompose anaerobically and produce a significant quantity of methane. When manure is handled as a solid (e.g., in stacks or pits) or when it is deposited on pastures and rangelands, it tends to decompose aerobically and little or no methane is produced.

a. Methodology

Methane emissions is also produced during the storage and treatment of livestock manure. The term 'manure' means dung and urine of livestocks. Emissions related to the using methane as a fuel are counted in the energy or waste sector (if burned without energy recover). The decomposition of waste happens under anaerobic conditions, during storage and treatment, therefore it generates CH_4. These conditions occur easily when large number of animals are managed in a centralised area (e.g dairy cow farm, swine farm or poultry farm).

The main factors impacting CH_4 emissions are the amount of livestock manure produced and the amount of anaerobic manure decomposition. The very first factor of the amount of manure depends on the rate of manure production by each type and the number of livestock. Second factor relates to how the manure is managed and treated. When waste is stored or disposed in liquid containers (e.g, in a tank or pit ...), it decomposes anaerobically and can generate significant amounts of CH_4. The storage device temperature and storage time also have an effect on the amount of released CH_4 gas. When waste is disposed as solid materials in pasture or grazing fields, it tends to decompose under aerobic conditions and produces less amount of CH_4.

CH_4 emissions in the livestock manure management subsector (3A2) in Viet Nam were estimated using a quadratic method based on the coefficients: country-specific MCF (CH_4 conversion factors), Bo (maximum CH_4 producing capacity), VS (Volatile solid excretion rates) and rate of livestock manure management.

b. AD

AD for estimating CH_4 emissions from manure management was the livestock population by animal category in climate regions (the temperate region with average temperature from 15-25^{0}C and the warm region that is >25^{0}C). The number of daily cows was taken from the Statistical yearbook of agriculture and rural development 2018 of MARD. The number of non-dairy cows was subtract of number of cows and number of dairy cows. Other livestock population numbers were taken from the Viet Nam Statistical yearbook 2018 by GSO, MPI and described in Table 5.5.

Table 5.5 Number of animals in climate regions for 2016

Animal category	From 15-25°C	From >25°C	Data source
	Head		
Dairy cow	147,291	135,699	Statistical yearbook of agriculture and rural development 2018, MARD, 2019
Non- dairy cow	3,024,832	2,188,735	Statistical yearbook 2018, GSO, 2019
Buffalo	2,272,387	247,024	Statistical yearbook of agriculture and rural development 2018, MARD, 2019
Sheep	430	125,703	
Goat	1,365,270	655,733	
Horse	53,461	656	
Swine	19,559,899	9,515,416	
Poultry	232,496,000	129,224,000	

According to the IPCC 2006 Guidelines, in order to accurately estimate emissions, it is necessary to classify regions with different climatic conditions due to the fact that the amount of emissions varies under temperature conditions. In the IPCC 2006 Guidelines, the livestock waste management (CH_4) subsector is divided into three climatic regions including area with the average temperature lower than 15^{0}C, area with temperature from 15 to 25^{0}C and area with the average temperature higher than 25^{0}C. Based on the average temperature of each geographic region of Viet Nam, it can be divided into two climate zones (the area with the average temperature from 15o to 25^{0}C, the area with the average temperature higher than 25^{0}C). With the data collected from the meteorological stations, the average temperature of the six regions were be calculated. The division of provinces by six regions follows the administrative division in the Viet Nam Statistical yearbook 2016 of GSO (page 29 - Section of administrative units, land and climate, 2017), detailed in Table 5.6.)

Table 5.6 Classification of climate regions

Climate region	Region	Province/City
Temperate (average temperature 15-25^{0}C)	Red River Delta	Ha Noi, Ha Tay, Vinh Phuc, Bac Ninh, Quang Ninh, Hai Duong, Hai Phong, Hung Yen, Thai Binh, Ha Nam, Nam Dinh, Ninh Binh
	Northern midlands and mountain areas	Ha Giang, Cao Bang, Bac Kạn, Tuyen Quang, Lao Cai, Yên Bai, Thai Nguyên, Lang Son, Bac Giang, Phu Tho, Dien Bien, Lai Chau, Son La, Hoa Binh
	Northern Central and Central coastal areas	Thanh Hoa, Nghe An, Ha Tinh, Quang Binh, Quang Tri, Thua Thien Hue
	Central Highlands	Kon Tum, Gia Lai, Dak Lak, Dak Nong, Lam Dong
Warm (average temperature higher than 25^{0}C)	Southern Central and Central coastal areas	Da Nang, Quang Nam, Quang Ngai, Binh Dinh, Phu Yen, Khanh Hoa, Ninh Thuan, Binh Thuan
	South East	Binh Phuoc, Tay Ninh, Binh Duong, Dong Nai, Ba Ria - Vung Tau, Ho Chi Minh City
	Mekong River Delta	Long An, Tien Giang, Ben Tre, Tra Vinh, Vinh Long, Dong Thap, An Giang, Kien Giang, Can Tho, Hau Giang, Soc Trang, Bac Lieu, Ca Mau

c. EFs

VSE by each type of livestock is taken from the default values in Table 10.13A, page 10.55, Chapter 10, the 2019 Refinement to the 2006 IPCC Guidelines, shown in Table 5.7.

VSE rates per day were calculated with the average weight of each livestock type in Viet Nam. Due to the lack of statistical number of average weight by each livestock type, values were proposed by agriculture experts, detailed in Table 5.7.

Table 5.7 VSE rates, average weight and amount of VS by each animal category

Animal Category	VS	Average weight	Amount of VS
	kg/day	*kg*	*kg/1,000kg/day*
Dairy cow	9	400	3.60
Non-dairy cow	9.8	300	2.94
Buffalo	13.5	380	5.13
Sheep	8.3	30	0.25
Goats	10.4	30	0.31
Horse	7.2	180	1.30
Swine	5.8	50	0.29
Poultry	11.2	2	0.02

Bo of each animal category is taken by the default value in both the IPCC 2016 Guidelines and 2019 Refinement to the IPCC 2016 Guidelines, detailed in Table 5.8.

Table 5.8 Default Bo value of each animal category

Animal category	Bo value	Source
	m^3/kg	
Dairy cow	0.13	IPCC 2006 Guidelines, Table 10A-4, Asia.
Non-dairy cow	0.1	IPCC 2006 Guidelines, Table 10A-5, Asia.
Buffalo	0.1	IPCC 2006 Guidelines, Table 10A-6, Asia.
Sheep	0.13	2019 Refinement to the IPCC 2006 Guidelines, Table 10A-16, page 10.66.
Goats	0.13	
Horse	0.26	
Swine	0.29	IPCC 2006 Guidelines, Table 10A-6, Asia.
Poultry	0.24	2019 Refinement to the IPCC 2006 Guidelines, Table 10-16, page 10.66.

MCF of each manure management was taken from the default value in the IPCC 2016 Guidelines , shown in Table 5.9.

Table 5.9 Default MCF value for manure management

Manure Management	From 15- 25^{0}C	From>25^{0}C	Data source
	%		
Daily spread	1.0	1.5	Table 10.17, Page 10.46, Chapter 10, IPCC 2006 Guidelines
Aerobic treatment	0.0	0.0	
Poultry manure with bedding	1.5	1.5	
Anaerobic digester	50	50	Table 10.17, Page 10.46, Chapter 10/ the average value, IPCC 2006 Guidelines
Pasture range and paddock	1.5	2.0	Table 10.17, Page 10.44, Chapter 10, IPCC 2006 Guidelines

The value of MS is synthesised from the Report on 2015 environmental status and solution for livestock waste under the Department of Livestock Production, MARD. At the same time, the expert judgment was considered. The fraction of manure management system by two classified regions namely temperate with average temperature from 15 to 25^{0}C and warm region with temperature higher than 25^{0}C in order to estimate CH4 emissions by each area. Values are shown in Table 5.10.

Table 5.10 Fraction of manure management system by types

Region	Classification of treatment type in Viet Nam					
	Total	For fertilisers	Daily spread	Biogas	Poultry manure with bedding	Other
	Classification type corresponding to 2006 IPCC Guidelines					
	Total	For fertilizers	Aerobic treatment	Anaerobic lagoon	Poultry manure with bedding	Pasture range and paddock
	%					
Country	100	55.00	26.00	10.00	5.00	4.00
From 15-25^{0}C	100	61.85	23.11	8.25	2.97	3.82
From >25^{0}C	100	29.96	36.56	16.39	12.43	4.66

CH_4 EFs of manure management for livestocks by climate region is calculated using VS, Bo, the defaults MCF value of the IPCC 2006 Guidelines and 2019 Refinement to the IPCC 2006 Guidelines and MS. Results are detailed in Table 5.11.

Table 5.11 EFs applied to manure management by climate region (CH_4)

Livestock Types	EF	
	From 15-250C	From >25^{0}C
	kgCH_4/head	
Dairy cow	5.55	10.21
Non-dairy cow	3.48	6.42
Buffalo	6.08	11.20
Sheep	0.38	0.71
Goats	0.48	0.89
Horse	3.99	7.35
Swine	1.00	1.84
Poultry	0.06	0.12

d. Results of emissions/removals

Total CH_4 emissions in manure management for 2016 were 111.83 thousand tonnes CH_4. The biggest emission subsector was swine (36.96 thousand tonnes CH_4) as detailed in Table 5.12.

Table 5.12 CH_4 emissions in Manure management for 2016

IPCC Code	Livestocks	From 15-25^{0}C		From 25^{0}C		Total	
		ktCH_4	*ktCO_2*	*ktCH_4*	*ktCO_2*	*ktCH_4*	*ktCO_2*
3A2	**Manure management**	**60.34**	**1,689.51**	**51.49**	**1,441.85**	**111.83**	**3,131.36**
3A2a	Cattle	11.36	317.92	15.43	432.02	26.79	749.94
3A2ai	Dairy cow	0.82	22.87	1.39	38.81	2.20	61.68
3A2aii	Other cattle	10.54	295.05	14.04	393.21	24.58	688.27
3A2b	Buffalo	13.81	386.77	2.77	77.44	16.58	464.20
3A2c	Sheep	0.00	0.00	0.09	2.49	0.09	2.49
3A2d	Goats	0.66	18.37	0.58	16.25	1.24	34.62
3A2f	Horses	0.21	5.98	0.00	0.14	0.22	6.11
3A2h	Swine	19.49	545.77	17.46	489.00	36.96	1,034.78
3A2i	Poultry	14.81	414.69	15.16	424.51	29.97	839.20

5.2.1.2.2 Direct N_2O emissions in Manure management

Direct N_2O emission is produced through the microbial processes of nitrification and denitrification in manure. N_2O emission from livestock manure during storage and treatment depends on the nitrogen and carbon of the livestock manure, storage time and type of treatment. Nitrification (oxidation of NH_3-N to NO_3-N) is a necessary condition for N_2O emitted from livestock manure. Nitrification is likely to occur in stored livestock manure provided sufficient oxygen. Nitrification does not occur under anaerobic conditions.

Nitrite and nitrate are converted to N_2O and N_2 during natural nitrate reduction or an anaerobic process. The ratio of N_2O to N_2 will rise with the increase of acidity, nitrate concentration and decrease of humidity. N_2O generation and emissions from livestock manure must include the presence of nitrite or nitrate in an anaerobic environment prior to the aerobic conditions that are necessary for the formation of these oxidised forms of nitrogen. In addition, the conditions must be in place to prevent the reduction of N_2O to N_2, such as low pH or limited humidity.

a. Methodology

N_2O emissions from livestock manure was estimated using first order decay method with default values of the IPCC 2006 Guidelines as there has not been enough data to use a quadratic method, such as the country specific values, N-emissions/removals and data on livestock manure management system rates.

b. AD

AD is the amount of N treated by each livestock manure management system by climate region (the average temperature is 15-25^{0}C and the warm is over 25^{0}C). AD is estimated by number of livestock by region ($N_{(T)}$), annual excretion N value per animal ($Nex_{(T)}$) and proportion of total annual excretion of each type of cattle in the livestock manure management system by climate regions ($MS_{(T,S)}$).

Livestock population ($N_{(T)}$): Details are presented in the section on CH_4 emissions from livestock manure management (Table 5.5). The number of livestock by climate region included an area with an average temperature from 15 to 25^{0}C and an area with the temperature higher than 25^{0}C in 2016.

Average annual excretion N value per animal ($Nex_{(T)}$): $Nex_{(T)}$value) was calculated using Equation 10.30, page 10.59, Chapter 10, the IPCC 2006 Guidelines. Values are listed in Table 5.13.

Table 5.13 Default values of N excretion rates in IPCC 2006 Guidelines

Animal category	Default excretion rate
	1,000kg /day
Dairy cow	0.47
Non-dairy cow	0.34
Buffalo	0.32
Sheep	1.17
Goats	1.37
Horse	0.46
Swine	0.42
Poultry	1.10

The value of average weight by each Viet Nam's livestock has not been statistically reported, so those values were assumed based on expert experience as detailed in Table 5.7.

Annual manure treatment system rate of each livestock ($MS_{(T,S)}$) was aggregated from the Report on the state of the environment and the Report on solution for livestock manure treatment 2015 of the Department of Livestock Production, MARD. Expert judgment was also considered. The rate of livestock manure management system was divided into two climate regions: one having the average temperature from 15 to 25^{0}C and one with the temperature higher than 25^{0}C to calculate emissions as detailed in Table 5.13.

c. EFs

EFs of each management system were the default values in Table 10.21, page 10.62, Chapter 10, the IPCC 2006 Guidelines and summarised in Table 5.14

Table 5.14 EF default values according to AWMS of IPCC 2006 Guidelines

AWMS	IPCC EF default
	kg N_2O-N/kg N
Poultry manure with bedding	0.001
Aerobic treatment	0.01
For fertilisers	0.01
Anaerobic digester	0
Pasture range and paddock	NA

d. Results of emissions/removals

Total of direct N_2O emissions in manure management in 2016 were 11.17 thousand tonnes N_2O. The largest emission sebsector was fertilisers (7.54 thousand tonnes N_2O). Results are presented in Table 5.15.

Table 5.15 Direct N_2O emissions in Manure management for 2016

IPCC Code	Animal waste management system (AWMS)	Emission	
		ktN_2O	$ktCO_2eq$
3A2	**Manure management**	**11.17**	**2,960.27**
	Poultry manure with bedding	0.07	18.16
	Aerobic treatment	3.56	944.38
	For fertilisers	7.54	1,997.73
	Anaerobic digester	0.00	0.00

5.2.2 Land (3B)

5.2.2.1 General information

5.2.2.1.1 General infom ation on land classification

According to the Circular No.27/2018/TT-BTNMT dated December 14, 2018 by MONRE in order to regulate land statistics, inventory and mapping status of land use, land is classified into three main categories, including agricultural land, non-agricultural land and unused land. Meanwhile, the IPCC Guidelines categorises six types of land to calculate GHG emissions. To apply to the national GHG inventory, the current state of Viet Nam's land is classified according to IPCC land types with information of subtypes described in Table 5.16.

Table 5.16 Conversion of Viet Nam land use following IPCC classification

No.	Primary Classification	Type of land use in detail	IPCC
1	Agricultural land	Productive forest	Forest land
2		Protective forest	
3		Specially used forest	
4		Weed land for animal raising	Cropland
5		Paddy land	
6		Other annual cropland	
7		Perennial crop land	

No.	Primary Classification	Type of land use in detail	IPCC
8	Non-agricultural land	Water surface land for fishing	Wetlands
9		Rivers and specialized water surfaces	
10		Rural home stead land	Settlements
11		Urban home stead land	
12		Land used by offices and non-profit agencies	
13		Security and defense land	
14		Land for non-agricultural production and business	
15		Public land	
16		Religious land	
17		Cemetery	
18		Other non-agricultural land	Other land
19	Agricultural land	Land for salt production	
20		Other agricultural land	
21	Unused land	Unused flat land	
22		Unused mountainous land	
23		Non tree rocky mountain	

The process of developing remote sensing maps for national GHG inventory for 2016 by the Department of National Remote Sensing, MONRE and also based on the above classification to group soil types according to the national classification.

According to the IPCC Guidelines, only anthropogenic emissions and removals should be estimated. In subsector 3D, emissions and removals occurring on 'managed land' are anthropogenic emissions and removals. By taking recommendations from experts into account, all the above land use types were considered as managed land. So that, unused flat land, mountainous land, non tree rocky mountain in MONRE classification do not mean 'unmanaged land'. As a result, those lands were also counted in GHG emission estimation.

Inventory of GHG emissions/removals from the soil (3B) sub-sector was closely related to the biomass of crops in the soil. After developing remote sensing maps and following the IPCC Guidelines, lands were classified into six categories based on biomass and in accordance with the national conditions. The above mentioned process is displayed in Table 5.17.

Table 5.17 Classification of subtypes of land cover according to IPCC

IPCC Code	IPCC Category	Land cover subtypes	Key word
3B1	Forest Land (F)	1. Woody forest: - Natural wood forest - Plantation	WODF
		2. Bamboo	BAMB
		3. Mix	MIXF
		4. Mangrove - Mangrove - Mangrove land without reserves	MANG
		5. Coconut palm forest	COCF
3B2	Cropland (C)	1. Annual	ACRP
		2. Perennial	PCRP
		3. Woody perennial trees land	WDPC
		4. Paddy land	WRIC
3B3	Grassland (G)	Forest land bushes	SCRB
3B4	Wetlands (W)	Water surface land	W
3B5	Settlements (S)	Settlements	S
3B6	Other land(O)	Other land	O

The land classification and subtype cover were determined as follows:

Forest land: includes natural forests and plantation forests meet the forest standards prescribed under the Law. The Department of National Remote Sensing, MONRE based on the forest classification of the Viet Nam Administration of Forestry, MARD, divided forest land into five following land types according to tree species as follows:

Timber forest: a forest consisting mainly of tree species and classified into natural forest and plantation forest.

The remote sensing technology does not allow the classification of natural forest and plantation forest even if they have different biomass and biomass growth. Consequently, the inventory was based on the ratio of natural forest and plantation forest of MARD to calculate the area of these two forest types;

Bamboo forest: a forest consisting mainly bamboo family trees.

Mixed timber-bamboo forest: a forest with timber trees accounting for more than 50% of the canopy;

Coconut palm forest: a forest with the main composition of all kinds of coconut palms;

Mangrove forest: forest developed along the coast and large estuaries with frequent or periodic flooding;

Mangrove land is used to develop forests for the main purpose of soil protection and prevention of saline intrusion, within the inventory was called mangrove land without reserves.

Cropland: or land for agricultural production including annual and perennial cropland. Based on the biomass and biomass growth rates of the crops, the cropland has been classified as:

Paddy land: land for rice cultivation with frequent or irregular flooding (including terraced fields);

Land for growing annual crops: including remaining land for rice cultivation (other than paddy land) and land for planting annual crops such as vegetables, crops, even medicinal plants, sugarcane, jute, thorns, papyrus, lemongrass, mulberries etc., and improved natural grass or grass for cattle feeding;

Land for perennial crops: land used for the purpose of planting trees planted once, growing and harvested for many years, including perennial industrial trees and perennial fruits trees; and

Land for perennial trees: similarly to land for perennial crops, however, tree species planted are wood.

Grassland: land area that includes only shrubs, due to the fact that the grassy area or natural turf has been improved for livestock and put in statistics as annual cropland (according to the Circular No.27/2018/TT-BTNMT grassland for livestock is listed in the annual cropland under cropland).

Wetlands, settlements and other land include land categories as classified in Table 5.16 and 5.17 with definitions of land types according to Circular No.27/2018/TT-BTNMT.

5.2.2.1.2 Results of building land use matrix and land conversion area for period of 2006-2016

Based on the process of land classification and subtypes, the National Department of Remote Sensing, MONRE released the development of land use and land use conversion (land use matrix) for the time from 2006 to 2016 in Table 5.18 and got results of land area for 2016 in Table 5.19.

Table 5.18 Land use matrix in 2006-2016

2006-2016	Key present	F	C (WRIC)	C (ACRP)	C (PCRP)	C (WDPC)	G	W	S	O	Total in 2006 (ha)
To/From		Forest land	Paddy land	Annual land	Land for perennial crops	Land for perennial trees	Grass land	Wetlands	Settlements	Other land	
Forest land	F	11,739,092	66,793	257,556	333,136	71,433	102,677	42,782	74,541	364,935	13,052,946
Paddy land	C (WRIC)	10,280	3,783,053	102,059	52,314	2,087	859	69,382	87,777	11,438	4,119,249
Annual land	C (ACRP)	336,678	70,931	2,669,208	158,320	2,084	58,627	33,166	80,010	246,858	3,655,883
Land for perennial crops	C (PCRP)	150,831	8,843	25,581	2,256,884	18,961	5,642	1,872	36,113	21,667	2,526,394
Land for perennial trees	C (WDPC)	130,002	282	889	902	595,994	358	3,036	8,559	2,447	742,469
Grassland	G	1,871,181	7,720	272,874	806,679	952	420,559	17,779	34,158	1,362,244	4,794,146
Wetlands	W	24,190	20,030	7,962	2,088	0	1,031	1,524,752	12,475	9,542	1,602,072
Settlements	S	1,636	918	1,734	4,275	0	460	4,191	2,518,968	834	2,533,017
Other land	O	9,987	126	2,626	1,155	0	69	10,014	3,874	69,334	97,186
Total in 2016 (ha)		14.273.878	3,958,697	3,340,489	3,615,755	691,512	590,282	1,706,974	2,856,475	2,089,299	33,123,361

Table 5.19 Land use and land use change in 2016

IPCC code	Land use and land use change	Square
		ha
3B	Land	33,123,361
3B1	Forest land	14,273,878
3B1a	Forest land remaining forest land	11,739,092
3B1b	Land converted to forest land	2,534,786
3B2	Cropland	11,606,456
3B2a	Cropland remaining cropland	9,748,392
3B2b	Land converted to cropland	1,858,060
3B3	Grassland	590,282
3B3a	Grassland remaining grassland	420,559
3B3b	Land converted to grassland	169,724
3B4	Wetlands	1,706,974
3B4a	Wetlands remaining wetlands	1,524,752
3B4b	Land converted to wetlands	182,222
3B5	Settlements	2,856,475
3B5a	Settlements remaining settlements	2,518,968
3B5b	Land converted to settlements	337,507
3B6	Other land	2,089,299
3B6a	Other land remaining other land	69,334
3B6b	Land converted to other land	2,019,965

5.2.2.1.3 Emission/removal source and GHG inventory method

- *GHG emission/removal sources*

GHG emission/removal from subsector land (3B) is the results of forestry activities and land use change, including:

- The change in living biomass carbon stocks: above and below ground biomass;

- The change in dead organic matter carbon stocks includes: dead wood and litter; and

- The change in soil carbon stocks: mineral soil, organic soil and inorganic substances in soil.

- *Inventory method*

The 2016 national GHG inventory results were calculated with the ALU software using the IPCC 2006 Guidelines and combining with remote sensing data from the National Department of Remote Sensing, MONRE. The ALU is a GHG inventory software for the AFOLU sector with detailed functions compared with other GHG inventory tools presented in Table 5.20.

Table 5.20 Comparison of national GHG inventory tools

Tool	UNFCCC	IPCC GL	ALU
Guideline	GPG 2000, GPG 2003	IPCC 2006	IPCC 2006
Sector	All sector	All sector	AFOLU
Tier	Tier 1	Tier 1	Tier 1 and Tier 2
Uncertainly analysis	No	Yes	Yes
Classification by user	No	Yes	Yes (most flexible)
QA/QC	No	No	Yes
Documentation	No	No	Yes
Input data from GIS/remote sensing	No	No	Yes
Key category analysis	Yes	Yes	No (need all sector)
Potential mitigation analysis	No	No	Yes

i. Methods of changing living biomass carbon stocks including above-ground biomass and below-ground biomass

The IPCC Guidelines provide stock change and the gain-loss methods. Due to the lack of data, it is necessary to use the gain-loss method to calculate the change of living biomass in carbon stocks, which includes:

- The calculation method for land remaining the same land: using equation 2.7, 2.8 and 2.9, page 2.12 and page 2.15, Chapter 2, Volume 4, the IPCC 2006 Guidelines; and

- Calculation method for Land Converted to a New Land: using equation 2.15 and 2.16, page 2.20, Chapter 2, Volume 4, the IPCC 2006 Guidelines.

ii. Calculation method for change of carbon stocks in dead wood and litter: using equation 2.23, page 2.26, Chapter 2, Volume 4, the IPCC 2006 Guidelines.

iii. Calculation method for the change of carbon stocks in soil: using equation 2.24, page 2.29; equation 2.25, page 2.30 and equation 2.26, page 2.35, Chapter 2, Volume 4, the IPCC 2006 Guidelines.

5.2.2.2 Forest land (3B1)

Under the Decision No.1819/QD-BNN-TCLN dated May 16, 2017 of MARD on approval of the national forest status in 2016, by December 31, 2016, the national forest area was 14,377,682ha, of which natural forests accounted for 10,242,141ha (including natural wood forest, bamboo forest, mixed forest) and plantation forests, 4,135,541ha (including plantation forests and mangrove forests).

According to the land use matrix map developed by the Department of National Remote Sensing, the total forest area of Viet Nam is 14,273,878ha, making a difference of 103,804ha compared to the data published by MARD (14,377,682ha). That shows the data of forest area from MARD is 0.7% higher than the data provided by the remote sensing map of MONRE.

This is explained by the fact that the forest area of MARD includes area under rubber trees while the land use matrix lists the area covered rubber trees in the category of perennial industrial trees (according to the GSO classification). It can also be attributed to other reasons such as the reliability of MARD statistics and the image reading and mapping techniques of the Department of National Remote Sensing. However, a difference of 0.7% is under the acceptable range.

GHG removals from Forest land for 2016 are presented in Table 5.21.

Table 5.21 GHG removals from Forest land for 2016

IPCC Code	Emission/removal source	Living biomass	Dead organic	Soil	Total
		$ktCO_2eq$			
3B1	**Forest land**	**-54,793.46**		**135.67**	**-54,667.78**
3B1a	Forest land Remaining forest land	-42,840.60	0	135.67	-42,704.93
3B1b	Land converted to forest land	-11,952.86	0	0	-11,952.86

5.2.2.2.1 Forest land remaining forest land

GHG inventory for Forest land remaining forest land included emissions/removals from:

i. The change of carbon stocks in living biomass;

ii. The change of carbon stocks in dead organic matter; and

iii. The change of carbon stocks in soils.

The calculation results of emission/removal sources from Forest land remaining forest land (3B1a) are reported in Table 5.22.

Table 5.22 GHG removals from Forest land remaining forest land for 2016

IPCC Code	Emission source/ Absorption sink	Net emissions
		$ktCO_2$
3B1a	**Forest land remaining lorest land**	**-42,704.93**
	Living biomass	-42,840.60
	Dead organic	0
	Soil	135.67

i. Change in carbon stock in living biomass

a. Methodology

Use the gain-loss method according to Equation 2.7 page 2.12, Chapter 2, Volume 4, the IPCC 2006 Guidelines.

b. AD

The AD of 'Gain' is the forest land remaining forest land provided by the remote sensing map of the Department of National Remote Sensing and detailed in Table 5.23 and Table 5.24.

The AD for calculating 'Loss' includes: the volume of commercial logging, firewood logging, and forest fires collected from GSO. Since logging, firewood and forest fires have not been specified in any location, the 'Loss' sections were assumed to occur entirely on Forest land remaining forest land (3B1a) and displayed in Table 5.24.

Table 5.23 AD for gain-loss method from Forest land remaining forest land

Data	Method	Value	Unit	Source
Forest area	gain-loss	Detailed in Table 5.24		Matrix 2006-2016, RSC
Volume of commercial logging	gain-loss	12,633,200	m^3	GSO, 2016
Fire logging	gain-loss	3,149	ha	GSO, 2016

Table 5.24 Forest areas and vegetation types of Land converted to forest land for 2016

Land type	Key present	Vegetation type	Areas
			ha
Forest land remaining Forest land	FF	Palm forest	2,524
		Woody forest - Natural wood forest - Timber plantation	10,464,157 7,210,268 3,243,889
		Mix forest	785,468
		Mangrove: - Mangrove - Mangrove land has no reserves	244,102 129,520 114,582
		Bamboo forest	242,841
Total			**11,739,090**

Areas of forest types were extracted from the remote sensing map. For the natural and plantation forests, areas were based on the proportion of these two forests published by the Viet Nam Administration of Forestry, MARD in 2016, as remote sensing maps could not classify the two types of forest by images.

c. EFs/ parameters

The main EFs and some other parameters applied are shown in Table 5.25 below.

- Growth factor of biomass on the ground - Iv (m3/ha/year): provided by experts from the Viet Nam Administration of Forestry, MARD;

- BCEFi factor (t.-dm/m3): Table 4.5, page 4.50, Chapter 4, Volume 4, the IPCC 2006 Guidelines, using the default coefficient of IPCC and some factors based on the experience of forestry experts;

- Rate of below ground biomass (R): proposed by experts from the Viet Nam Administration of Forestry, MARD;

- Carbon fraction of above-ground biomass (CF) (t-C/t-d.m): uses default values of IPCC 2006 Guidelines data, Table 4.3, Tropical and subtropical;

- BCEFr (t-d.m/m3): suggested by forestry expert estimates from the Viet Nam Administration of Forestry, MARD; and

- Percentage of below-ground biomass (R) for estimation decreased from loss: provided by an expert of Viet Nam Administration of Forestry, MARD, details in Table 5.25.

Table 5.25 Parameters used for gain-loss method

Type of parameter	Applicability	Value	Unit	Source
Carbon Fraction	All	0.47	t-C/t-d.m.	Table 4.3, Tropical and Subtropical- ALL, IPCC 2006
Root to shoot ratio (R)	Woody forest	0.205	-	Estimation of expert from the Viet Nam Administration of Forestry, MARD
Root to shoot ratio R)	Bamboo forest	0.205	-	
Root to shoot ratio (R)	Mix forest	0.205	-	
Root to shoot ratio (R)	Mangrove forest	0.220	-	
Root to shoot ratio (R)	Palm forest	0.201	-	Nguyen Thi Thanh Truc And Le Anh Tuan, 2015, " The estimation of carbon-dioxide (CO_2) absorptive capacity of coconut tree through biomass in Giong Trom district, Ben Tre province", College of Environment and Natural Resources, Can Tho University
Root to shoot ratio (R)	Plantation forest	0.205	-	Estimation by experts from the Viet Nam Administration of Forestry, MARD
AGB increment (Iv)	Woody forest	2.00	m^3/ha/year	
AGB increment (Iv)	Bamboo forest	0.70	m^3/ha/year	
AGB increment (Iv)	Mix forest	2.20	m^3/ha/year	
AGB increment (Iv)	Mangrove forest	2.50	m^3/ha/year	
AGB increment (Iv)	Rocky forest	3.35	m^3/ha/year	Nguyen Thi Thanh Truc And Le Anh Tuan, 2015, 'The estimation of carbon-dioxide (CO2) absorptive capacity of coconut tree through biomass in Giong Trom district, Ben Tre province', College of Environment and Natural Resources, Can Tho University
AGB increment (Iv	Plantation forest	12.00	m^3/ha/year	Decision No.774/QD-BNN-TCLN dated April 18, 2014. The average volume of planted forests is 10-13 m3/ha/year

Type of parameter	Applicability	Value	Unit	Source
BCEFi	Woody forest	0.87	t-d.m/m^3	Table 4.5, page 4.52, Part 4, Chapter 4, the IPCC 2006 Guidelines, using the default coefficient of IPCC, Humid tropics, Nature Forest.
BCEFi	Bamboo forest	0.93	t-d.m/m^3	
BCEFi	Mix forest	0.87	t-d.m/m^3	
BCEFi	Mangrove forest	0.87	t-d.m/m^3	Based on the biomass stocks of the vegetation types. Bulk stocks of vegetation types are shown in Section of land converted to cropland (Table 5.39).
BCEFi	Palm Forest	0.65	t-d.m/m^3	Estimation by experts from the Viet Nam Administration of Forestry, MARD
BCEFi	Plantation forest	0.55	t-d.m/m^3	
BCEFr	Plantation forest	1.12	t-d.m/m^3	
(R) for calculated from wood logging	Plantation forest	0.21	t-d.m/t-d.m	

d. Results of emissions/removals

The emissions of the changing carbon stocks in living biomass following gain - loss method are reported in Table 5.26.

Table 5.26 Net removals from living biomass of Forest land remaining forest land for 2016

Gain	Loss due to logging	Loss due to fuelwood logging	Loss Disturbance		Total net change
			Fire	Pest	
ktCO$_2$					
-74,596.95	31,481.18	NE	275.17	NE	-42,840.60

The calculated results from Forest land remaining forest land include gain in Forest land remaining in forest land and loss of biomass due to timber harvested, fuelwood harvested, fire and pest disturbance (due to lack of information on fire zones, logging areas and firewood should be assumed to be in the Forest land remaining forest land area). It was not able to collect data on logging for fuelwood and pests, so emissions from the two subsectors were not calculated.

The total net removals from living biomass of forest land remaining forest land were -42,840.60 ktCO_2.

ii. Change of carbon stock in dead organic

According to the IPCC 2006 Guidelines, section 2.3.2, page 2.21, Tier 1 method assumes carbon stock in dead organic (including dead wood and litter) (DOM) in Forest land remaining forest land is constant over time. Since no specific time series information on DOM in Viet Nam was available, Tier 1 was applied and the associated carbon stock change was assumed to be zero.

iii. Carbon stock changes in soil

Annual change in carbon stock in soils was calculated by equation 2.24, Chapter 2, Volume 4, the IPCC 2006 Guidelines, including emissions/removals by carbon stock changes in mineral soil, organic soil and inorganic carbon stocks in soils. Emissions/removals from the change of carbon stocks in soil were 125.67 ktCO_2.

• Carbon stock changes in mineral soil

For mineral soils, the default method is based on change in organic carbon stocks which has been reserved over a certain time period (20 years). The change is calculated based on the C stock after changing the management method in the absence of degradation or improvement of the vegetation. Assumptions are included:

- The organic C in the soil over time reaches the average value and is stable with respect to soil characteristics, climate and soil management practices; and

- Soil organic C changes during the transition to new linear organic C in soil (SOC).

Since the current results of soil monitoring information in Viet Nam have not been sufficient to show the long-term trend of changes in carbon stocks in the intact soils, these emissions/removals were not taken into account.

• Carbon stock changes in organic soil

Calculation method for carbon stocks changes in organic soils (soils derived from peatland) based on post-drainage C loss. According to AD from the remote sensing map of the Department of National Remote Sensing, MONRE, the area of organic soil in the Mekong River Delta for mangrove soils belonging to Forest land remaining forest land was assumed to be draining (due to tides) with a total area of 27,206ha. EF was a default value of 1.36tC/ha/year. The emissions for 2016 were 135.67ktCO_2.

• Inorganic carbon stock changes in soil

The impacts of land use and management practices on inorganic C stocks in soil are related to hydrology conditions and soil mineralisation. Viet Nam has not yet had conditions to assess and monitor changes in inorganic carbon stocks in the soil, so emissions from this activity were not calculated.

5.2.2.2.2 Land converted to forest land (3B1b)

National GHG inventory for 2016 for land converted to forest land (3B1b) includes:

i. Carbon stock changes in living biomass;

ii. Carbon stock changes in DOM; and

iii. Carbon stock changes in soil;

The emissions and removals of Land converted to forest land (3B1b) were calculated through such sinks as: living biomass, dead organic and soil of forest land with details shown in Table 5.27.

Table 5.27 Net emissions from land converted to forest land for 2016

IPCC Code	Emission/Removal source	Living biomass	DOM	Soil	Total
		$ktCO_2eq$			
3B1b	**Land converted to forest land**	**-11,952.85**	**0**	**NE**	**-11,952.85**
	CF	-793.85	0	NE	-793.85
	GF	-11,030.95	0	NE	-11,030.95
	WF	-65.85	0	NE	-65.85
	SF	-9.59	0	NE	-9.59
	OF	-52.62	0	NE	-52.62

i. Carbon stock changes in living biomass

Carbon stock changes in living biomass of Land converted to forest land (3B1b), include:

- The increase in the annual biomass reserves from forest land;
- The decrease in biomass reserves from wood logging and disturbance; and
- The change of biomass carbon stocks from soil before converting to forest land.

a. Methodology

For carbon stock changes in living biomass from Land converted to forest land, the methodology was used as follows:

- Annual increase in biomass carbon stocks due to biomass from forest land using Formula 2.9, Chapter 2, Volume 4, the IPCC 2006 Guidelines;

- Reduction in biomass carbon stocks from logging, disturbance using Formula 2.11 Chapter 2, Volume 4, the IPCC 2006 Guidelines;

- Changes in biomass carbon stocks due to land use conversion of land converted to forest land using Formula 2.16 Chapter 2, Volume 4, the IPCC 2006 Guidelines.

b. AD

Data for calculating annual growth of biomass in carbon stocks from Land converted to forest land is the area converted to forest land and classified by vegetation types due to the unavailability of data. The converted area of the inventory year (2016) should be estimated as the 10-year average area during the 2006-2016 period and described in Table 5.28.

Table 5.28 Forest areas and Land converted to forest land areas for 2016

Land type	Key word	Vegetation type	Area
			ha
Crop Land Converted to Forest Land	CF	Coconut forest	223
		Woody forest	**475,857**
		- Natural wood forest	328,341
		- Plantation forest	147,516
		Mix forest	145,009
		Mangrove	**2,866**
		- Mangrove	1,519
		- Mangrove land has no reserves	1,347
		Bamboo forest	3,882
		Total	**627,788**
Grassland converted to forest land	GF	Coconut forest	1,680
		Woody forest	**1,508,148**
		- Natural wood forest	1,061,333
		- Plantation forest	475,401
		Mix forest	307,874
		Mangrove	**1,470**
		- Mangrove	780
		- Mangrove land has no reserves	690
		Bamboo forest	26,607
		Total	**1,871,180**

Land type	Key word	Vegetation type	Area
			ha
Wetlands converted to forest land	WF	Coconut forest	0
		Woody forest	**1,555**
		- Natural wood forest	1,074
		- Plantation forest	481
		Mix forest	219
		Mangrove	**22,403**
		- Mangrove	11,888
		- Mangrove land has no reserves	10,515
		Bamboo forest	12
		Total	**24,189**
Settlements converted to forest land	SF	Coconut forest	0
		Woody forest	**1,150**
		- Natural wood forest	794
		- Plantation forest	356
		Mix forest	425
		Mangrove	**62**
		- Mangrove	33
		- Mangrove land has no reserves	29
		Bamboo forest	0
		Total	**1,637**
Other land converted to forest land	OF	Coconut forest	0
		Woody forest	**5,818**
		- Natural wood forest	4,015
		- Plantation forest	1,803
		Mix forest	2,117
		Mangrove	2,053
		- Mangrove	1,091
		- Mangrove land has no reserves	962
		Bamboo forest	0
		Total	**9,988**
Total			**2,534,782***

**: The area 2,534,786 ha becomes 2,534,782 ha due to rounding when using the ALU software.*

Annual biomass carbon stock reduction due to logging, disturbance was assumed and included in Forest land remaining forest land (3B1a).

c. EFs/ Parameters

EFs/parameters for the calculation annual biomass carbon stock growth using the factors given in Table 5.26 of subsector Forest land remaining forest land (3B1a). EFs/parameters used for the calculation of changes in biomass carbon stocks due to the land use conversion of Land converted to forest land are depicted in Table 5.29.

Table 5.29 Living biomass parameter to calculate Land converted to forest land

Land type		Value	Unit	Source
Before converted				
(CF)		0.47	t-C/t-d.m	Table 4.3, Tropical and subtropical- all, IPCC 2006
Cropland	Annual cropland biomass	5 10.64	tC/ha t-dm/ha	Table 5.9, Annual cropland, page 5.28, Section 5, Chapter 5, Arable land, IPCC 2006 Guidelines
	Perennial cropland biomass	21 44.87	tC/ha t-dm/ha	Table 5.1, Perennial cropland, page 5.9, Section 5, Chapter 5, Arable land, IPCC 2006 Guidelines
Grassland	Biomass before converted	2.1	t-d.m./ha	Table 2.4, page 2.45-2.46, Biomass selection for grassland, IPCC 2006 Guidelines, since the Land for grass cultivation includes in the cultivated land (Annual crop land), the remaining grass land is shrubs
	CF	0.4	tC/t-d.m.	IPCC 2006 Guidelines
Other land use		0	tC/ha	Assume is 0
After converted				
Total		0	tC/ha	IPCC 2006 Guidelines

d. Results of emissions/removals

The results of net removals from living biomass of land converted to forest land are reported in Table 5.30.

Table 5.30 Net emissions from living biomass of Land converted to forest land for 2016

Gain	Loss due to logging	Loss due to Disturbance		Loss due to land conversion	Total net change
		Fire	Pest		
$ktCO_2$					
-15,531.82	IE	IE	IE	3,578.97	-11,952.85

ii. Carbon stock changes in DOM

According to IPCC 2006, section 2.3.2.2, Tier 1 (default) assumes that there is no change in carbon in the DOM in forest land converted to other land. For Land converted to forest land, carbon accumulation in DOM was calculated linearly from zero over a conversion period (assuming the default time of 20 years).

This default time period may be suitable for carbon stocks from litter, but in temperate and northern regions, it is too short to account for dead wood.

Due to the lack of detailed information and the negligible change in carbon stocks in DOM for Viet Nam, the Tier 1 method was applied and zero carbon stock change was assumed.

iii. Carbon stock changes in mineral soil

Similar to Forest land remaining forest land, carbon stock changes in mineral soil were calculated by Equation 2.24, Chapter 2, Volume 4, the IPCC 2006 Guidelines, including changes in carbon stocks in mineral soils, organic soil, and inorganic carbon in the soil.

- Change of carbon stocks in mineral soil was not calculated yet;

- Change of carbon stocks in organic soil: according to the remote sensing map, no area of organic soil was present in the total area of land converted to forest land. Therefore, CO2 emissions from organic soils from this subsector should be zero.

- Change in inorganic carbon stocks in the soil: Similar to forest land remaining forest land, Viet Nam has not had sufficient conditions to assess and monitor the process of changing inorganic carbon stocks in soil. Therefore, emissions from this subsector were not estimated.

5.2.2.3 Cropland (3B2)

According to data from the land use matrix provided by the Department of National Remote Sensing Department, the total crop land area in 2016 was 11,606,452 ha, including paddy land, annual cropland, perennial trees, and woody perennials. Meanwhile, according to the Decision No.2311/QD-BTNMT dated September 28, 2017 by MONRE on approving and announcing the statistical results of land area in 2016, the total cropland area in 2016 was 11,526,797 ha. These two figures were different by about 79,600 ha.

This difference could be explained as rubber plantation were put in perennial trees, while MONRE classified it as plantation forest. Besides, it could be due to image interpretation during the development of the land use matrix by the National Department of Remote Sensing as well as the MONRE statistical data process.

In cropland (3B2), emissions/removals occurring during changes in carbon stocks in living biomass, DOM, and soil were calculated.

GHG emissions/removals from Cropland in 2016 are reported in Table 5.31.

Table 5.31 Net GHG emissions/removals from Cropland for 2016

IPCC Code	Emissions/Removals source	Living biomass	DOM	Soil	Total
		$ktCO_2$			
3B2	**Cropland**	**3,399.49**		**238.11**	**3,607.60**
3B2a	Cropland remaining cropland	-1,062.41		36.37	-1,026.04
3B2b	Land converted to cropland	4,461.90		201.74	4,663.64

5.2.2.3.1 Cropland remaining cropland (3B2a)

In this section, emissions/removals were estimated from changes in living biomass carbon stocks for immature perennial crops.

No change in carbon stocks in DOM (Tier 1 method) in cropland was assumed.

Soil carbon stocks were not estimated due to the lack of information on long-term changes in soil carbon stocks in Viet Nam.

GHG removals from Cropland for 2016 are reported in Table 5.32.

Table 5.32 Net GHG removals from Cropland remaining cropland for 2016

Biomass	DOM	Soil	Total
$ktCO_2$			
-1,062.41	0	36.37	-1,026.04

i. Carbon biomass stock changes

a. Methodology

Use Equation 2.7, chapter 2, part 4, the IPCC 2006 Guidelines to calculate the change in carbon stock in living biomass.

- For the calculation for the Gain part: Use Equation 2.9, Chapter 2, Volume 4, the IPCC 2006 Guidelines; and

- For the calculation of the Loss part: use Equation 2.11, Chapter 2, Volume 4, the IPCC 2006 Guidelines.

b. AD

AD for calculation gain of carbon stocks from land of woody perennial trees.

The growth cycle of a woody perennial tree is 8 years. It is assumed that perennial trees will grow in the first 8 years and reach a steady state of carbon content starting from year 9.

The data extracted from the map only provided area of woody perennial trees but could not divide into areas of mature or immature parts. Therefore, the ratio of perennial industrial and fruit trees (woody perennial trees) provided by GSO for 2016 and 2008 (harvest/maturity cycle of 8 years). For woody perennial trees the mature rate was 82% and immature rate was 18%, detailed in Table 5.33.

Table 5.33 Area of woody perennial crops for calculation of gained living biomass from Cropland remaining cropland

No	Regions	Mature	Immature	Total
		ha		
1	Northern Central and Central coastal region	46,022	10,102	56,124
2	Mekong River Delta	3,780	830	4,610
3	Red River Delta	716	157	873
4	South East	63,886	14,024	77,910
5	Northern midlands and mountainous region	1,300	285	1,585
6	Central Highlands	391,979	86,044	478,023
Total		**507,683**	**111,442**	**619,125**

Thus, the total area of immature perennial crops calculated for absorption amount was 111,442 ha.

AD of Loss includes biomass loss due to logging, harvesting timber and fire. The assumed biomass loss data from logging was included in the logging calculation of the Forest land remaining forest land. Harvesting timber and fire data from this subsector could not be collected, therefore they were not calculated.

c. EFs/ Parameters

The parameter used for the calculation of the Gain in carbon stocks from woody perennial crop lands was the cumulative rate of living biomass carbon stocks in Cropland. The default parameter given from Table 5.9, page 5.28, the IPCC 2006 Guidelines for the tropical moist area was 2.6tC/ha/year.

d. Results of emissions/removals

Emissions by gain-loss method in the living biomass from Cropland remaining cropland are reported in Table 5.34.

Table 5.34 Net removals of living biomass of Cropland remaining cropland for 2016

Gain	Loss due to logging	Loss due to harvesting timber	Disturbance		Total net change
			Fire	Pest	
$ktCO_2$					
-1,062.41	IE	NE	NE	NE	-1,062.41

ii. Carbon stock changes in dead organic matter

Similar to the Forest land remaining forest land section, section 2.3.2, page 2.21, the IPCC 2006 Guidelines, Tier 1 assumed the carbon stocks in DOM (including dead wood and litter) in Cropland remaining cropland remained unchanged over time, which should be reported as zero.

iii. Carbon stock changes in soils

Carbon stocks in soils was calculated using Equation 2.24 Chapter 2, Volume 4, the IPCC 2006 Guidelines, which is included changes in mineral soil, organic soil, and inorganic C in soil.

Similar to Forest land remaining forest land, for mineral soil, the current results of soil monitoring information in Viet Nam have been insufficient to show the long-term trend of changes in carbon stocks in this type of soil.

For organic soils, the calculation method changed the carbon stock in organic soils (soils derived from peatland) based on the post-drainage C loss. The draining process stimulated the oxidation of previously formed organic matter in an anaerobic atmosphere. The calculation method is shown in Equation 2.26, Chapter 2, Part 4, the IPCC 2006 Guidelines.

According to the AD from the Department of National Remote Sensing, the organic land area in the Mekong River Delta was 496 ha for annual cropland and 2,465ha for paddy land. The total area of land receding occurred in the annual cropland was 496ha with EF of 20tC/ha/year (Table 5.6, page 5.19, Chapter 5, Volume 4, the IPCC 2006 Guidelines). The emissions were 9,920 tC/year equivalent to 36.37 $ktCO_2$/year.

Regarding inorganic carbon stocks in soil, Viet Nam has not yet had enough conditions to evaluate and monitor changes in inorganic carbon stocks in this type of soil.

5.2.2.3.2 Land converted to cropland (3B2b)

Annual change in carbon stock in living biomass from Land converted to cropland, GHG emissions from DOM and from soils were estimated.

GHG emissions from Land converted to cropland are reported in Table 5.35.

Table 5.35 Net GHG emissions from Land converted to cropland

Converted land use	Living biomass	Dead organic matter	Soil	Total
	$ktCO_2eq$			
Total	**4,461.90**	**0**	**201.74**	**4,663.64**
FC	5,421.59	0	201.74	5,623.33
GC	-891.27	0	NE	-891.27
WC	-53.32	0	NE	-53.32
SC	-8.93	0	NE	-8.93
OC	-6.17	0	NE	-6.17

i. Carbon stock changes of living biomass

a. Methodology

Changes in carbon stocks in living biomass include:

- Gain from annual living biomass carbon stocks for immature woody perennial crops using Formula 2.9, Chapter 2, Volume 4, the IPCC 2006 Guidelines;

- Carbon stocks loss from fogging and disturbance using formula 2.11, Chapter 2, Volume 4, the IPCC 2006 Guidelines; and

- Changes in biomass carbon stocks due to the conversion of Land Converted to Cropland using formula 2.16, Chapter 2, Volume 4, the IPCC 2006 Guidelines.

b. AD

• *Calculation of annual biomass carbon growth for immature woody perennial crops*

AD used for calculation of Gain in carbon stocks from woody perennial trees land was area converted to cropland extracted from the 2006-2016 remote sensing map. Area of mature and immature woody perennial crops were 82% and 18%, respectively as calculated in section Cropland remaining cropland, detailed in Table 5.36.

Table 5.36 Area of woody perennial crops for gain of annual living biomass carbon stocks from Land converted to cropland

No	Land conversion type	Area of mature perennial crops	Area of immature perennial crops	Total
		ha		
Total		**59,356**	**13,031**	**72,387**
1	Forest land converted to cropland (FC)	58,575	12,859	71,434
2	Grassland converted to cropland (GC)	781	172	953
3	Wetland converted to cropland (WC)	0	0	0
4	Settlements converted to cropland (SC)	0	0	0
5	Other land converted to cropland (OC)	0	0	0

As shown in the section Cropland remaining cropland, the calculation of the annual gain in biomass carbon stocks was taken from immature woody perennial crops only. Mature woody perennial crops was considered to reach a steady state. Thus, the total area of annual biomass growth of immature woody perennial crops was 13,031ha.

• *Carbon stock loss due to wood logging, disturbance*

The included the loss of biomass due to logging, timber harvest and fire. The assumed biomass loss data from logging was included in the emissions calculation for the Logging of the Forest land remaining forest land. For timber harvest and fire, data for such subsectors could not be collected and estimated.

• *Biomass carbon stock changes due to land use conversion*

Area of all types of Land converted to cropland using the data from the the land use matrix (extracted from the map) divided by an average of 10 years (2006-2016 period) to obtain the area converted in 1 year.

As for the area of Forest land converted to cropland, the amount converted from plantation forest has been subtracted from the amount of biomass loss from this activity included in the forest loss due to logging of category Forest land remaining forest land to avoid overlaping.

The data on Forest land converted to cropland is shown in Table 5.37.

Table 5.37 Forest land converted to cropland areas according to forest types

Vegetation type	Areas
	ha
Total	**43,723**
1. Woody forest	34,819
Natural woody forest	2,410
Plantation forest	3,241
2. Bamboo forest	5,402
3. Mix forest	24,059
4. Coconut -palm forest	NA
5. Mangrove	8,611
- Mangrove	4,569
-Mangrove land has no reserves	4,042
Total area does not include plantation forest	**40,481**

Thus, the total area of Forest land converted to cropland was 43,723 ha, of which 3,241 ha had been converted from plantation forest. Thus, the total converted area used to calculate the change of biomass carbon stocks due to the land use conversion process was 40,481 ha. The total area of land converted to cropland is presented in Table 5.38.

Table 5.38 Area of Land converted to cropland to calculate emissions from land use conversion

No	Conversion Type	Conversion area
		ha
Total		**153,396**
1	Forest land converted to cropland (FC)	40,481
2	Grassland Converted to cropland (GC)	108,822
3	Wetland converted to cropland (WC)	3,009
4	Settlements converted to cropland (SC)	692
5	Other land converted to cropland (OC)	392

c. EFs/ Parameters

Annual calculated biomass carbon growth for immature woody perennials

The parameter used for the calculation of annual biomass carbon growth for immature woody perennial crops is the rate of biomass carbon accumulation on Cropland. The default parameter was taken from Table 5.9, page 5.28 the IPCC 2006 Guidelines for the tropic moist area is 2.6tC/ha/year.

• *Changes in biomass carbon stocks due to land use conversion of Land converted to cropland*

The parameters used for calculating emissions/removals from land use conversion included:

- Biomass on the ground of the Land before conversion;
- Biomass of the land after conversion: Assumption of Tier 1 method was that at the time of conversion, the living biomass was cleared and the carbon stocks of living biomass after conversion was assumed to be zero; and
- Growth of biomass carbon in the year after the conversion.

The parameters used for the calculation are shown in Table 5.39.

Table 5.39 Parameters applied to calculate emissions/removals from land use conversion of Land converted to cropland

Land use		Value	Unit	Source
Before converted				
Forest Land	Natural woody forest	83.09	t-d.m/ha	Forest Inventory and Planning Institute
	Plantation forest	42.08		
	Bamboo forest	35.79	t-d.m/ha	
	Mix forest	85.25	t-d.m/ha	
	Mangrove	101.15	t-d.m/ha	
	Coconut forest	24.09	t-d.m/ha	Nguyen Thi Thanh Truc And Le Anh Tuan, 2015, " The estimation of carbon-dioxide (CO2) absorptive capacity of coconut tree through biomass in Giong Trom district, Ben Tre province", College of Environment and Natural Resources, Can Tho University

Land use		Value	Unit	Source
Grassland biomass		2.1	t-d.m./ha	Table 2.4, page 2.45-2.46, Biomass selection for grassland, IPCC 2006 Guidelines as the area of land for grass farming has been inventoried into the cropland (annual crop land), the remaining grass land was shrubs.
Other Land use		0	tC/ha	Assumed to be 0
After converted				
Total land use types		0	tC/ha	IPCC 2006 Guidelines
Biomass carbon stock after 1 year				
Forest land		The parameters are more specified in the section Forestland		
Cropland	Annual cropland	5	tC/ha/year	Table 5.9, Annual cropland, page 5.28, Part 5, Chapter 5, Arable land, IPCC 2006 Guidelines
	Perennial cropland	2.6	tC/ha/year	Table 5.9, Annual cropland, page 5.28, Part 5, Chapter 5, Arable land, IPCC 2006 Guidelines

d. Results of emissions/removals

Using the calculation method, AD and EFs as mentioned above, the results of calculation of emissions/removals from living biomass of Land converted to cropland are shown in Table 5.40.

Table 5.40 Net emissions from living biomass of Land converted to cropland for 2006

Gain	Loss due to logging	Loss due to disturbance		Loss by conversion land use	Total net change
		Fire	Pest		
$ktCO_2$					
-124.23	IE	NE	NE	4,586.13	4,461.90

ii. Carbon stock changes in Dead organic matter

Similar to Forest land remaining forest land, in section 2.3.2, page 2.21, the IPCC 2006 Guidelines, Tier 1 method assumed the carbon stocks in the DOM (including dead wood and litter) in Cropland remaining cropland remained unchanged over time and was reported as zero.

iii. Carbon stock changes in Soils

Changes in soil carbon stocks are calculated through Equation 2.24, Chapter 2, Volume 4, the IPCC 2006 Guidelines which covered changes in carbon stocks in soils, organic soils, and inorganic carbon in soil.

Similar to Forest land remaining forest land, for mineral soils, the current results of soil monitoring information in Viet Nam have not been sufficient enough to demonstrate the long-term trend of changes in carbon stocks in the remaining Cropland counted. Therefore carbon stock change in mineral soil was not estimated.

According to the data of area of organic soil in the Mekong River Delta for Forestland converted to cropland was 11,229 ha, including 2,751 ha of annual crop land (draining) and 8,478 ha paddy land (without draining). The total area of drained land for annual crops was 2,751 ha. EF was 20tC/ha/year (Table 5.6, page 5.19, Chapter 5, Volume 4, the IPCC 2006 Guidelines). Emissions were 55,020tC/year equivalent to 201.74 ktCO_2e/year.

Regarding inorganic carbon stocks in soil, Viet Nam has not yet had suitable conditions to evaluate and monitor changes in inorganic carbon stocks in soil.

5.2.2.4 Grassland (3B3)

In the Grassland, the amount of change in carbon stocks of living biomass of shrubs (Grassland is counted into the annual crops of Cropland) from Land converted to grassland. Changes in carbon stocks in DOM and soils were assumed not to occur in Grassland. Net emissions from Grassland are reported in Table 5.41.

Table 5.41 Net emissions from Grassland for 2016

IPCC Code	Emission/Removal source	Living biomass	Dead organic matter	Soil	Total
		ktCO_2eq			
3B3	**Grassland**	**1,383.64**	**NE**	**NE**	**1,383.64**
3B3a	Grassland remaining grassland	0	NE	NE	0
3B3b	Land converted to grassland	1,383.64	NE	NE	1,383.64

5.2.2.4.1 Grassland remaining grassland (3B3a)

a. Methodology

For carbon stock change of Grassland remaining grassland in Tier 1 method, the living biomass carbon stocks would reach a steady state in the intact grassland (i.e. carbon accumulation through balanced crops growth with losses through decomposition and fire). Hence the Tier 1 assumed no changes in the carbon stock in the living biomass for the intact grassland and was reported as zero.

Also by applying the Tier 1, assumptions of no changes were made in carbon stocks in the grassland and insufficient data to calculate emissions from soils.

b. Results of emissions/removals

Emission from Grassland remaining grassland are reported in Table 5.42.

Table 5.42 Net GHG emissions from Grassland remaining grassland for 2016

Biomass	DOM	Soil
$ktCO_2eq$		
0	0	NE

5.2.2.4.2 Land converted to grassland (3B3b)

Emissions/removals from Land converted to grassland are reported in Table 5.43.

Table 5.43 Net emissions from Land converted to grassland for 2016

Land conversion	Living biomass	DOM	Soil	Total
	$ktCO_2eq$			
Total	**1,383.64**	**0**	**NE**	**1,383.64**
FG	1,168.70	0	NE	1,168.70
CG	216.13	0	NE	216.13
WG	-0.79	0	NE	-0.79
SG	-0.35	0	NE	-0.35
OG	-0.05	0	NE	-0.05

i. Carbon stock changes in living biomass

a. Methodology

Change the living biomass carbon stocks of Land converted to grasslands used Equation 2.16 in Chapter 2, Volume 2, the IPCC 2006 Guidelines.

b. AD

AD of change in living biomass carbon stocks was areas of the land converted to grass area and data on logging and disturbance occurring in Land converted to grassland.

Area of Land converted to grassland used the data from the land use matrix divided by an average of 10 years (2006-2016) to obtain the converted area per year.

For the area of Forest land converted to grassland, the area converted from Plantation forest was subtracted from the biomass loss from this activity and was included in the Forest loss due to Logging of Forest land remaining forest land to avoid overlapping.

Data on Forest land converted to grassland is presented in Table 5.44.

Table 5.44 Area of Forest land converted to grassland by forest types

Vegetation type	Area *ha*
1. Woody forest	6,153
Natural woody forest	4,259
Plantation forest	1,895
2. Bamboo forest	140
3. Mix forest	3,975
4. Coconut -palm forest	0
5. Mangrove	0
Mangrove	0
Mangrove land has no reserves	0
Total	**10,269**
Total area except for area of Plantation forest	**8,374**

Thus, the total area of Forest land converted to grassland was 10,269 ha, including 1,895 ha converted from Plantation forest. The total converted area used to calculate the change in carbon stock in living biomass was 8,374 ha. The total area of Land converted to cropland is shown in Table 5.45.

Table 5.45 Area of Land converted to grassland to calculate of emissions from land use conversion

No.	Conversion type	Conversion area in inventory year *ha*
1	Forest land converted to grassland (FG)	8,374
2	Grassland converted to grassland (GG)	6,584
3	Wetlands converted to grassland (WG)	103
4	Settlements converted to grassland (SG)	46
5	Other land converted to grassland (OG)	6
Total		**15,077**

Information on the logging and disturbance that occurred in Land converted to grasslands could not be collected and calculated.

c. EFs/ Parameters

The parameters used for calculating emissions/removals from land use conversion include:

- Above-ground biomass of the land before conversion;

- Biomass of the land after conversion: Tier 1 assumption states that at the time of conversion, the living biomass is cleared and the carbon stocks of living biomass immediately after conversion was assumed as zero; and

- Growth of biomass carbon in the year after conversion.

The parameters are shown in Table 5.46.

Table 5.46 Parameters applied to calculate emissions/removals from land use conversion of Land converted to grassland

Land use		Value	Unit	Source
Before converted				
Forest land	Natural woody forest	83.09	t-d.m/ha	Forest Inventory and Planning Institute (not announced)
	Plantation forest	42.08		
	Bamboo forest	35.79	t-d.m/ha	
	Mix forest	85.25	t-d.m/ha	
	Mangrove forest	101.15	t-d.m/ha	
	Coconut forest	24.09	t-d.m/ha	Nguyen Thi Thanh Truc And Le Anh Tuan, 2015, 'The estimation of carbon-dioxide (CO_2) absorptive capacity of coconut tree through biomass in Giong Trom district, Ben Tre province', College of Environment and Natural Resources, Can Tho University
Cropland	Annual cropland	5 10.64	tC/ha t-dm/ha	Table 5.9, Annual cropland, page 5.28, Part 5, Chapter 5, Arable land, IPCC 2006 Guidelines
	Perennial cropland	21 44.87	tC/ha t-dm/ha	Table 5.1, Perennial cropland, page 5.9, Section 5, Chapter 5, Arable land, IPCC 2006 Guidelines
Other land use type		0	tC/ha	Assumed as 0

Land use		Value	Unit	Source
After converted				
Total of land use type		0	tC/ha	IPCC 2006 Guidelines
Carbon stock in biomass after 1 yr.				
Grassland	Production of ground-based primary biomass	2.1	t-d.m./ ha/year	Table 2.4, page 2.45-2.46, IPCC 2006 Guidelines, Biomass selection for grassland. Because the area of grass land for farming has been counted into Cropland subsector (Annual crops), the remaining of grass land is shrubs.

d. Results of emissions/removals

Using the calculation method as well as AD and the above parameters, the emissions/ removals from living biomass of Land converted to grassland are reported in Table 5.47.

Table 5.47 Net emissions from living biomass of Land converted to grassland for 2016

Land use conversion	Loss by wood logging	Disturbance		Total net change
		Fire	Pest	
$ktCO_2$				
1,383.64	NE	NE	NE	1,383.64

ii. Carbon stock changes in DOM

To calculate the carbon stocks in DOM, general approach to land conversion was used. See section Carbon stock changes in DOM of Land converted to cropland for further information.

iii. Carbon stock changes in soils

There is no change of carbon stock in mineral and inorganic soils. According to the Viet Nam land use matrix, Land converted to grassland had no organic soil, therefore emissions were zero.

5.2.2.5 Wetlands (3B4)

According to the IPCC Guidelines, Wetlands include peatlands (not for other land uses) and waterlogged land. It is not required to report GHG emissions from waterlogged land. In the 3B4 subsector, the change in the carbon stock of the living biomass in the conversion to wetlands was calculated.

Net emissions from Wetlands are reported in Table 5.48.

Table 5.48 Net GHG emissions from Wetlands for 2016

IPCC Code	Emission/removal source	Living biomass	DOM	Soil	Total
		$ktCO_2eq$			
3B4	**Wetlands**	**1,046.90**	**NE**	**NE**	**1,046.90**
3B4a	Wetlands remaining wetlands	0	NE	NE	0
3B4b	Land converted to wetlands	1,046.90	NE	NE	1,046.90

5.2.2.5.1 Wetlands remaining wetlands (3B4a)

According to the IPCC guidelines, it is not required to report GHG emissions from Wetlands remaining wetlands. As no information on emissions from Wetlands remaining wetlands has been available so the value was zero.

5.2.2.5.2 Land converted to wetlands (3B4b)

For Land converted to wetlands, only changes in carbon stocks in living biomass were estimated. Information on carbon stocks in the DOM and Soils were insufficient. GHG emissions/removals from Land converted to wetlands for 2016 are reported in Table 5.49.

Table 5.49 Net GHG emissions from Land converted to wetlands for 2016

Land use conversion	Living biomass	DOM	Soils	Total
	$ktCO_2eq$			
Total	**1,046.90**	**0**	**NE**	**1,046.90**
FW	526.56	0	NE	526.56
CW	513.90	0	NE	513.90
GW	6.43	0	NE	6.43
SW	0	0	NE	0
OW	0	0	NE	0

i. Carbon stock changes in living biomass

a. Methodology

Change the living biomass carbon stocks of Land converted to wetlands was calculated with Equation 2.16 in Chapter 2, Volume 2, the IPCC 2006 Guidelines.

b. AD

AD of change in living biomass carbon stocks was areas of the land converted to wetlands area and information on logging and disturbance occurring in Land converted to wetlands.

Area of Land converted to wetlands used data from the land use matrix divided by an average of 10 years (2006-2016) to obtain the converted area per year.

For the area of Forest land converted to wetlands, the area converted from Plantation forest s subtracted from the biomass loss from this activity and has been included in the Forest loss due to Logging of Forest land remaining forest land to avoid overlapping.

Data on Forest land converted to grassland is presented in Table 5.50.

Table 5.50 Area of Forest land converted to wetlands by forest types

Vegetation types	Area
	ha
1. Woody forest	**1,302**
Natural woody forest	**901**
Plantation forest	**401**
2. Bamboo forest	**331**
3. Mix forest	**750**
4. Coconut -palm forest	**NA**
5. Mangrove	**1,895**
Mangrove	**1,005**
Mangrove land has no reserves	**889**
Total	**4,277**
The total area except to Plantation Forest	**3,876**

The total area of Forest land converted to wetlands was 4,277 ha, of which 401 ha was converted from Plantation forest. Thus, the total converted area used to calculate the change in carbon stock in living biomass was 3,876 ha. The total area of Land converted to wetlands is shown in Table 5.51.

Table 5.51 Area of Land converted to wetlands to calculate emissions from land use conversion

No	Conversation type	Area conversation in inventory year
		ha
	Total	**17,818**
1	Forest land converted to wetlands (FW)	3876
2	Grassland converted to wetlands (GW)	10,744
3	Wetlands converted to wetlands (WW)	1,778
4	Settlements converted to wetlands (SW)	419
5	Other land converted to wetlands (OW)	1,001

Information on logging and disturbance that occurred in Land converted to wetlands could not be collected, so its emission were not calculated.

c. EFs/ Parameters

The parameters used for calculating emissions/removals from land use conversion include:

- Above-ground biomass of the land before conversion;

- Biomass of the land after conversion: Tier 1 assumption states that at the time of conversion, the living biomass was cleared and the carbon stocks of living biomass immediately after conversion was assumed as zero; and

- Growth of biomass carbon in the year after the conversion: In Wetlands, no biomass growth was assumed immediately after conversion of land use. The parameters are detailed in Table 5.52.

Table 5.52 Parameters applied to calculate emissions/removals from land use conversion of Land converted to wetlands

Land use		Value	Unit	Source
Before converted				
Forest Land	Natural woody forest	83.09	t-d.m/ha	Forest Inventory and Planning Institute
	Plantation forest	42.08	t-d.m/ha	
	Bamboo forest	35.79	t-d.m/ha	
	Mix forest	85.25	t-d.m/ha	
	Mangrove forest	101.15	t-d.m/ha	
	Coconut forest	24.09	t-d.m/ha	Nguyen Thi Thanh Truc And Le Anh Tuan, 2015, " The estimation of carbon-dioxide (CO2) absorptive capacity of coconut tree through biomass in Giong Trom district, Ben Tre province", College of Environment and Natural Resources, Can Tho University
Cropland	Annual cropland	5	tC/ha	Table 5.9, Annual cropland, page 5.28, Part 5, Chapter 5, Arable land, IPCC 2006 Guidelines
	Perennial cropland	21	tC/ha	Table 5.1, Perennial cropland, page 5.9, Section 5, Chapter 5, Arable land, IPCC 2006 Guidelines
Grassland biomass		2.1	t-d.m./ha	Table 2.4, page 2.45-2.46, IPCC 2006, Biomass selection for grassland as the area of Land for grass farming has been inventoried into the cropland (Annual cropland), the remaining grass land was shrubs.
Other land use type		0	tC/ha	Assume as 0
After converted				
Total land use type		0	tC/ha	IPCC 2006 Guidelines
Carbon stock in biomass after 1 year				
Wetlands		0	tC/ha	IPCC 2006 Guidelines

d. Results of emissions/removals

Using the calculation method, AD and calculation parameters mentioned above, the emissions/removals from living biomass of Land converted to wetlands are reported in Table 5.53.

Table 5.53 Net emissions from biomass of Land converted to wetlands for 2016

Land use conversion	Loss due to logging	Disturbance		Total net change
		Fire	Pest	
$ktCO_2$				
1,064.90	NE	NE	NE	1,064.90

ii. Carbon stock changes in Dead organic matter

The general approach of land use conversion has been adopted. See section Land converted to cropland.

iii. Carbon stock changes in soil

Carbon stock changes in mineral soils of Land converted to wetlands were similar to Forest remaining forest land. Soil monitoring information in Viet Nam are under research to point out the long-term trend of changes, therefore carbon stocks was not calculated yet.

According to the data of area of organic soil in the Mekong River Delta for Forestland converted to wetlands was 109ha without draining. The total area of drained land for annual crops was 2,751ha. With an EF of 0tC/ha/year according to Table 5.6, page 5.19, Chapter 5, Volume 4, the IPCC 2006 Guidelines, the result was 0tC/year equivalent to 0 $ktCO_2$/year.

Regarding inorganic carbon stocks in soil, Viet Nam has not yet had suitable conditions to evaluate and monitor changes in inorganic carbon stocks in soil.

5.2.2.6 Settlements (3B5)

In the Settlements subsector (3B5), emissions were calculated from changes in carbon stocks in living biomass, DOM and soils in Land converted to settlements. Net emissions from Settlements are reported in Table 5.54.

Table 5.54 Net GHG emissions from Settlements for 2016

IPCC Code	Emissions/Removals	Living biomass	DOM	Soil	Total
		$ktCO_2eq$			
3B5	**Settlements**	**1,908.36**		**10.78**	**1,919.14**
3B5a	Settlements remaining settlements	0			0
3B5b	Land converted to settlements	1,908.36	NE	10.78	1,919.14

5.2.2.6.1 Settlements remaining settlements (3B5a)

No change in living biomass carbon stocks was estimated in section Settlements remaining settlements as national data on living biomass was insufficient in the Settlements subsector (for scattered trees).

No methodology and data were available on litter and soil types of Settlements remaining settlements in the IPCC 2006 Guidelines.

5.2.2.6.2 Land converted to settlements (3B5b)

This section calculated carbon stocks change of living biomass and DOM. Emissions for change in carbon stocks in soil were not estminated. GHG emissions/removals from Land converted to settlements are reported in Table 5.55.

Table 5.55 Net GHG emissions from Land converted to settlements for 2016

Land conversion	Living biomass	DOM	Soil	Total
	$ktCO_2eq$			
Total	**1,908.36**	**NE**	**10.78**	**1,919.14**
FS	879.87	0	10.78	890.65
CS	1,016.12	0	NE	1,016.12
GS	12.37	0	NE	12.37
OS	0	0	NE	0
WS	0	0	NE	0

i. Carbon stock changes in living biomass

a. Methodology

Change the living biomass carbon stocks of Land converted to settlements was calculated by using Equation 2.16 in Chapter 2, Volume 2, the IPCC 2006 Guidelines.

b. AD

AD of change in living biomass carbon stocks included areas of the land converted to settlements and information on logging and disturbance occurring in Land converted to settlements.

Area of Land converted to settlements used the data from the land use matrix divided by 10 years (2006-2016 period) to obtain an average of converted area per year.

For the area of Forest land converted to settlements, the area converted from Plantation forest was subtracted from the biomass loss from this activity and was included in the Forest loss due to Logging of the Forest land remaining forest land to avoid overlapping.

Data on Forest land converted to settlements for 2016 is presented in Table 5.56.

Table 5.56 Area of Forest land converted to settlements by vegetation types

Vegetation type	Area
	ha
Total	**7,454**
1. Woody forest	6,522
Natural woody forest	4,513
Plantation forest	2,008
2. Bamboo forest	336
3. Mix forest	137
4. Coconut -palm forest	-
5. Mangrove	460
Mangrove	244
Mangrove land has no reserves	216
Total areas not include timber forest	**5,446**

The total area of Forest land converted to settlements was 7,454ha, of which 2,008ha was converted from Plantation forest. Thus, the total converted area used to calculate carbon stock changes in living biomass was 5,446ha. The total area of Land converted to settlements is demonstrated in Table 5.57.

Table 5.57 Area of Land converted to settlements to calculate emissions from land use conversion for 2016

No	Conversion types	Conversion area
		ha
	Total	**31,744**
1	Forest land converted to settlements (FS)	5,446
2	Cropland converted to settlements (CS)	21,244
3	Grassland converted to settlements (GS)	3,417
4	Wetlands convert to settlements (WS)	1,248
5	Other land converted to settlements (OS)	389

Information on logging and disturbance that occurred in Land converted to settlements could not be collected and calculated.

c. EFs/ Parameters

EFs/parameters given in Table 5.52 of Land converted to wetlands were applied to estimate change in emissions of carbon stocks of living biomass in subsector Land converted to settlements.

d. Results of emissions/removals

Using the calculation method as well as AD and the above EFs, the emissions/removas from living biomass of Land converted to settlements are reported in Table 5.58.

Table 5.58 Net emissions from living biomass of Land converted to settlements for 2016

Land use conversion	Loss due to logging	Disturbance		Total net change
		Fire	Pest	
$ktCO_2$				
1,908.36	NE	NE	NE	1,908.36

ii. Carbon stock changes in DOM

The same method as Land converted to wetlands was used.

iii. Carbon stock changes in organic soil

Carbon stock changes in mineral soils of Land converted to wetlands was similar to the Forest land remaining forest land. Soil monitoring information in Viet Nam are under research to point out the long-term trend of changes, therefore carbon stocks was not calculated yet.

According to the data of area of organic soil in the Mekong River Delta for Forest land converted to settlements was 147ha. With an EF of 20tC/ha/year according to Table 5.6, page 5.19, Chapter 5, Volume 4, the IPCC 2006 Guidelines, the result was 2,940tC/year equivalent to 10.78ktCO2e/year.

Regarding inorganic carbon stocks in soil, Viet Nam has not yet had suitable conditions to evaluate and monitor changes in inorganic carbon stocks in soil.

5.2.2.7 Other land (3B6)

GHG emissions/removals from Other land in 2016 are reported in Table 5.59.

Table 5.59 Net GHG emissions from Other land for 2016

IPCC Code	Emission/Removal	Living biomass	DOM	Soil	Total
		$ktCO_2$			
3B6	Other Land	7,179.27	NE	NE	7,179.27
3B6a	Other land remaining other land	0	NE	NE	0
3B6b	Land converted to other land	7,179.27	NE	NE	7,179.27

5.2.2.7.1 Other land remaining other land (3B6a)

The change in carbon stocks in living biomass in Other land remaining other land was zero as no living biomass was on other soils.

Emissions/removals from DOM and other soils in Other land were not estimated due to lack of data and information.

5.2.2.7.2 Land converted to other land (3B6b)

Net emission results from Land converted to other land are reported in Table 5.60.

Table 5.60 Net GHG emission from Land converted to other land for 2016

Land use conversion	Living Biomass	DOM	Soil	Total
	$ktCO_2$			
3B6b	**7,179.27**	**0**	**NE**	**7,179.27**
FO	5,335.51	0	NE	5,335.51
CO	1,350.75	0	NE	1,350.75
GO	493.00	0	NE	493.00
WO	0.00	0	NE	0.00
SO	0.00	0	NE	0.00

i. Carbon stock changes of Living biomass

a. Methodology

Change the living biomass carbon stocks of Land converted to other land was calculated by using Equation 2.16 in Chapter 2, Volume 4, the IPCC 2006 Guidelines.

b. AD

AD of change in living biomass carbon stocks was areas of the land converted to other land and information on logging and disturbance occurring in Land converted to other land.

Area of Land converted to other land used the data from the land use matrix divided by 10 years (2006-2016 period) to obtain the an average of converted area per year.

For the area of Forest land converted to other land, the area converted from Plantation forest was subtracted from the biomass loss from this activity and was included in the Forest loss due to Logging of the Forest land remaining forest land to avoid overlapping.

Data on Forest land converted to other land for 2016 is shown in Table 5.61.

Table 5.61 Area of Forest land converted to other land by forest type

Vegetation types	Area
	ha
Total	**36,494**
1. Woody forest	16,613.77
Natural woody forest	11,498
Plantation forest	5,116
2. Bamboo forest	1,604
3. Mix forest	18,229
4. Coconut -palm forest	-
5. Mangrove	47
Mangrove	25
Mangrove land has no reserves	22
Total area except for Plantation forest	**31,378**

The total area Forest land converted to other land was 36,494ha, of which 5,116ha was converted from Plantation forest. Thus, the total converted area used to calculate the change in carbon stock in living biomass was 31,378ha. Total area of Land converted to other land is shown in Table 5.62.

Table 5.62 Area of Land converted to other land to calculate emissions from land use conversion

No	Conversion types	Conversion area
		ha
Total		**196,883**
1	Forest fand converted to other land (FO)	31,378
2	Cropland converted to other land (CO)	28,240
3	Grassland Converted to other land (GO)	136,226
4	Wetlands converted to other land (WO)	955
5	Other land converted to other land (SO)	84

Data of wood due to logging and disturbance occurring in Land converted to other land could not be collected.

c. EFs/ Parameters

EFs/parameters given in Table 5.52 Land converted to wetlands were applied to estimate change in emissions of carbon stocks of living biomass in Land converted to other land.

d. Results of emissions/removals

Using the calculation method as well as AD and the above parameters, emissions/removals from living biomass of Land converted to other land are reported in Table 5.63.

Table 5.63 Net emissions from living biomass of Land converted to other land for 2016

Land use conversion	Loss due to logging	Disturbance		Total net change
		Fire	Pest	
$ktCO_2$				
7,179.27	NE	NE	NE	7,179.27

ii. Carbon stock changes in Dead organic matter

The same method as Land converted to wetlands were used.

iii. Carbon stock changes in soil

This part could not be calculated due to lack of AD.

5.2.3 Other emission source and non-CO2 emission (3C)

Total emissions from subsector Other emission sources and non-CO_2 (3C) were 65,047.60 $ktCO_2eq$, of which, the largest emissions came from subsector Rice cultivations, followed by subsector Direct N_2O emissions from soil, as follows:

- Emissions from Biomass burning were 1,624.13 $ktCO_2eq$;
- Emissions from Liming were 565.79 $ktCO_2eq$.
- Emission from Urea application (nitrogenous fertiliser) was 1,436.11 $ktCO_2eq$.
- Direct N_2O emissions from Managed soil were 7,754.11 $ktCO_2eq$.
- Indirect N_2O emissions from Managed soil were 3,752.55 $ktCO_2eq$.
- Indirect N_2O emissions from Manure management were 221.90 $ktCO_2eq$.
- Emissions from Rice cultivations were 49,693.02 $ktCO_2eq$.

5.2.3.1 GHG emissions from Biomass burning (3C1)

The total emissions from Biomass burning were 1,788.00 ktCO_2eq including: emissions from Biomass burning in Forest land, Cropland, Grasslands and Other land.

5.2.3.1.1 Emission by Biomass burning in forest land (3C1a)

The source of Biomass burning in forest land is forest fire. GHG emissions from Biomass burning include CH_4, N_2O, NO_x and CO. Only CO_2 is not included in this part as it is calculated by the stock change method.

a. Methodology

Equation 2.27, Chapter 2, Volume 4, the IPCC 2006 Guidelines was applied to calculate Non-CO_2 emissions from forest fire at Tier 1, with respective biomass and combustion efficiency or biomass ratio to be burned and EFs of CH_4, N_2O, NO_x and CO. The amount of CH_4 and N_2O were then converted to CO_2eq. The emissions of two gases of CO and NO_x were not converted to CO_2eq as they have not been included in the total national emissions.

b. AD

AD included burnt forest and converted forest provided by GSO, which was 3,149ha as detailed in Table 3.25, category Forest land remaining forest land.

c. EFs/ Parameters

The parameters used include:

- Biomass burned volume: the living biomass of plantation (type of vegetation in which fire occurs) wass 42.08 (tdm/ha) detailed in Table 5.52;
- Combustion factor value is 0.45 as shown in Table 2.6 page 2.48, Chapter 2, Volume 4, the IPCC 2006 Guidelines; and
- EFs for various types of burning emitting CH_4, CO, NO_x and N_2O have been given in Table 2.5, page 2.47, Chapter 2, Volume 4, Extra tropical forest, the IPCC 2006 Guidelines.

EFs applied to calculate emissions from Non-CO_2 gases are summarised in Table 5.64.

Table 5.64 GHG EFs of non-CO_2 gases

Gas	EF *g/kgdm*
CH_4	6.8
CO	104
NOx	1.6
N_2O	0.2

d. Results of emissions/removals

Total GHG emissions from Biomass burning of Non-CO2 gases are reported in Table 5.65.

Table 5.65 GHG emissions by Biomass burning in forest fire of Forest land in 2016

IPCC Code	Emission source	CH_4	N_2O	NO_x	CO	Total CO_2eq
		kt				*ktCO₂eq*
3C1a	Biomass burning in forest land	0.405	0.012	0.095	6.201	14.514

5.2.3.1.2 Emission by Biomass burning in cropland (3C1b)

Total emissions from Biomass burning in cropland were 1,544.08ktCO2eq as presented in Table 5.66.

Table 5.66 Emissions by Biomass burning in cropland

IPCC Code	Emission source	CH_4	N_2O	NO_x	CO	Total CO_2eq
		kt				*$ktCO_2eq$*
3C1b	**Biomass burning in cropland**	**44.45**	**1.17**	**38.09**	**1,431.06**	**1,544.08**
	Field burning of agricultural residues	40.00	1.04	37.04	1,363.05	1,394.90
	Biomass burning from land use conversion	4.45	0.13	1.05	68.01	159.18

i. Emissions from Field burning of agricultural residues

When burning agricultural residues, GHG are released from the burning of organic matter.

a. Methodology

Emissions from the burning of agricultural residues in the fields were estimated by using Equation 2.27, page 2.42, Chapter 2, the IPCC 2006 Guidelines.

b. AD

Crop yield data was obtained from GSO and FAOSTAT Statistical yearbooks and detailed in Table 5.67.

Table 5.67 Annual crop production in 2016

Crop type	Production	Area	Source
	Thousand tonnes	ha	
Maize	5,246.50	1,152,700	GSO
Rice	43,165.10	7,737,100	GSO
Millet	0.37	1,428	FAOSTAT
Soybeans	160.70	99,600	GSO
Potatoes	302.21	21,173	FAOSTAT
Sweet potato	1,269.30	120,300	GSO
Cassava	10,909.90	569,000	GSO
Sugar cane	17,211.20	267,600	GSO
Peanut	427.20	184,800	GSO
Beans	167.70	159,400	FAOSTAT
Cotton	0.60	500	GSO
Rush	0.84	208	GSO
Jute	43.44	9,470	GSO
Sesame	34.75	50,550	GSO
Tobacco	56.50	14,650	GSO

Table 5.68 Fraction of agricultural residues burned in field

Crop type	Value	Source
Maize	0.3	Expert judgment
Rice	0.29	Assessing the current situation and proposing solutions for waste management in the field of cultivation - Summary report of environmental project of the Institute of Agricultural Environment.
Millet	0.25	The default value of developing country, page 4.83, IPCC 1996 Revised
Soybeans	0.25	
Potatoes	0.25	

Crop type	Value	Source
Sweet potato	0.1	Expert judgment
Cassava	0.35	
Sugar cane	0.6	
Peanut	0.35	
Beans	0.25	The default value of developing country, page 4.83, IPCC 1996 Revised.
Cottonne	0.25	
Rush	0.25	
Jute	0.25	
Sesame	0.25	
Tobacco	0.25	

c. EFs/ Parameters

EFs for each gas from Burning of agricultural residues were taken from the IPCC 2006 Guidelines as detailed in Table 5.69.

Table 5.69 EFs applied to Field burning of agricultural residues

Type gas	Emission rate	Source
CH_4	2.7	Table 2.5, page 2.47, Chapter 2, IPCC 2006 Guidelines
N_2O	0.07	
NO_x	2.5	
CO	92	

d. Results of emissions/removals

Emissions from Field Burning of agricultural residues for 2016 were 1,394.90 ktCO_2eq, detailed in Table 5.66.

ii. Biomass emissions from land use conversion

The source of biomass burning from land use conversion was from on-site cropland burning combined with conversion from Forest land converted to cropland.

GHG emissions from biomass burning includes CH_4, N_2O, NO_x and CO. Only CO_2 was not included in this part because it was calculated with the stock change method.

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a. Methodology

Similar to the emissions from biomass burning from Forest land, Equation 2.27, Chapter 2, Part 4, the IPCC 2006 Guidelines was used to calculate the on-site burning due to conversion of Forest land to cropland.

b. AD

AD was the area of 40,481 ha of Forest land converted to cropland shown in Table 5.38, of which, the converted fire area was estimated to be 50% of total area in the inventory year, or 20,239 ha.

c. EFs/ Parameters

The parameters used in the calculation included:

- The biomass burned volume: living biomass of the pre-converted soils as shown in Table 5.52;

- Combustion factor value of 0.45 as shown in Table 2.6, page 2.48, Chapter 2, Volume 4, the IPCC 2006 Guidelines; and

- The default values of the EFs for such gases as CH4, CO, NOx and N_2O given in Table 2.5, page 2.47, Chapter 2, Volume 4, Extra tropical forest, the IPCC 2006 Guidelines.

d. Results of emissions/removals

Total GHG emissions from biomass burning of non-CO2 gases were estimated at 159.18 $ktCO_2eq$ as detailed in Table 5.66.

5.2.3.1.3 Emission by Biomass burning in grassland (3C1c)

Total emissions of Biomass burning in grassland were 41.72 $ktCO_2eq$ and reported in Table 5.70.

Table 5.70 Emissions from Biomass burning in grassland

IPCC Code	Emission Source	CH_4	N_2O	NO_x	CO	Total CO_2eq
		kt				*$ktCO_2eq$*
3C1c	**Biomass burning from grassland**	**1.14**	**0.04**	**0.36**	**18.23**	**41.72**
	Burning grass	0.07	0.01	0.11	1.90	3.50
	Biomass burning from land use conversion	1.07	0.03	0.25	16.33	38.22

i. Emission by Biomass burning in grassland

Grasslands (savanna) are grassy areas with tropical and subtropical plants, sometimes mixed with some shrubs and small trees. Pastures are burned during the dry season mainly for agricultural purposes such as killing weeds and pests, promoting vegetative processes and stimulating the growth of new grasses for grazing. Burning grassland produces CH_4, CO, N_2O, NO_x and NMVOCs.

a. Methodology

Emissions from savanna burning were calculated using Equation 2.27, page 2.42, Chapter 2, the IPCC 2006 Guidelines.

b. AD

Viet Nam has two types of grassland: shrubland and grass. The statistics on the burning area of shrubs and grasses in 2016 were assumed to have decreased against 2014, as detailed in Table 5.71.

Table 5.71 The area of grassland burned in 2016

Type	Area
	thousand ha
Grass	1.09
Shrubland	0.38

c. EFs/ Parameters

EFs for gases from burning grassland were default values of Table 2.5, page 2.47, Chapter 2, the IPCC 2006 Guidelines, detailed in Table 5.72.

Table 5.72 EFs applied to calculate emissions from grassland burning

Type	Emission rate
CH_4	2.3
CO	65
N_2O	0.21
NO_x	3.9

d. Results of emissions/removals

Emissions from Grassland burning in 2016 were 3.50 $ktCO_2eq$ and reported in Table 5.70.

ii. Biomass emissions from land use conversion

The source of biomass burning from land use conversion is from on-site cropland burning combined with conversion from Forest land converted to grassland.

GHG emissions from biomass burning includes CH_4, N_2O, NOx and CO. Only CO_2 was not included in this part because it was calculated by the stock change method..

a. Methodology

Similar to the emissions resulting from Biomass burning from Forest land, formula 2.27 was used to calculate the burning due to conversion of Forest land to grassland.

b. AD

The area of Forest land converted to grassland shown in Table 5.45 was 8,374 ha, of which the converted fire area was estimated to be 50% of total area in the inventory year, or 4,188 ha.

c. EFs/ Parameters

The parameters used in the calculation included:

- The amount of biomass burned: the living biomass of the soil types before conversion is shown in Table 5.52.

- The combustion factor value of 0.45 as given in Table 2.6, page 2.48, Chapter 2, Volume 4, the IPCC 2006 Guidelines; and

- The default values of EFs for CH_4, CO, NO_x and N_2O are given in Table 2.5, page 2.47, Chapter 2, Volume 4, Extra tropical forest, the IPCC 2006 Guidelines.

d. Results of emissions/removals

Total GHG emissions from biomass burning of non-CO_2 gases in 2016 were calculated at 38.22 thousand tonnes CO2eq, details in Table 5.69.

5.2.3.1.4 Emission by Burning biomass in wetlands (3C1d)

a. Methodology

Formula 2.27, page 2.42, Chapter 2, the IPCC 2006 Guidelines was used.

b. AD

The area of Forest land converted to wetlands shown in Table 5.51 was 3,876 ha, of which the converted fire area was estimated to be 50% of the converted year of the inventory year, or 1,938 ha.

c. EFs/ Parameters

The parameters used in the calculation included:

- The amount of biomass burned: the living biomass of the soil types before conversion shown in Table 5.52.

- The combustion factor value of 0.45 as shown in Table 2.6, page 2.48, Chapter 2, Volume 4, the IPCC 2006 Guidelines; and

- The default values of the EFs for such gases as CH_4, CO, NO_x and N_2O given in Table 2.5, page 2.47, Chapter 2, Volume 4, Extra tropical forest, the IPCC 2006 Guidelines.

d. Results of emissions/removals

Total GHG emissions from Biomass burning of non-CO_2 gases in wetlands was estimated at 177.68 ktCO_2eq in 2016, detailed in Table 5.73.

Table 5.73 Emissions of Biomass burning in wetlands from land use conversion for 2016

IPCC Code	Emission source	CH4	N_2O	NO_x	CO	Total
		kt				*ktCO_2eq*
3C1d	Biomass burning from wetlands	0.386	0.011	0.091	5.900	13.81

5.2.3.2 Lime (3C2)

Lime is applied into the soil to reduce soil acidity and improve plant growth in managed systems, especially in soil and forests. Adding carbonate to the soil in the form of lime ($CaCO_3$) or $CaMg(CO_3)_2$ results in CO_2 emissions.

a. Methodology

Emissions from lime to the soil were estimated by using Equation 11.12, page 11.27, Chapter 11, Part 4, the IPCC 2006 Guidelines.

b. AD

The figures on the production of lime in agriculture were obtained from the Decision No.507/ QD-BXD by MOC on approval of the planning for lime industry development to 2020 with an orientation to 2030. Under the Decision, the total demand for soil improvement of acid, acid, salinity, aquaculture and other needs used for 2016 and 2020 varieties were 1,270,000 tonnes.

According to subsector 2A2 lime production of the IPPU sector, if the lime production data is not separated by lime type, the default ratio for calcium/dolomite lime is 85/15. This ratio was applied to assess the 2016 emissions of the lime production subsector. This value was used for agricultural lime performance data as it was not disaggregated by lime type. Therefore, the number of calcium lime was 1,079,500 tonnes and dolomite lime, 190,500 tonnes.

c. EFs

EFs were used from the default value of the IPCC 2006 Guidelines, where calcium lime was 0.12, dolomite lime, 0.13.

d. Results of emissions

Emissions from lime (including calcium lime and dolomite lime) for 2016 were 556.79 ktCO_2.

5.2.3.3 Use of urea application (3C3)

Adding urea to the soil during fertilization leads to a fixed CO_2 loss during industrial production. Urea ($CO(NH_2)_2$) is converted to ammonium (NH_{4+}), hydroxyl ions (OH_-) and bicarbonate (HCO_3-), in the presence of water and urease enzymes. Similar to the reaction in soil after adding lime, the bicarbonate formed is converted to CO_2 and water.

a. Methodology

Emissions from urea to the soil were estimated using by Equation 11.13, page 11.32, Chapter 11, Volume 4, the IPCC 2006 Guidelines.

b. AD

Data on the total amount of urea application (urea fertiliser) in 2016 was obtained from the Department of Plant Protection, of which 2,218,894 tonnes were produced; 622,847 tonnes, imported; and 110,885 tonnes, exported.

According to the data taken from the Viet Nam Fertiliser Report 2016, in the inorganic fertiliser category of Viet Nam, the consumption of urea is 2,500,000 tonnes. Data used for inventory in 2016 was about 230,856 tonnes.

Total amount of urea consumed in 2018 from the Fertiliser industry report (September 2019) was 2,400,000 tonnes. Of which, the amount used for agricultural production was 1,880,000 tonnes. According to the ratio of urea use in agriculture in 2018, a calculation made for 2016 was 1,958,333 tonnes.

c. EFs

The EF of 0.2 was derived from the IPCC 2006 Guidelines default value.

d. Results of emissions

The emissions from urea application for 2016 were 1,436.11ktCO_2.

Direct N_2O emission from soil (3C4)

Total direct N_2O emissions from soil was 7,754.11 $ktCO_2eq$, in which:

- Direct N_2O emissions from agricultural residues, manure, grazing land/grassland waste were 7,605.49 $ktCO_2eq$;

- Direct emissions of N_2O from the decomposition of organic matter in mineral soil were not estimated; and

- Emission from organic soil were 148.63 $ktCO_2eq$.

5.2.3.4.1 Agricultural residues, livestock waste, grazing/pasture waste

Direct N_2O emissions from agricultural land due to N use and human farming activities supplementing nitrogen from the application of synthetic fertilisers and animal wastes, nitrogen-fixing crops, incorporation of agricultural residues into soil and mineral nitrogen soil due to organic soil farming.

a. Methodology

Direct soil N_2O emissions were estimated using Equation 11.1, page 11.7, Chapter 11, the IPCC 2006 Guidelines.

b. AD

Currently, in Viet Nam, the demand and use of fertilisers has been diverse. The main fertilisers include: urea, phosphorus, NPK, SA, potassium, DAP. The demand for urea, phosphorus, NPK has been fully met, but not for the imported SA, potassium and a part of DAP.

- The amount of urea fertiliser with N as the main ingredient accounts for about 50%;

- NPK fertiliser is a mixed fertiliser with components N, P, K;

- Sulfate nitrogenous fertiliser also called SA [$(NH_4)_2SO_4$], N accounts for about 21%; and

- DAP [$(NH_4)_2HPO_4$] is N fertiliser, accounting for about 18%.

According to AD of the Department of Plant Protection, the figures on the production of urea were as follows: the volume of urea produced domestically (including that of the fertiliser factories of Phu My, Ca Mau, Ninh Binh and Ha Bac) was 2,218,894 tonnes; of which, the imported volume was 622,847 tonnes; and the exported volume, 110,885 tonnes. According to the Viet Nam's fertiliser industry report in 2016, the country consumed 2.5 million tonnes of urea fertiliser. Urea fertiliser in stock could be calculated at about 230,856 tonnes. From there, the amount of urea used in agriculture was 1,958,333.33 tonnes.

For the production of Sulfate fertiliser, also known as SA nitrogenous fertiliser. As Viet Nam has not produced SA fertiliser, the imported amount was 1,049,706 tonnes and exported, 5,517 tonnes. Therefore, SA fertiliser production was 1,044,189 tonnes.

Annual domestic DAP consumption is about 1.1 million tonnes, including direct consumption for crops (70-75%), from which a DAP consumption for crops can be calculated as 825,000 tonnes.

Applying the parameters of the N percentage in the fertilisers, the total N consumption for the major fertilisers containing N was calculated as detailed in Table 5.74.

Table 5.74 Total consumption N in 2016

Fertiliser type	Consumption	N Component	N Consumption
	tonne	*%*	*tonne*
Total			**1,346,946.36**
Urea	1,958,333.33	0.50	979,166.67
SA	1,044,189.00	0.21	219,279.69
DAP	825,000.00	0.18	148,500.00

The amount of N in livestock waste, fertiliser, sludge and additional organic N to the soil (FON) will include the total N from the manure treatment process in the anaerobic compost, poutry manure with bedding, fertilisation, and aerobic treatment. However, in the amount of solid waste as fertiliser calculated in the waste sector, 620.1 thousand tonnes/year of solid waste are treated into fertiliser (4B). As a result, the amount of N in treated solid waste into fertiliser was 12.4 thousand tonnes.

c. EFs

EFs of N_2O emissions directly from agricultural land included the EF1 which estimated the amount of N from fertilisers, livestock waste, agricultural residues and the EF3PRP factor that estimated the amount of N from Livestock grazing. All are default values according to Table 11.1 page 11.11, Chapter 11, the IPCC 2006 Guidelines, detailed in Table 5.75.

Table 5.75 EFs of N_2O emissions directly from Managed land

EF	Value	Value range
The EF1 estimates the amount of N from fertilisers, livestock waste, agricultural residues [kg N_2O - N/(kg N)]	0.01	0.003-0.03
The EF1FR estimates the amount of N from fertilisers, animal wastes, and agricultural residues from rice [kg N_2O - N/(kg N)]	0.003	0.000 - 0.006
The EF3PRP, CPP estimate the amount of N from the grazing field for cattle (Cow, Dairy, Buffalo), Poultry, and Pig [kg N_2O - N/kg N]	0.02	0.007 - 0.06
The EF3PRP, SO estimates the amount of N from the grazing field for Sheep and other animals [kg N_2O - N/kg N]	0.01	0.003 - 0.03

d. Results of emissions/removals

Emission from livestock manure was 13.35 ktN_2O. The largest emissions came from synthetic fertilisers, 13.27 ktN_2O while emissions from crop agricultural residues into the soil was 2.81 ktN_2O. Emissions from livestock manure grazed is 1.01 ktN_2O, detailed in Table 5.76.

Table 5.76 Direct N2O emissions from soil

Type N added to soil	Emissions		
	ktN_2O-N	*ktN_2O*	*ktCO_2eq*
Total	**18.26**	**28.70**	**7,605.49**
Synthetic fertiliser for plants	7.34	11.54	3,056.94
Livestock manure	8.50	13.35	3,538.59
Agricultural residues of crops	1.79	2.81	743.59
Meadow, cattle grazing fields	0.64	1.01	266.36

5.2.3.4.2 Emission from Organic matter decomposition in mineral soil

As the change in carbon stocks in mineral soils was not reported, no N_2O emissions were estimated.

5.2.3.4.3 Direct N_2O emission from organic soil

a. Methodology

The draining of Managed organic soils causes CH_4 and N_2O emissions from the soil. Direct N_2O emissions from Organic soils are based on the Tier 1 according to Equation 11.1, page 11.7, Chapter 11, Volume 4, the IPCC 2006 Guidelines.

b. AD

AD was taken according to the land use matrix of the Department of National Remote Sensing in 2016, of which respective land use types and areas of organic soils in the Mekong River Delta are displayed in Table 5.77.

c. EFs

EFs value are shown in Table 11.1 on page 11.11, the IPCC 2006 Guidelines. Since Tier 1 is available for calculating CH_2 emissions, they were not included in the calculation.

d. Results of emissions

Direct N_2O emissions from Organic soil were 148.63 ktCO_2eq, detailed in Table 5.77.

Table 5.77 Direct N_2O emissions from Organic soil

Land type	Area	EF	Emission	
	ha	*kg N_2O-N ha-1 year-1*	*ktN_2O*	*ktCO_2eq*
Total emissions from organic soil	**41,652**		**0.561**	**148.63**
FF	27,206	8	0.342	90.64
CC	2,961	16	0.074	19.73
FC	11,229	16	0.141	37.41
FS	147	16	0.002	0.49
FW	109	16	0.001	0.36

5.2.3.5 Indirect N_2O emission from soil (3C5)

Total indirect N_2O emissions from soil were 3,752.55 ktCO_2eq, in which:

- Indirect N_2O emissions from evaporation, leaching and leakage were 3,752.55 ktCO_2eq; and

- N_2O simplified emissions from the decomposition of organic matter in mineral soil were not counted.

5.2.3.5.1 Indirect N_2O emission from evaporation, leaching and leakage

Indirect N_2O emissions include leaching and leakage of N (as NH_3), NO_x and volatilization (ammonium (NH_4), NO_x in soil and water).

a. Methodology

Indirect N_2O emissions were calculated using the Tier 1 and the EF using default values according to the IPCC 2006 Guidelines, detailed in Table 5.78.

b. AD

The AD of FSN, FON, FCR, FSOM, FPRP are presented in the section Direct N_2O emissions from soild (3C4).

Table 5.78 EFs to estimate indirect N_2O emissions

Parameters	Value	Unit	Source
$Frac_{GASF}$	0.1	kg NH_3-N + NO_x-N/kg of synthetic fertiliser is applied	Table 11.3, page 11.24, chapter 11, IPCC 2006 Guidelines
$Frac_{GASM}$	0.1	kg NH_3-N + NO_x-N/kg of N livestock emissions	
$Frac_{LEACH}$	0.3	kg N/kg of fertiliser and urea fertiliser	

c. EFs

The default EFs in the IPCC 2006 Guidelines were used to estimate Indirect N_2O emissions from N used in agriculture since no country specific value was available for Viet Nam yet.

Table 5.79 EF for atmospheric deposition, volatilisation and leakage

EF	Value	Unit	Source
EF4	0.01	kg N_2O-N/kg NH_4-N & NO_x-N due to volatilisation	Table 11.3, page 11.24, Chapter 11, IPCC 2006 Guidelines
EF5	0.0075	kg N_2O-N/kg N was leached and leaking	

d. Results of emissions

Total indirect N_2O emissions from volatilisation and leaching for 2016 are reported in detail in Table 5.80.

Table 5.80 Indirect emissions from volatilisation and leaching

Emission source	Indirect N_2O emissions	Indirect N_2O emissions
	kt	*$ktCO_2eq$*
Total	**14.16**	**3,752.55**
Volatilisation	4.90	1,297.68
Leaching	9.26	2,454.86

5.2.3.5.2 Emission from or ganic matter decomposition in mineral soil

As the change in carbon stocks in mineral soils was not estimated, no N_2O emissions were estimated.

Indirect N_2O emissions from Manure management (3C6)

Indirect emissions result from the loss of volatile nitrogen that occurs mainly in the form of NH_3 and NO_x. The rate of excreted organic nitrogen that is mineralised into ammonia nitrogen during manure collection and storage depends mainly on the lower temperature and time. Simple organic nitrogen forms such as urea (mammals) and uric acid (poultry) are rapidly mineralized into ammonia nitrogen, which is easily volatile and easily diffused into the surrounding air. Nitrogen loss begins at the excretion points at households and other animal production areas (and continues through on-site management in storage and disposal systems (i.e., livestock waste management systems). Nitrogen is also lost through runoff and leached into the soil from livestock waste storage in outdoor areas, on farms and where animals are grazing in pastures. Grazing in the pastures is considered separately.

a. Methodology

The Tier 1 calculation method was used to calculate the amount of N volatiles in the form of NH3 and NOx from livestock manure treatment systems according to formula 10.26, page 10.54, the IPCC 2006 Guidelines.

According to Tier 1, the amount of excretion N uses the default value, the N factor lost from volatilisation of livestock manure management systems also uses the default value according to Table 10.22, page 10.65, the IPCC 2006 Guidelines;

Indirect N_2O emissions from the volatilisation of N in the form of NH_3 and NOx were calculated according to the formula 10.27, page 10.56, the IPCC 2006 Guidelines;

The N_2O EF for atmospheric deposition of N from soil and water surface (EF4) took the default value of 0.01 kg N_2O-N (kg NH_3-N + NO_x-N volatilised)-1 from Table 11.3, page 10.56, Chapter 10, the IPCC 2006 Guidelines.

b. AD

AD was the amount (N) disposed of manure management system for each type of livestock by climate region (one region with the average temperature of between 15-25^{0}C and another region with temperature higher than 25^{0}C). AD were also estimated by number of livestock by region ($N_{(T)}$), mean annual excretion N value per animal ($Nex_{(T)}$) and proportion of total annual excretion of each type of livestock in the livestock waste management system by climate ($MS_{(T,S)}$).

Number of livestock ($N_{(T)}$): See details in the CH_4 emissions from Manure management (number of livestock by climate region (one region with average temperature of 15-25^{0}C and another region with average temperature higher than 25^{0}C in 2016).

Mean annual excretion N value per animal ($Nex_{(T)}$) was calculated by using Equation 10.30, page 10.57, Chapter 10, the IPCC 2006 Guidelines.

The MS value (Manure management system ratio) was obtained from the Department of Livestock Production, MARD. Since no data on the proportion of the manure management system for each type of livestock was available, MS data was applicable to all livestock, as detailed in Table 5.81.

Table 5.81 Manure management factor by climate region (MS)

Region	Disposal type (%) according to Department of Livestock Production					
	Total	For fertilisers	Daily spread	Biogas	Poultry manure with bedding	Other
	Disposal type (%) corresponding to IPCC 2016					
	Total	For fertilisers	Aerobic treatment	Anaerobic lagoon	Poultry manure with bedding	Pasture range and paddock
Country	**100**	**55**	**26**	**10**	**5**	**4**
North	100	61.85	23.11	8.25	2.97	3.82
South	100	29.96	36.56	16.39	12.43	4.66

c. EFs

The N_2O EF from nitrogen volatilisation is default value of 0.01 kg N_2O-N and the leaching EF is 0.0075 kg N_2O-N according to Table 11.3, page 10.56, Chapter 10, Volume 4, the IPCC 2006 Guidelines.

d. Results of emissions

Total indirect N_2O emissions from livestock Manure management in 2016 were 0.84 ktN_2O. The biggest emission is from composting for fertiliser which is 0.48kt N_2O, detailed in Table 5.82.

Table 5.82 Indirect N_2O emission from Manure management

AWMS	Emission	
	kt	*ktCO$_2$eq*
Total	**0.84**	**221.90**
Poultry manure with bedding	0.04	11.56
Aerobic treatment	0.23	60.10
For fertilisers	0.48	127.13
Anaerobic lagoon	0.09	23.11

5.2.3.7 Rice cultivations (3C7)

a. Methodology

The anaerobic decomposition of organic material in flooded rice fields produces CH_4. Soil types, temperature, also affect CH_4 emission. CH_4 emissions from Rice cultivations were estimated by using Equation 5.1, page 5.45, Chapter 5, Volume 4, the IPCC 2006 Guidelines.

b. AD

AD on the irrigated rice field area in 2016 was classified by region (North, Central and South) as follows:

- Total irrigated areas were taken from tee Statistical yearbook of MARD. The division of regions (North, Central and South) is subject to administrative division of Viet Nam. According to administrative division, the Northern region includes the Red River Delta, Northeast and Northwest; the Central region includes northern Central, southern Central and the Central Highlands; and the Southern region includes the Southeast and the Mekong River Delta.

- The area of intermittened rice fields in 2016 was calculated from the data on irrigated rice area in 2015. Data for 2015 were taken from the Agriculture-forestry-fisheries statistics in 2015 of the National Institute of Agricultural Planning and Projection, MARD.

- The area of irrigated rice for intermittent flooding in 2016 was calculated from the data on the area of irrigated rice in 2016, the data on single and multiple-inlet rice irrigation provided by the General Department of Irrigation.

Data on areas of continuous flooded rice was regularly calculated by area of irrigated rice minus intermittened flooded rice.

Due to the absence of information on upland rice area in 2016, data on upland rice area was taken from 2014. The data on the upland rice area was provided by the Soils and Fertilisers Research Institute, MARD.

The area of rain-fed rice in 2016 was the substract of total area of flooded rice minus irrigated rice and upland rice, as detailed in Table 5.83.

Table 5.83 Area of cultivation, irrigated, rain fed and upland rice

2016	North	Central	South	Total
	ha			
Total area of Rice cultivations	**1,777,000**	**1,448,600**	**4,511,500**	**7,737,100**
1. Irrigated area	1,660,273	1,293,313	4,442,889	7,396,474
1.1. Active irrigated area	1,437,861	1,149,611	2,469,569	5,057,041
Partial alternate wetting and drying area	164,812	29,488	50,964	245,264
Full alternate wetting and drying area	38,692	4,818	8,616	52,126
Continuous flooded	1,234,357	1,115,305	2,409,989	4,759,651
1.2. Passive irrigated area	222,412	143,701	1,973,320	2,339,433
2. Upland area	98,988	21,777	0	120,765
3. Rain-fed area	17,739	133,510	68,611	219,860

c. EFs

EF for different types of organic fertiliser supplementation (Sfo) was 1.0, assuming that additional fertilisation was less applicable in Viet Nam. EF for soil types (SFs,r) were not applicable since no data was available. The scale factor for calculating the difference in pre-cultivation water management regime (SFp) using the default value of 1.00 from the IPCC 2006 Guidelines. Efs and others parameters were taken according to the default values of the IPCC 2006 Guidelines, detailed in Table 5.84, Table 5.85 and Table 5.86.

Table 5.84 EFs for Continuously flooded rice

Water management regime continuously flooded irrigated	EF for Continuously flooded rice	Data source
	$kgCH_4/ha/crop$	
North	375.0	Project report for development country specific emission factor by GEF/UNEP, MONRE, 2007
Central	335.9	
South	217.2	

Table 5.85 Default SFw according to IPCC 2006 Guidelines for rice irrigation types

Water regime SFw		General		Not general	
		SFw	Value range	SFw	Value range
Upland area		0		0	
Irrigated	Continuous flooded	0.78	0.62-0.98	1	0.79-1.26
	Intermittently flooded single aeration			0.60	0.46-0.80
	Intermittently flooded multiple aeration			0.52	0.41-0.66
Rain-fed	Rain-fed	0.27	0.21-0.34	0.28	0.21-0.37
	Easily drought			0.25	0.18-0.36
	Deep immersion			0.31	

Table 5.86 Default SFw factor before applying water regimes

Pre-water regimes	General		Particular	
	SFw	Value range	SFw	Value range
Not flooded before planting <180 days	1.22	1.07-1.40	1	0.88-1.14
Not flood before planting> 180 days			0.68	0.58-0.80
Flooded before planting> 30 days			1.90	1.65-2.18

d. Results of emissions

CH_4 emissions from Rice cultivations for 2016 are reported in Table 5.87.

Table 5.87 CH_4 emissions from Rice cultivations for 2016

IPCC Code	Type	Emission	
		kt	*$ktCO_2eq$*
3C7	Rice cultivations	1,774.75	49,693.02
	Continuous flooded	1,360.96	38,107.00
	Intermittently flooded single aeration	385.83	10,803.37
	Intermittently flooded multiple aeration	9.36	262.07
	Rain-fed	18.59	520.58

5.2.3.8 Harvested wood products (3D1)

Harvested wood products (HWP) include all wood material (including bark), branches and leaves that are considered organic matter in the land use category (DOM). HWP forms a carbon sink. The amount of time the carbon stored in a product will vary depending on the product and how it is used. According to the IPCC 2006 Guidelines, provided national guidance for reporting contributions from HWP is zero and not necessarily a detailed estimation. Calculation of emissions from HWP requires very detailed data and is closely related to historical data. Viet Nam does not have sufficient data to serve as a basis for calculation in this subsector. Therefore, the harvested wood production is assumed to be evenly oxidized during the inventory year and this is calculated in the Forest land subsector (3B).

5.3 Conclusions and Recommendations

5.3.1 Improvements compared to the previous inventories

Livestock (3A)

- The average livestock weights were listed on the basis of expert judgements in accordance with the Vietnamese conditions for the CH_4 emission calculation of the Manure management subsector (3A1).

- Updated and used EFs for each livestock manure management system (subsector 3A1) such as bio-padding, aerobic treatment, composting as fertiliser, anaerobic compost and grazing grounds were applied for calculating N_2O emissions.

Land (3B)

- Used AD from remote sensing maps provided by the National Remote Sensing Department for calculating emissions/removals from soil and land use conversion;

- The amount of biomass of the land before conversion of the land types converted to forest land was bspecified;

- Parameters related to living biomass and biomass growth, biomass loss factor due to logging of forest types for 2016 based on the experience of forestry experts were updated;

- The data during the 2006-2016 period of land were taken from matrix of Forest land converted to other types of land as well as excluded converted areas from Plantation forest to avoid duplication.

- Remote sensing map counted the area of organic soils, contributing to the calculation of emissions in this field.

Other sources of emissions and non-CO_2 emissions (3C)

Emission from Burning biomass in cropland (3C1b):

Updated and used value of field burn rate for rice was 0.29 according to the Report on the assessment of the current situation and proposal of solutions on manure management in cultivation under the Summary of Environmental Projects under the Institute of Agricultural Environment to calculate emissions for the Burning of agricultural residues in the fields.

Direct emissions of N_2O from soil (3C4):

The amount of N into the soil was separated by annual crop-related activities and rice-related activities. At the same time, the use of separate EFs for the two activities mentioned above was updated according to the IPCC 2006 Guidelines. In addition, total N consumption consumed from fertiliser was calculated based on national data.

5.3.2 Difficulties, shortcomings and recommendations

5.3.2.1 Difficulties, shortcomings

Livestock (3A)

For Livestock (3A), the EFs in general and cattle in particular were still based on the default value given by the IPCC for Asia, without the separate country specific values according to the characteristics of domestic cattle, thus affecting the reliability of the calculation results. On the other hand, the use of IPCC default values will make it difficult to meet MRV requirements when implementing mitigation activities. IPCC always encourages countries to develop country specific EFs, especially for countries with transition economies and livestock sectors that are considered as the main source of emissions like Viet Nam. Furthermore, the implementation of the voluntary mitigation programme for livestock production requiring international funding also has to develop a separate GHG inventory system on the basis of country specific EFs and national conditions.

Soil (3B)

Emissions related to carbon storage in soils and inorganic carbon in soil have not been considered according to the IPCC guidelines as default time to calculate emissions from soil is 20 years. The land use matrix map was prepared only for a 10-year cycle, so it was not reasonable to calculate carbon emissions in the soil.

Emissions from Carbon stock change in DOM used Tier 1 assuming no change over time. Data has not been sufficient enough to evaluate the amount of biomass after conversion as well as time and retention of litter and dead wood.

Other sources of emissions and non-CO2 emissions (3C)

Emissions from Rice cultivations (3C7) hav not taken into account rice cultivation areas by each annual water management regime (Continuously flooded, Intermittently flooded single aeration, Intermittently flooded multiple aeration). This is important as emissions from Rice cultivations occupy a large proportion in the AFOLU sector so the statistics of areas of these types in fact will ensure transparency and accuracy of the inventory results.

5.3.2.2 Recommendations

Livestock (3A)

Emissions from Food Digestion (3A1)

Since the data on the characteristics of cattle head has not yet been collected, it is necessary to continue to survey, study, evaluate and collect in a systematic manner and research complete EFs aiming at improving the quality of inventories in the coming time. When using Tier 2 of GHG inventories in the livestock sector, it should include both the development of national EFs and the collection of detailed AD.

For the EF of animal feed digestibility, it is required to calculate the energy for the maintenance, growth, lactation, forage, reproduction, etc.. Unit of calculation is MJ/cattle/day).

Meanwhile, the EF of livestock manure management is variable of GE and MS% (percentage of livestock waste by collection and treatment types). For domestic animals, buffaloes and cows are divided into herds: dairy cow, non-dairy cow, calves, buffalo and mature buffalo. For each herd, data on the weight (kg), feeding method, fertility rate, milk volume, milk fat ratio, number of hours of labour, digestibility ... of the cattle should be collected and analysed.

Soil (3B)

It is necessary to develop a continuous remote sensing data set to monitor carbon storage in mineral soils, for inventory and to ensure series data for calculation of emissions/removals from Soil (category 3B).

Other sources of emissions and non-CO_2 emissions (3C)

Liming emissions into soil ($3C_2$)

It is required to collect actual lime used in agriculture that emits GHG.

Emission from urea application to soil (3C3)

It is necessary to collect statistics on the actual amount of urea used in agriculture.

Direct and indirect emissions of N_2O from soil (3C4, 3C5)

It is necessary to collect statistics on the annual rate of livestock manure management systems from the Department of Livestock Production as the rate will change each year according to the trend of less emissions and more environmental protection thanks to advanced livestock manure management and treatment

CHAPTER 6

WASTE

6.1 Introduction

The GHG emissions for waste sector in the year of 2016 were calculated under the IPCC 2006 Guidelines. The waste sector covers CO_2, CH_4 and N_2O emissions from different sources, including:

- Solid waste disposal (4A);
- Biological treatment of solid waste (4B);
- Incineration and open burning of waste (4C); and
- Wastewater treatment and discharge (4D).

Total GHG emissions in the waste sector in 2016 were 20,738.38 $ktCO_2eq$. In which, the largest emissions came from Solid waste disposal, 10,438.86 $ktCO_2eq$, accounting for 50.3%. The GHG emissions in the waste sector in 2016 are reported in Table 6.1.

Table 6.1 GHG emissions of waste for 2016

IPCC Code	Category	CO_2	CH_4	N_2O	Total	Proportion
		$ktCO_2eq$				*%*
4	**Waste**	**802.00**	**17,948.30**	**1,988.07**	**20,738.38**	**100**
4A	Solid waste disposal		10,438.86		10,438.86	50.3
4A1	Managed waste disposal sites		10,438.86		10,438.86	50.3
4A2	Unmanaged waste disposal sites		IE		IE	0.0
4A3	Uncategorised waste disposal sites		IE		IE	0.0
4B	Biological treatment of solid waste		69.45	39.44	108.89	0.5
4C	Incineration and open burning of waste	802.00	377.28	62.08	1,241.36	6.0
4C1	Waste incineration	528.09	0.13	11.38	539.60	2.6
4C2	Open burning of waste	273.91	377.15	50.70	701.76	3.4
4D	Wastewater treatment and discharge		7,062.71	1,886.55	8,949.26	43.2
4D1	Domestic wastewater treatment And discharge		4,805.66	1,886.55	6,692.21	32.3
4D2	Industrial wastewater treatment And discharge		2,257.05		2,257.05	10.9

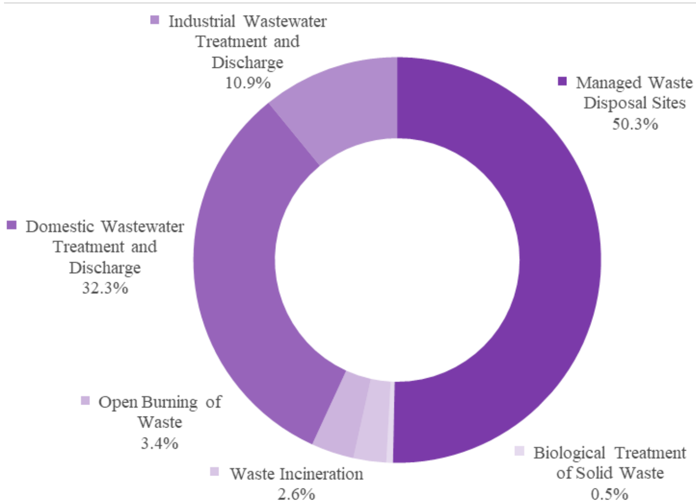

Figure 6.1 Propotion of GHG emissions of waste for 2016.

6.2 Description of emission sources

6.2.1 Solid waste disposal sites (4A)

CH_4 is released during the anaerobic decomposition of organic waste landfilled in Solid waste disposal sites (SWDS). Organic solid waste disposal (SWD) decomposes at a decreasing rate and it takes many years to fully decompose.

Since SWD in the Viet Nam SWDS has not been classified by level of management, partial management or unmanaged, SWD emissions were assumed to be calculated for Managed waste disposal sites (4A1). The emissions for Unmanaged waste disposal sites (4A2) and Uncategorised waste disposal sites (4A3) sub-sectors were included in the 4A1 sub-sector.

6.2.1.1 Managed waste disposal sites (4A1)

a. Methodology

The use of the mass balance method (Tier 1 approach) is discouraged according to the IPCC 2006 Guidelines, as the GHG inventory results do not show the decomposition of waste that produces CH_4 gas over the years. Therefore, the FOD (Tier 2 approach method) based on solid waste decomposition is used for the calculating of SWD emissions. The following formulas used to calculate:

- Equation 3.1, page 3.8, Chapter 3, Volume 5, the IPCC 2006 Guidelines;
- Equation 3.6, page 3.10, Chapter 3, Volume 5, the IPCC 2006 Guidelines;
- Equation 3.5, page 3.9, Chapter 3, Volume 5, the IPCC 2006 Guidelines;
- Equation 3.4, page 3.9, Chapter 3, Volume 5, the IPCC 2006 Guidelines; and
- Equation 3.2, page 3.9, Chapter 3, Volume 5, the IPCC 2006 Guidelines.

b. AD

The AD for calculating SWD emissions included total amount of solid waste collected to the sites from 1990-2014 and the composition of the waste.

i. Data of total SWD collected and brought to SWDS.

To apply the FOD method, waste data from previous years were needed to collect. However, since the pre-1995 population figures were unavailable, the figures for the period 1990-1994 were estimated using the 1995 population.

According to the IPCC 2006 Guidelines, Open burning of waste emissions were taken into account, so the amount of the waste not being collected was assumed to be exposed (piled up as waste sites over time) and exposed to Open burning of waste. The rate was assumed to be 70% waste incineration and 30% open burning of waste based on the expert judgment.

• Municipal solid waste

Period of 1995-2013

Urban population data was obtained in the Statistical yearbook 1995-2013 by the GSO, detailed in Table 6.3.

For urban areas from 1995-2013, the amount of urban solid waste disposed at sites was calculated from the average rate of solid wastes per person/day and the rate of urban solid waste disposal at sites. These factors and ratios were applied according to the data in the Viet Nam Environmental change report 2004 - Solid waste, VEA, MONRE, 2007 and the National Strategy on integrated solid waste management to 2025 with a vision to 2050 of MOC, 2008.

Data on the total volume of SWD treated in the period of 1995-2003 was collected from the Viet Nam Environment report 2004 - Solid Waste, VEA, MONRE, 2004, detailed in Table 6.3.

The proportion of municipal solid wastes buried in sites for the period of 2004-2013 was interpolated based on the average rates of 2014 and 2003 to calculate the value for the years without data. The detailed data and parameters are shown in Table 6.2.

Table 6.2 Solid waste disposal generated in urban areas estimated for 1995-2013

Year	Urban population	Ratios of solid waste generation per capita	Proportion of municipal solid wastes buried in sites	Total of managed semi-aerobic solid waste	Total of unmanaged shallow solid waste
	thousand people	*kg/person/ day*	*%*	*thousand tonnes*	
1995	14,938	0.70	55.00	2,099	1,718
1996	15,420	0.70	57.00	2,246	1,694
1997	16,835	0.70	59.00	2,538	1,764
1998	17,465	0.70	61.00	2,722	1,740
1999	18,082	0.70	63.00	2,911	1,709
2000	18,725	0.70	65.00	3,110	1,675
2001	19,299	0.70	67.00	3,304	1,627
2002	19,873	0.70	69.00	3,504	1,574
2003	20,725	0.70	71.00	3,760	1,536
2004	21,601	0.70	73.03	4,031	1,489
2005	22,332	0.70	75.06	4,283	1,423
2006	23,046	0.78	77.09	5,058	1,503
2007	23,746	0.78	79.12	5,349	1,412
2008	24,673	0.85	81.15	6,212	1,443
2009	25,585	0.95	83.17	7,379	1,493
2010	26,516	0.95	85.20	7,834	1,360
2011	27,719	0.96	87.23	8,473	1,240
2012	28,269	0.97	89.26	8,934	1,075
2013	28,875	0.98	91.29	9,429	900

The volume of solid waste remaining untreated included the amount of solid waste either open landfilled or open-burned. Based on waste expert assumptions, 70% were open landfill and 30%, incinerated; the total amount of solid waste treated was calculated as detailed in Table 6.3.

Table 6.3 Amount of solid waste open landfilled and open-burned from 1995 to 2013

Year	Total of unmanaged shallow solid waste disposal	Total of open landfilled solid waste	Total of open-burned solid waste
	thousand tonnes		
1995	1,718	1,202	515
1996	1,694	1,186	508
1997	1,764	1,235	529
1998	1,740	1,218	522
1999	1,709	1,197	513
2000	1,675	1,172	502
2001	1,627	1,139	488
2002	1,574	1,102	472
2003	1,536	1,075	461
2004	1,489	1,042	447
2005	1,423	996	427
2006	1,503	1,052	451
2007	1,412	988	424
2008	1,443	1,010	433
2009	1,493	1,045	448
2010	1,360	952	408
2011	1,240	868	372
2012	1,075	752	322
2013	900	630	270

Period of 2014-2016

For the period of 2014 to 2016, AD of the total volume of solid waste collected and treated according to national technical standards and regulations were taken from the National environmental status report 2017 of MONRE and the Viet Nam Statistical yearbook 2016, GSO, 2017, detailed in Table 6.4.

Table 6.4 Total weight of solid waste collected and treated in accordance with national technical standards and regulations for 2014-2016

No	Region/ Province/ City	Total weight					
		Solid waste collected			Solid waste treated in accordance with national technical standards and regulations		
		tonnes/day					
		2014	2015	2016	2014	2015	2016
I	**Red River Delta**	**8,730**	**9,400**	**10,017**	**7,544**	**7,933**	**8,902**
1	Ha Noi	4,980	5,400	5,906	4,980	5,300	5,806
2	Vinh Phuc	237	296	235	237	296	180
3	Bac Ninh	300	300	335			131
4	Quang Ninh	737	737	815	578	587	663
5	Hai Duong	243	243	360	180	180	287
6	Hai Phong	1,380	1,408	1,086	998	998	1,003
7	Hung Yen	94	257	338	77	77	230
8	Thai Binh	307	307	487	110	110	171
9	Ha Nam	105	105	145	100	100	140
10	Nam Dinh	219	219	193	212	212	191
11	Ninh Binh	128	128	117	72	73	100
II	**Northern midlands and mountainous region**	**1,895**	**2,276**	**2,458**	**1,090**	**1,034**	**1,323**
12	Ha Giang	127	147	139	70	70	107
13	Cao Bang	63	63	52	32	40	46
14	Bac Kan	68	68	68	33	33	
15	Tuyen Quang	103	134	103	75	91	88
16	Lao Cai	166	182	166			120
17	Yen Bai	168	196	167	50	98	129
18	Thai Nguyen	192	237	452	156	177	210
19	Lang Son	218	200	251	109	100	
20	Bac Giang	122	231	200	101	134	135
21	Phu Tho	257	257	294	227	152	218
22	Ddien Bien	62	93	98	62	50	32
23	Lai Chau	68	68	102			102
24	Son La	159	277	277	80	80	80
25	Hoa Binh	122	123	89	95	9	56
III	**Northern Central and Central coastal**	**4,333**	**5,143**	**4,907**	**2,579**	**3,020**	**3,036**
26	Thanh Hoa	407	762	768	16	127	168
27	Nghe An	366	640	392	254	397	280

No	Region/ Province/ City	Total weight					
		Solid waste collected			Solid waste treated in accordance with national technical standards and regulations		
		tonnes/day					
		2014	2015	2016	2014	2015	2016
28	Ha Tinh	149	149	214	135	135	190
29	Quang Binh	204	204	133		92	133
30	Quang Tri	89	187	198	30	66	116
31	Thua Thien Hue	292	289	310	200	244	307
32	Da Nang	715	730	751	715	730	751
33	Quang Nam	455	455	520	157	240	55
34	Quang Ngai	171	171	225	130	130	96
35	Binh Dinh	216	216	300	204	204	210
36	Phu Yen	209	209	209	151	150	150
37	Khanh Hoa	475	475	475	285	285	320
38	Ninh Thuan	177	177	205	177	177	205
39	Binh Thuan	408	479	207	125	43	55
IV	**Central Highlands**	**1,013**	**1,062**	**1,126**	**490**	**627**	**646**
40	Kon Tum	94	145	92	75	104	54
41	Gia Lai	160	160	252	90	100	123
42	Dac Lac	327	363	347	295	193	229
43	Dac Nong	91	91	56	30	30	40
44	Lam Dong	341	303	379		200	200
V	**Southeast**	**12,283**	**10,878**	**10,995**	**10,653**	**10,192**	**10,932**
45	Binh Phuoc	206	206	175	70	70	112
46	Tay Ninh	110	131	98	5	15	98
47	Binh Duong	1,198	1,074	1,221	1,198	1,074	1,221
48	Dong Nai	2,469	1,365	1,442	1,105	1,019	1,442
49	Ba Ria Vung Tau	1,300	602	409	1,275	514	409
50	Ho Chi Minh City	7,000	7,500	7,650	7,000	7,500	7,650
VI	**Mekong River Delta**	**3,345**	**3,656**	**3,665**	**1,577**	**1,522**	**2,165**
51	Long An	192	192	300	82	82	300
52	Tien Giang	257	332	291	70	70	
53	Ben Tre	134	147	163	99	110	145
54	Tra Vinh	297	297	111	33	30	36
55	Vinh Long	142	142	118	90	90	100
56	Dong Thap	368	368	414	149	165	271
57	An Giang	275	349	542	115	99	21

No	Region/ Province/ City	Total weight					
		Solid waste collected			Solid waste treated in accordance with national technical standards and regulations		
		tonnes/day					
		2014	2015	2016	2014	2015	2016
58	Kien Giang	357	396	433	309	250	345
59	Can Tho	650	650	518	69	281	480
60	Hau Giang	162	212	212	128	111	152
61	Soc Trang	236	236	288	212		74
62	Bac Lieu	128	188	134	100	128	100
63	Ca Mau	147	147	141	121	106	141
Total *(tonnes/day)*		**31,599**	**32,415**	**33,168**	**23,933**	**24,328**	**27,004**
Total *(thousand tonnes/year)*		**11,534**	**11,831**	**12,106**	**8,736**	**8,880**	**9,856**

Total weight of solid waste collected nationwide in 2016 reached 33,168 tonnes/day, of which total amount of common solid waste collected and treated according to the national technical standards and regulations reached 27,004 tonnes/day, accounting for 81% of the total corresponding to 9,856 thousand tonnes/year.

The volume of solid waste treated according to the corresponding national technical regulations and standards is defined as the volume of daily-life solid waste treated in accordance with the standards and regulations. The standards and regulations are prescribed in the Circular No.06/2018/TT-BXD dated August 8, 2018 on the issuance of a system of statistical indicators for the construction sector.

Treated solid waste (with the method of landfilling in sites, biological treating or incinerating) was 9,856 thousand tonnes/year. GHG emissions raising from the solid waste are shown in sub-sectors 4B and 4C. The amount of solid waste yearly landfilled in sites in the period 2014-2016 was calculated by subtracting the volume of the solid waste biologically treated and incinerated, as detailed in Table 6.4.

The amount of solid waste collected but not treated according to the standards and regulations was 2,249 thousand tonnes/year. This amount of waste was assumed treated by open burning, piling at sites, or open incinerating. Open solid waste incineration was spontaneous and unmanaged. In fact, majority of solid waste was still piled up on sites. According to waste experts, the percentage of solid waste on open sites was 70% and the remaining 30% was treated by open burning. The detailed data of urban solid waste from 2014 to 2016 is shown in Table 6.5.

Table 6.5 Total weight of municipal domestic solid waste from 2014 to 2016

Year	Total of managed semi-aerobic solid waste	Total of open landfill solid waste	Total of open burning solid waste
	thousand tonnes		
2014	8.152	1.959	839
2015	8.296	2.066	886
2016	8.625	1.575	675

• *Rural solid waste*

So far, there is no AD reported on the rural solid waste. Therefore, the figures of solid waste generation in rural areas from 1995 to 2016 are estimated based on the rural population according to the Viet Nam Statistical Yearbook, GSO and the factor of solid waste generation per capita in rural areas.

According to the National environment report 2011-Solid waste, VEA, MONRE, the solid waste generation factor was 0.3 kg/person/day for the period of 1995-2010, about 0.34 kg/person/day for the years from 2011 to 2012, 0.35 kg/person/day for 2013, and 0.40 kg/person day for the years from 2014 to 2016. The solid waste collection factors in rural areas were estimated by interpolation method. The factors were assumed to be 20% in 1990, 40% in 2000 and 47.5% between 2010 and 2016. The estimates for rural solid waste are shown in Table 6.6.

Table 6.6 Estimates of treated solid waste in rural areas from 1995 to 2016

Year	Rural population	Waste generation factor	Proportion of solid waste lanfilled and treated at sites	Total of sanitary landfill solid waste	Remaining solid waste
	thousand people	*kg/person/day*	*%*	*thousand tonnes*	
1995	57,057.4	0.30	30	1,874	4,373
1996	57,736.8	0.30	32	2,023	4,299
1997	57,471.5	0.30	34	2,140	4,153
1998	57,991.7	0.30	36	2,286	4,064
1999	58,515.1	0.30	38	2,435	3,973
2000	58,905.5	0.30	40	2,580	3,870
2001	59,321.4	0.30	40	2,598	3,897
2002	59,664.5	0.30	40	2,613	3,920
2003	59,742.4	0.30	40	2,617	3,925
2004	59,835.2	0.30	40	2,621	3,931
2005	60,060.1	0.30	40	2,631	3,946

Year	Rural population	Waste generation factor	Proportion of solid waste lanfilled and treated at sites	Total of sanitary landfill solid waste	Remaining solid waste
	thousand people	*kg/person/day*	*%*	*thousand tonnes*	
2006	60,265.4	0.30	47	2,640	3,959
2007	60,472.2	0.30	47	2,649	3,973
2008	60,445.6	0.30	47	2,648	3,971
2009	60,440.3	0.30	47	2,647	3,971
2010	60,416.6	0.30	47.5	3,109	3,506
2011	60,120.7	0.34	47.5	3,545	3,918
2012	60,416.5	0.34	47.5	3,569	3,944
2013	60,884.6	0.35	47.5	3,695	4,083
2014	60,693.5	0.40	47.5	4,209	4,652
2015	60,642.3	0.40	47.5	4,206	4,648
2016	60,765.9	0.40	47.5	4,214	4,658

The volume of landfill solid waste including sanitary and open landfill of the years from 1995 to 2013 and from 2014 to 2016 is summarised in Table 6.7.

Table 6.7 Total weight of landfill solid waste nationwide from 1995 to 2016

Year	Volume of sanitary landfill solid waste	Volume of open lanfill solid waste	Total volume of landfill solid waste
	thousand tonnes/year		
1995	3,973.5	4,263.7	8,237.2
1996	4,268.8	4,195.2	8,464.0
1997	4,677.5	4,141.9	8,819.5
1998	5,008.0	4,063.0	9,071.0
1999	5,345.3	3,977.4	9,322.7
2000	5,689.9	3,881.2	9,571.1
2001	5,902.0	3,867.2	9,769.2
2002	6,116.9	3,845.8	9,962.7
2003	6,376.3	3,822.5	10,198.8
2004	6,651.3	3,793.8	10,445.1
2005	6,913.3	3,758.4	10,671.7
2006	7,697.4	3,824.0	11,521.4
2007	7,997.4	3,769.4	11,766.8
2008	8,859.0	3,790.2	12,649.2
2009	10,026.1	3,824.6	13,850.6
2010	10,943.2	3,406.7	14,350.0
2011	12,017.9	3,610.9	15,628.8

Year	Volume of sanitary landfill solid waste	Volume of open lanfill solid waste	Total volume of landfill solid waste
	thousand tonnes/year		
2012	12,502.6	3,513.4	16,016.0
2013	13,123.5	3,488.1	16,611.6
2014	12,361.2	5,215.2	17,576.4
2015	12,501.4	5,320.0	17,821.4
2016	12,885.5	4,835.3	17,701.8

ii. The composition of landfill waste

Based on data from the Environmental status reports from provinces and centrally-run cities of Viet Nam in the period of 2005-2010, the waste composition for the period of 2005-2010 was used to extrapolate for that of the remaining years from 1990 to 2013 due to the lack of data.

Based on the aggregated data from the Environmental status reports for the period of 2011-2015, the waste composition for the period of 2011-2015 was also used to extrapolate for the period of 2014-2016 as shown in Table 6.8.

Table 6.8 Average waste composition for periods of 1990-2013 and 2014-2016

No.	Waste composition	1990-2013	2014-2016
		%	
1	Food, organic waste	59.2	59.1
2	Plant waste	2.9	2.9
3	Paper waste	3.2	3.2
4	Wood waste	1.3	1.3
5	Textile waste	3.5	3.4
6	Diaper waste	0.01	0.01
7	Plastic and others waste	29.9	30.0

c. EFs

The following EFs were used to calculate CH_4 emissions from solid waste disposal:

i. Methane correction factor (MCF): default value in Table 3.1, page 3.14, Section 3.2.3, Chapter 3, Volume 5, the IPCC 2006 Guidelines

- Unmanaged solid waste disposal sites - deep and/or with high water table (depths of greater than or equal to 5 metres): MCF= 0.8

- Unmanaged shallow solid waste disposal sites (depths of less than 5 metres): MCF= 0.4.
- Anaerobic managed solid waste disposal sites: MCF= 1.
- Semi-aerobic managed solid waste disposal sites: MCF= 0.5.
- Uncategorised solid waste disposal sites: MCF= 0.6.

In the case of Viet Nam, due to the lack of AD, the calculation of GHG emissions for the period from 2013 and earlier was assumed that the Unmanaged shallow solid waste disposal sites accounted for about 50%, Unmanaged solid waste disposal sites - deep and/or with high water table accounted for about 40%, Semi-aerobic managed solid waste disposal sites accounted for 5% and Anaerobic managed solid waste disposal sites 5% based on expert method; therefore, the average MCF value for these landfill types was 0.60.

In the period of 2014-2016, based on AD, the ratio of sanitary landfill solid waste and open landfill solid waste is shown in Table 6.7. In Viet Nam, sanitary landfill solid waste is in mainly managed semi-aerobic disposal sites or managed partial-aerobic disposal sites, and open landfill solid waste is in unmanaged shallow solid waste disposal sites. The results are shown in Table 6.9 and Table 6.10.

Table 6.9 Ratio of sanitary landfill and open landfill solid waste

Year	Total volume of landfill solid waste		The ratio of landfill solid waste	
	Sanitary landfill	Open landfill	Sanitary landfill	Open landfill
	thousand tonnes/year		*%*	
2010	10,943.2	3,406.74	76	24
2011	12,017.9	3,610.94	77	23
2012	12,502.6	3,513.42	78	22
2013	13,123.5	3,488.15	79	21
2014	12,361.2	5,215.17	70	30
2015	12,501.4	5,319.99	70	30
2016	12,600.7	4,835.30	72	28

Table 6.10 Proportion of waste sites by type from 2014 to 2016

Year	Unmanaged shallow solid waste disposal sites	Unmanaged solid waste disposal sites - deep	Managed anaerobic solid waste disposal sites	Managed semi-aerobic solid waste disposal sites	Other type of waste sites	Average MCF
	%					
	MCF= 0.4	**MCF= 0.8**	**MCF= 1**	**MCF= 0.5**	**MCF= 0.6**	
2010	24	0	0	76	0	0.48
2011	23	0	0	77	0	0.48
2012	22	0	0	78	0	0.48
2013	21	0	0	79	0	0.48
2014	30	0	0	70	0	0.47
2015	30	0	0	70	0	0.47
2016	28	0	0	70	0	0.46

ii. Degradable organic carbon which decomposes (DOCf)

The DOC_f in waste is calculated based on Formula 3.7, page 3.13, Chapter 3, Volume 5, the IPCC 2006 Guidelines.

Fraction of DOC_f for each type of waste refers to the default values given in Table 2.4, page 2.14, Chapter 2, Volume 5, the IPCC 2006 Guidelines, detailed in Table 6.11.

Table 6.11 Fraction of DOCI by type of waste

No	Type of waste	DOCi	
		IPCC default range	Used values
		%	
1	Food, organic waste	8-20	15
2	Plant waste	18-22	17
3	Paper waste	36-45	40
4	Wood waste	39-46	30
5	Textile waste	20-40	40
6	Diaper waste	18-32	17

iii. Fraction of CH_4 in generated landfill gas (F)

Most landfill waste produces landfill gas with about 50% CH_4 according to the IPCC 2006 Guidelines. Only materials including a high amount of fat or oil can produce greater amounts of CH_4. The default fraction of CH_4 in generated landfill gas used in Viet Nam was 50%.

iv. Oxidation factor (OX)

The oxidation factor (OX) reflects the amount of CH_4 from SWDS that is oxidised in the soil or other material covering the waste, has a default value of 0 for managed landfill and unmanaged landfill types according to Table 3.2, page 3.15, Chapter 3, Volume 5, the IPCC 2006 Guidelines.

v. Half-life (t1/2)

The half-life value, t1/2 is the time taken for the DOCm in waste to decay to half its initial mass calculated using the reaction constant k. Reaction constant k is selected based on the default values for humid tropical climate according to Table 3.3, page 3.17, Chapter 3, Volume 5, the IPCC 2006 Guidelines, detailed in Table 6.12.

Table 6.12 Reaction constant (k) CH_4

No	Type of waste	k	t1/2
1	Food, organic waste	0.2	3.5
2	Plant waste	0.03	23.1
3	Paper waste	0.03	23.1
4	Wood waste	0.03	23.1
5	Textile waste	0.05	13.9
6	Diaper waste	0.05	13.9

d. CH_4 emissions

Applying the calculation method of the IPCC 2006 Guidelines with the total volume of SWDS in 2016 was 17,436.0 thousand tonnes, CH_4 emissions from the SWDS were 372.82 thousand tonnes.

6.1.2.1 Unmanaged waste disposal sites (4A2)

Since AD was insufficient in order to separate the amount of managed solid waste, untreated solid waste and unclassified solid waste in Viet Nam, emissions for sub-sector 4A2 were included in sub-sector 4A1.

6.1.2.2 Uncategorised waste disposal sites (4A3)

Since AD was insufficient in order to separate the amount of managed solid waste, untreated solid waste and unclassified solid waste in Viet Nam, emissions for category 4A3 were included in category 4A1.

6.2.2 Biological treatment of solid waste (4B)

a. Methodology

Composting and anaerobic digestion of organic waste, such as food waste, garden (yard) and park waste and sludge, is common both in developed and developing countries. Advantages of the biological treatment include: reduced volume in the waste material, stabilisation of the waste, destruction of pathogens in the waste material, and production of biogas for energy use. The end products of the biological treatment can, depending on its quality, be recycled as fertiliser and soil amendment, or be disposed in SWDS. CH_4 and N_2O emissions from biological treatment are calculated using Equations 4.1 and 4.2, page 4.5, Chapter 4, Volume 5, the IPCC 2006 Guidelines.

b. AD

According to the National environmental status report in 2017, five solid waste treatment technologies had been recognised by MOC, including: two bio-composting technologies for organic fertiliser (Seraphin and Anh Sinh - ASC); one MBT-CD.08 technology (RDF fuel pelletizer) and two combustion technologies (ENVIC and BD-ANPHA technology). Viet Nam had about 35 solid waste treatment facilities/plants using bio-composting technology to make organic fertilisers. AD serving the calculation of emissions from biological treatment was based on data on the treatment capacity of factories/provinces in the National environmental status report 2017 of VEA, MONRE. Since no data on the total amount of solid waste treated by biotechnology was available, the assumption was based on the capacity of the biotech solid waste treatment plants in localities with total volume of solid waste treated equal to 70% of the maximum design capacity of factories/localities as detailed in Table 6.13.

Table 6.13 Solid waste biological treatment capacity of factories/localities

No	Factories / localities	Capacity	Total weight of treated solid waste
		tonnes/day	*thousand tonnes/year*
1	Phan Thiet city	500	127.75
2	Long An city	400	102.20
3	Hue City	200	51.10
4	Rach Gia - Kien Giang province	200	51.10
5	Phu Quoc district, Kien Giang Province	200	51.10
6	Ha Nam province	100	25.55

No	Factories / localities	Capacity	Total weight of treated solid waste
		tonnes/day	*thousand tonnes/year*
7	Cau Dien district, Ha Noi	NA	35.00
8	Nam Dinh province	250	63.88
9	Hoc Mon district, Ho Chi Minh City	240	61.32
10	Hai Phong city	200	51.10
Total			**620.10**

c. EFs

Since no national-specific EF was available, the default EF was selected based on Table 4.1, page 4.6, Chapter 4, Volume 5, the IPCC 2006 Guidelines, including:

- EF(CH_4) = 4 gCH_4/kg of treated waste; and

- EF(N_2O) = 0.24 gN_2O/kg of treated waste.

d. Emissions

Based on the methodology, equation and selected EF, GHG emissions from solid waste treatment by biological methods were calculated as presented in Table 6.14.

Table 6.14 GHG emissions from solid waste treatment by biological methods

No	Type of gas	Total GHG emissions	Total GHG emissions
		kt	*ktCO_2eq*
Total (4B)			**108.89**
1	CO_2		
2	CH_4	2.48	69.45
3	N_2O	0.15	39.44

6.2.3 Incineration and Open burning of waste (4C)

The incineration and open burning of solid waste generates three types of gases: CO_2, CH_4 and N_2O. Total GHG emissions in the sub-sector of waste incineration and open burning were 1,241.00 ktCO_2e, of which emissions from waste incineration were 539,598 ktCO_2e and emissions from waste open burning, 701.76 thousand tonnes of CO_2 equivalent.

In Viet Nam, the types of solid waste burned include common solid waste and hazardous solid waste.

6.2.3.1 Waste incineration (4C1)

The incineration of solid waste is defined as the burning of solid and liquid waste in controlled incineration facilities. Modern incinerator with high stacks and specially designed combustion chamber provides high combustion temperature, long storage time and efficient mixing of waste, providing more air for combustion completely burned.

a. Methodology

Based on the decision tree and current status of waste management in Viet Nam, the Tier 1 approach method was chosen to estimate the emissions for the 4C1 sub-sector and use the following formulas:

- CO_2 emissions: Equation 5.1, page 5.7, Chapter 5, Volume 5, the IPCC 2006 Guidelines;

- CH_4 emissions: Equation 5.4, page 5.12, Chapter 5, Volume 5, the IPCC 2006 Guidelines; and

- N_2O emissions: Equation 5.5, page 5.14, Chapter 5, Volume 5, the IPCC 2006 Guidelines.

b. AD

Waste incineration AD mainly includes: a portion of domestic waste and hazardous waste, in which, domestic waste includes both municipal and medical waste.

Domestic solid waste incineration data.

As the data on waste incineration was not collected for 2016, the data of 2014 was used for estimation as detailed in Table 6.15.

Table 6.15 Weight of domestic solid waste treated by incineration

Province/City	Weight of solid waste treated by incineration	Weight of solid waste treated by incineration	Source
	tonne/year	*thousand tonnes/year*	
Total	**506,985**	**506,985**	Report on environmental status of provinces and cities in the period of 2011-2015
Ha Noi city	310,250	310.25	
Binh Phuoc province	36,500	36.50	
Phu Tho province	14,600	14.60	
Nam Dinh province	6,935	6,935	
Thai Binh province	10,950	10.95	
Hai Duong province	14,600	14.60	
Ha Tinh province	18,250	18.25	
Kien Giang province	21,900	21.90	
Ha Nam province	100	100	
Can Tho province	100	100	

Domestic solid waste incineration data generated from medical activities

Medical waste includes solid waste generated from domestic activities and hazardous solid waste generated from medical treatment processes, calculated based on the number of hospital beds of the provinces/ cities by Statistical yearbook 2016, GSO. According to the National environment report 2011 - Solid waste of the MONRE, the rate of hazardous medical solid waste generation was 20%, the remaining 80% was generated from daily life as detailed in Table 6.16.

Table 6.16 Data on medical solid waste in 2016

Content	Unit	2016
Number of hospital beds	1000 beds	315.0
Rate of solid waste generation	kg/bed/day	0.9
Total generated solid waste	thousand tonnes/year	98.9
Rate of hazardous solid waste generation	kg/bed/day	0.1
Total amount of hazardous solid waste generated	thousand tonnes/year	21.9
Total amount of generated daily life solid waste	thousand tonnes/year	77.0

As a result, the total amount of incinerated domestic solid waste included both municipal solid waste and domestic solid waste generated in hospitals, detailed in Table 6.17.

Table 6.17 Total domestic solid waste incinerated in 2016

Total municipal domestic solid waste incinerated	Total domestic hospital solid waste incinerated	Total solid waste incinerated
thousand tonnes/year		
506,985.00	77.00	584.00

Data on hazardous solid waste incineration

Hazardous solid waste incinerated includes: industrial, domestic, medical and agricultural solid waste. According to the National environmental status report 2017, MONRE, due to the fact that the AD on provinces and cities could not be collected, the calculated data for industrial hazardous solid waste was based on the amount generated in Ha Tinh, Ba Ria-Vung Tau provinces and Ho Chi Minh City with treated hazardous waste accounting for 75% as shown in Table 6.18.

Table 6.18 Weight of hazardous industrial solid waste generated in 2016 in some provinces/cities

No	Province/City	Volume of hazardous industrial solid waste generated	Volume of hazardous industrial solid waste treated
		thousand tonnes	
Total		**207.21**	**155.41**
1	Ha Tinh	1.5	1.13
2	Ho Chi Minh City	131.25	98.44
3	Ba Ria-Vung Tau	74.46	55.85

In Table 6.16, total amount medical hazardous waste generated was 21.9 thousand tonnes. Based on the synthesised data from 54 units under the Ministry of Health (42 hospitals, 12 institutes) and the Departments of Health in 51 of 63 provinces/cities in 2016, volume of medical hazardous wastes treated was 20.801 thousand tonnes (the National environmental status report, MONRE, 2017).

Domestic hazardous solid waste is mainly electronic waste and civil electricity discharged from urban areas such as televisions, refrigerators, electric fans, computers... No statistics were available on the amount of hazardous domestic waste collected and treated. Most of hazardous domestic waste is disposed of with the normal domestic solid waste and is brought to landfill.

Agricultural activities generate yearly about 9,000 tonnes of agricultural hazardous waste, such as packaging and fertiliser and pesticide containers including toxic drugs banned from use according to the National environmental status report, MONRE, 2017. Since no data was available on the rate of treated agricultural hazardous wastes, it was assumed that 75% of industrial hazardous waste were treated as detailed in Table 6.19.

Table 6.19 Weight of hazardous waste treated with incineration method in 2016

No.	Type of hazardous waste	Volume of incinerated hazardous waste
		thousand tonnes
Total		**182.96**
1	Medical hazardous solid waste	20.80
2	Industrial hazardous solid waste	155.41
3	Domestic hazardous solid waste	NA
4	Agricultural hazardous solid waste	6.75

Thus, total amount of incinerated domestic solid waste including municipal and hospital solid waste was 584.00 thousand tonnes and hazardous solid waste burned, 182.96 thousand tonnes.

c. EFs

i. CO_2 EF

The Dry Matter content in % of wet weight by solid waste composition, Total Carbon content in % of Dry weight (CF) and Fossil carbon fraction in % of total carbon (FCF) use the default coefficients given in Table 2.4, page 2.14, Chapter 2, Volume 5, IPCC 2006, details in Table 6.20.

Table 6.20 Dry matter content by solid waste composition

No	MSW component	Dry matter content by solid waste composition	CF	FCF	Source
		%			
I	**Domestic solid waste**				
1	Plastic	100	75	100	Table 2.4, page 2.14, Chapter 2, Volume 5, IPCC 2006 Guidelines
2	Textiles	80	50	20	
3	Wood	85	50	-	
4	Nappies	40	70	10	
5	Food and organic waste	40	38	-	
6	Plant waste	40	49	0	
7	Paper/cardboard	90	46	1	
II	**Medical solid waste**	100	75	100	Table 2.4, page 2.14, Chapter 2, Volume 5, IPCC 2006 Guidelines (values were chosen based on the feature of waste in Viet Nam)
III	**Industrial solid waste**	50	50	50	
IV	**Agricultural solid waste**	100	75	100	

Since Viet Nam has not conducted studies on the incineration and open burning efficiency of waste in incinerators, the default value for the oxidation factor (OF) of 100% is used for waste incineration according to Table 5.2, page 5.18, Chapter 5, Volume 5, the IPCC 2006 Guidelines.

ii. CH_4 Emissions

CH_4 emissions from the solid waste incineration depend heavily on incineration continuity, incineration technology and management practices. In Viet Nam, with thermal technology for waste disposal, 50 hazardous waste treatment facilities are licensed to apply this technology including the number of 69 static incinerators with a capacity of 100-2,000 kg/h (VEA-MONRE, 2017). Two-stage stationary furnace technology has the advantages of simple technology, availability, reasonable investment cost and easy to operate in accordance with Vietnamese conditions. Based on the current status of incineration technology and operations of incinerators in Viet Nam, CH_4 EF is selected as 6 kg/Gg waste incinerated on a wet weight basis according to Table 5.3, page 5.20, Chapter 5, Volume 5, the IPCC 2006 Guidelines.

iii. N_2O EFs

Since Viet Nam does not have a country specific N_2O EF for solid waste incineration, the Japanese default value of N_2O EF which is 41 gN_2O/tonne of incineration waste is applied according to Table 5.4, page 5.21, Chapter 5, Volume 5, the IPCC 2006 Guidelines.

d. Results of emissions

Based on the methodology and AD and given EFs, GHG emissions from solid waste incineration are reported in Table 6.21.

Table 6.21 GHG emissions from solid waste incineration

IPCC Code	Category	CO_2	CH_4	N_2O	Total
		kt			*$ktCO_2eq$*
4C1	Waste incineration	528,087.00	0.01	0.04	539,598.00

6.2.3.2 Open burning of waste (4C2)

Open burning of waste can be defined as the combustion of unwanted combustible materials such as paper, wood, plastics, textiles, rubber, waste oils and other debris in nature (open-air) or in open dumps, where smoke and other emissions are released directly into the air without passing through a chimney or stack. Open burning can also include incineration devices that do not control the combustion air to maintain an adequate temperature and do not provide sufficient residence time for complete combustion. The open burning of waste mainly occurs in rural areas rather than in urban areas.

a. Methodology

Based on the current status of solid waste management in Viet Nam, the Tier 1 method was chosen to calculate the emissions for the 4C2 sub-sector and following formulas were used:

- CO_2 emissions: Equation 5.1, page 5.7, Chapter 5, Volume 5, the IPCC 2006 Guidelines;
- CH_4 emissions: Equation 5.4, page 5.12, Chapter 5, Volume 5, the IPCC 2006 Guidelines; and
- N_2O emissions: Equation 5.5, page 5.14, Chapter 5, Volume 5, the IPCC 2006 Guidelines.

b. AD

The open burning of waste was assumed to account for 30% of the total remaining waste not collected and treated in accordance with the national standards and regulations as detailed in Table 6.22.

Table 6.22 Total domestic solid waste open-burned in urban and rural areas

Year	Total domestic solid waste open-burned in urban areas	Total domestic solid waste open-burned in rural areas	Total domestic solid waste open-burned
	thousand tonnes/year		
2014	839.43	1,395.65	2,235.07
2015	885.53	1,593.68	2,479.21
2016	674.96	1,397.31	2,072.27

The total domestic solid waste openly burned in 2016 was 2,072.27 thousand tonnes.

c. EFs

i. CO_2 EF

The Dry matter content in % of wet weight by solid waste composition, Total carbon content in MSW (CF) and fossil carbon fraction (FCF) in % of total carbon used default coefficients given in Table 2.4, page 2.14, Chapter 2, Volume 5, the IPCC 2006 Guidelines, detailed in Table 6.20.

Oxidation factor (OX): Since Viet Nam has not had studies on the efficiency of Open burning of waste, the default factor of 58% was used. The factors are provided in Table 5.2, page 5.18, Chapter 5, Volume 5, the IPCC 2006 Guidelines.

ii. CH_4 EF

Based on the current status of incineration technology and operations of the incinerators in Viet Nam, CH_4 EF of Open burning of waste was selected based on Table 5.3, page 5.20, Chapter 5, Volume 5, the IPCC 2006 Guidelines, as 6,500g/tonne waste wet weight.

iii. N_2O EF

Since Viet Nam has not had any EFs of N_2O for incineration of MSW and open-burning, the default values are used. For incineration of MSW used the default values of Japan in Table 5.4 page 5.21 is 41 gN_2O/t MSW, for open-burning used the default values in Table 5.6, page 5.22, Chapter 5, Volume 5, IPCC 2006 which is 150 gN_2O/t MSW.

d. Results of emissions

Based on the methodology and AD, the given EFs, GHG emissions from Open burning of waste are reported in Table 6.23.

Table 6.23 GHG emissions from Open burning of waste

IPCC Code	Emission source	CO_2	CH_4	N_2O	Total
		kt			*$ktCO_2eq$*
4C2	Open burning of waste	273.91	13.47	0.19	701.76

6.2.4 Wastewater treatment and discharge (4D)

Wastewater can be a source of CH_4 when treated or disposed anaerobically. It can also be a source of N_2O emissions. CO_2 emissions from wastewater are not considered in the IPCC Guidelines because these are of biogenic origin and should not be included in national total emissions. Wastewater originates from a variety of domestic, commercial and industrial sources and may be treated on site (uncollected), sewered to a centralized plant (collected) or disposed untreated nearby or via an outfall. Domestic wastewater is defined as wastewater from household water use, while industrial wastewater is from industrial practices only.

The wastewater treatment and discharge systems may differ among countries. In addition, the wastewater treatment and discharge systems may differ for areas such as urban and rural and for high- and low-income users.

The IPCC 1996 Revised includes separate equations for estimating wastewater and sludge emissions. In the IPCC 2006 Guidelines, this separation is eliminated because CH_4 emissions for sludge and wastewater with dissolved organic matter are generally the same, thus, separate equations are not required.

Total GHG emissions from wastewater treatment and discharge (4D) were 8,949.26 $ktCO_2eq$, of which, the emissions in sub-sector 4D1 were 6,692.21 $ktCO_2eq$ and the emissions in the sub-sector 4D2 sector, 2,257.05 $ktCO_2eq$.

6.2.4.1 Domestic wastewater treatment and discharge (4D1)

CH_4 and N_2O emissions can occur as direct emissions from treatment plants or from indirect gas emissions from domestic wastewater after wastewater is discharged into lakes, rivers or seas. Direct emissions from the nitrification and denitrification processes at wastewater treatment plants can be considered a small source. Typically, these emissions are of concern only to countries of advanced centralised wastewater treatment plants with nitrate reduction steps.

GHG emissions from Domestic wastewater treatment and discharge are reported in detail in Table 6.24.

Table 6.24 GHG emissions from Domestic wastewater treatment and discharge

IPCC Code	Category	CO_2	CH_4	N_2O	Total
		kt			*$ktCO_2eq$*
4D1	Domestic wastewater treatment and discharge		171.63	7.12	6,692.21

6.2.4.1.1 CH_4 emissions from Domestic wastewater

a. Methodology

Based on the decision tree in Figure 6.2, page 6.10, Chapter 6, Volume 5, IPCC 2006, the Tier 1 approach method was applied to calculate the 4D1 sub-sector and the following formulas were used:

- CH_4 emissions from domestic wastewater were calculated in accordance with Equation 6.1, page 6.11, Chapter 6, Volume 5, the IPCC 2006 Guidelines;

- CH_4 emissions factor for each wastewater discharge/treatment system were calculated according to Equation 6.2, page 6.12, Chapter 6, Volume 5, the IPCC 2006 Guidelines; and

- Total amount of dissolved organic matter in domestic wastewater was according to Equation 6.3, page 6.13, Chapter 6, Volume 5, the IPCC 2006 Guidelines.

b. AD

AD on CH_4 emissions from domestic wastewater were 1) Population; 2) Proportion of population by high income and low income; 3) Proportion of wastewater treatment system type; and 4) BOD factor calculated according to Equation 6.1, page 6.11, Chapter 6, Volume 5, the IPCC 2006 Guidelines.

1) Population data

- Population data collected from the GSO, 2016 are as follows:

- Urban population: 31,926,300.

- Rural population: 60,765,900.

- Total urban and rural population is: 92,692,200.

2) Proportion of the population by region

According to the IPCC 2006 Guidelines, it is necessary to survey the proportion of the population by low income and high income groups. However, Viet Nam have not had standards to classify and define low and high income earner groups. Wastewater treatment, moreover, according to different types of wastewater treatment systems is highly dependent on area. Therefore, instead of categorising population data by low- and high-income earner groups as guided, it would classify population data according to region of residence as urban and rural to be homogeneous with the different types of wastewater treatment systems in that areas and more suitable with the country conditions.

Based on the population data, urban population accounted for 34% and rural population, 66%.

3) Proportion of wastewater treatment system type

According to the Environmental status report, VEA, MONRE, 2017, in urban areas, the domestic wastewater treatment had seen positive changes. According to 2016 statistics, 44 out of 781 urban centres across the country had wastewater treatment facilities meeting the standards, accounting for 5.63%. The rate of wastewater treatment systems of the kind was determined as the rate of domestic wastewater treatment in the wastewater treatment systems in large cities or from a high-income source. The remaining coefficients for low-income wastewater treatment systems and septic systems, which could not be treated, were based on the assumptions of waste experts.

• *Urban areas*

+ Proportion of domestic wastewater treated in a centralised treatment area by the aerobic method: 5.6%.

+ Proportion of domestic wastewater treated by the septic system: 28.3% (accounting for 30% of the remaining wastewater after being treated in the centralised treatment area).

+ Proportion of untreated domestic wastewater: 66.1% (accounting for 70% of the remaining wastewater after being treated in the centralized treatment area).

• *Rural areas*

+ Proportion of domestic wastewater treated in a centralised treatment area by the aerobic method: 0.00%.

+ Proportion of domestic wastewater treated by a septic system: 10%.

+ Proportion of untreated domestic wastewater: 90%.

4) BOD factor

The default value of 14.6kgBOD/1000/year in Table 6.4, page 6.14, Chapter 6, Volume 5, the IPCC 2006 Guidelines was used.

c. EFs

The EFs used to calculate CH_4 emissions from domestic wastewater included:

- Maximum CH_4 producing capacity: B0= 0.6kgCH_4/kgBOD (default value in Table 6.2, page 6.12, Chapter 6, Volume 5, the IPCC 2006 Guidelines);

- Correction factor for additional industrial BOD discharged into sewers (I): default coefficient of 1.25; and

- Methane correction factor for each type of wastewater treatment system: factor given in Table 6.3, page 6.13, Chapter 6, Volume 5, the IPCC 2006 Guidelines, MCFs are selected as follows:

Centralised, aerobic treatment plant: 0.3;

Septic system: 0.5;

Sea, river and lake discharge: 0.1.

d. Results of emissions

CH_4 emissions from domestic wastewater are reported in Table 6.24.

6.2.4.1.2 Nitrous oxide (N_2O) emissions from wastewater

a. Methodology

N_2O emissions from domestic wastewater were calculated according to Equation 6.7, page 6.23, Chapter 6, Volume 5, the IPCC 2006 Guidelines;

The total Nitrogen (N) in the effluent generated from wastewater was calculated according to Equation 6.8, page 6.25, Chapter 6, Volume 5, the IPCC 2006 Guidelines.

b. AD

AD used to calculate N_2O emissions from wastewater included: 1) Population; and 2) Annual per capita protein consumption.

1) Population: Total population in 2016 was 92,692,200;

2) Annual per capita protein consumption: According to the report from the Viet Nam Institute of Nutrition, MOH, the protein consumption per capita was 22.6kg/person/year in 2000 and 27.1 kg/person/year, in 2010. The estimated figure for 2016 was 30.5kg/person/year.

c. EFs

EF used to calculate N_2O emissions from domestic wastewater: default value for the $EF_{EFFLUENT}$ factor used was 0.01kgN_2O-N/kg-N according to Table 6.11, page 6.27, Chapter 6, Volume 5, the IPCC 2006 Guidelines.

d. Result of emissions

N_2O emissions from domestic wastewater are reported in Table 6.24.

6.2.4.2 Industrial wastewater treatment and discharge (4D2)

Industrial wastewater may be treated on site or released into domestic sewer systems. If it is released into the domestic sewer system, the emissions are to be included with the domestic wastewater emissions. This section deals with estimating CH_4 emissions from on-site industrial wastewater treatment. Only industrial wastewater with significant carbon loading that is treated under intended or unintended anaerobic conditions will produce CH_4. Organics in industrial wastewater are often expressed in terms of chemical oxygen demand (COD), which is used here.

a. Methodology

Based on the Decision tree shown in Figure 6.3, page 6.19, Chapter 6, Volume 5, IPCC 2006, the Tier 1 approach method was chosen to calculate CH_4 emissions from Industrial wastewater treatment using the following formulas:

- Total CH_4 emissions from industrial wastewater: Equation 6.4, page 6.20, Chapter 6, Volume 5, the IPCC 2006 Guidelines;

- CH_4 EF for industrial wastewater: Equation 6.5, page 6.21, Chapter 6, Volume 5, the IPCC 2006 Guidelines; and

- Organically degradable material in industrial wastewater: Equation 6.6, page 6.22, Chapter 6, Volume 5, the IPCC 2006 Guidelines.

b. AD

According to Equation 6.4, page 6.20, Chapter 6, Volume 5, the IPCC 2006 Guidelines, AD for calculating CH_4 emissions from domestic wastewater included: 1) Total industrial product; 2) Amount of wastewater generated by each type of industry; 3) COD value in wastewater of each type of industry; and 4) Proportion of industrial wastewater treatment systems.

Production data of industries collected by GSO, 2016, is detailed in Table 6.25.

Table 6.25 Products of important industries in 2016

No.	Industry type	Product in 2016	Source
		tonnes/yaear	
1	Iron and steel	20,995,400	Statistical yearbook 2016, GSO, 2017
2	Non-ferrous metal	259,326	
3	Chemical fertilisers	3,536,600	
4	Beer	3,845,100	
5	Spirit and white wine	306,800	
6	Granulated sugar	1,695,300	
7	Canned and frozen seafood	1,865,400	
8	Powdered coffee and instant coffee	95,400	
9	Beverage	1,016,600	
10	Paper	1,614,400	
11	Pulp	437,600	
12	Rubber	953,700	
13	Detergent and cleaning products	1,121,700	
14	Canned meat	4,314	
15	Refined vegetable oil	1,034,700	

Volume of wastewater generated from each industrial type was collected according to data of MOIT, VEA, MONRE, the Viet Nam Cleaner Production Centre and the IPCC 2006 Guidelines as detailed in Table 6.26.

Table 6.26 Wastewater calculated on product of key industries

No.	Industry type	Wastewater generation *m^3/tonne*	Source
1	Iron and steel	0.1	NIR2014, MONRE, 2019 Synthesized information from MOIT
2	Non-ferrous metal	0.1	
3	Chemical fertilisers	0.2	
4	Spirit and white wine	12	
5	Milk	7.5	
6	Granulated sugar	7	
7	Canned and frozen seafood	21.5	
8	Powdered coffee and instant coffee	0.63	
9	Beverage	11.38	
10	Rubber	0.5	
11	Beer	11.5	Technical documents to assess the suitability of wastewater treatment technologies for several industries, VEA, MONRE, 2011
12	Paper	225	Guidance to cleaner production - Pulp and paper industry, Viet Nam Cleaner Production Centre, 2008
13	Pulp	225	
14	Detergent and cleaning products	3	Default values, IPCC 2006 Guidelines
15	Canned meat	13	
16	Refined vegetable oil	3.1	

COD/unit wastewater of each industrial type was based on data from MOIT; VEA, MONRE; and the Viet Nam Cleaner Production Centre and default value of the IPCC 2006 Guidelines, details in Table 6.27.

Table 6.27 COD values for the wastewater types of key industries

No.	Industry Type	COD *kg COD/m³*	Source
1	Iron and steel	0.5	NIR2014, MONRE, 2019, Synthesized information from MOIT
2	Non-ferrous metal	0.5	
3	Chemical fertilisers	0.23	
4	Spirit and white wine	1.2	
5	Milk	0.8	
6	Sugar refining	0.2	
7	Canned and frozen seafood	1.47	
8	Powdered coffee and instant coffee	0.02	
9	Beverage	1.7	
10	Rubber	0.23	
11	Beer	3.5	Technical documents to assess the suitability of wastewater treatment technologies for several industries, VEA, MONRE, 2011
12	Paper	2.94	Guidance to Cleaner Production - Pulp and Paper Industry, Viet Nam Cleaner Production Centre, 2008
13	Pulp	2.94	
14	Detergent and cleaning products	0.9	Defalt values, IPCC 2006 Guidelines
15	Canned meat	4.1	
16	Refined vegetable oil	0.85	

Proportion of industrial wastewater treatment systems

Domestic wastewater treatment technologies include aerobic treatment, semi-aerobic treatment, anaerobic treatment and sea, river and lake discharge. Since, there is no specific AD, it is recommended to rely on the expert method to rate the types of systems as follows:

- Aerobic treatment: 30%

- Semi-aerobic treatment: 40%

- Anaerobic treatment: 0%

- Discharge into sea, rivers and lakes: 30%

c. EFs

The EFs used to calculate CH_4 emissions from industrial wastewater include:

- The maximum CH_4 producing capacity (B0) takes the default value of 0.25 kg CH_4/ kgCOD according to Table 6.2, page 6.12, Chapter 6, Volume 5, the IPCC 2006 Guidelines;

- Methane correction factor (MCF) for each type of treatment system: Use the default value according to Table 6.8, page 6.21, Chapter 6, Volume 5, the IPCC 2006 Guidelines;

- Centralized aerobic wastewater treatment system: MCF= 0.3;

- Septic system: MCF= 0.2; and

- Discharge into sea, rivers and lakes: MCF= 0.1.

d. GHG Emissions

Table 6.28 GHG emissions from industrial wastewater treatment and discharge

IPCC Code	Category	CO_2	CH_4	N_2O	Total
		kt			*$ktCO_2eq$*
4D1	Domestic wastewater treatment and discharge		80.61		2,257.05

6.3 Conclusion and Recommendations

6.3.1 Improvements compared to the previous inventories

Solid waste disposal (4A)

- AD data of urban domestic solid waste was collected from GSO, with clearly provided data for the total amount of collected solid waste treated to meet the national standards, thus, the amount of landfill solid waste was separated into managed sanitary landfill, open landfill and open burning. Whereas, in the previous inventories, the data was mainly collected from the 5-year environmental status reports of provinces and cities in Viet Nam.

- Some more sub-sectors were calculated against the previous inventories including Biological treatment of solid waste (4B) and Open burning of waste (4C2).

- Reassessment and more detailed calculation of emissions from category Wastewater treatment and discharge through the proportion of wastewater treatment systems by urban and rural areas.

Biological treatment of solid waste (4B)

Previous inventories had not taken into account CH_4 and N_2O emissions from biological waste treatment. In 2016, the amount of GHG emissions from biological treatment was calculated based on the available AD.

Incineration and Open burning of waste (4C)

- The amount of hazardous industrial, agricultural and domestic solid waste from medical activities were added to calculate GHG emissions in Waste incineration (4C1);

- GHG emissions from Open burning of waste (4C2) were additionally estimated in this inventory.

Wastewater treatment and discharge (4D)

- GHG emissions from Wastewater treatment and discharge by urban and rural areas were calculated based on available AD;

- GHG emissions from Industrial wastewater treatment and discharge by type of treatment technologies were calculated.

Difficulties, shortcomings and recommendations

6.3.2 Difficulties, shortcomings and recommendations

Solid waste disposal (4A)

- Since no data were collected on the proportion of urban and rural open landfill and open burning waste, this proportion was assumed to be 70% for open landfill and 30% for open burning.

- Data on total amount of rural domestic solid waste landfilled was based on population data and the rate of waste generation per capita due to the lack of detailed statistics.

Biological treatment of solid waste (4B)

- AD for the calculation of GHG emissions from solid waste treatment by biological methods were also based on solid waste treatment capacity using Tan Sinh Nghia technology and bio-composting as organic fertiliser of factories and localities with the assumption that factories operated at 70% capacity.

Incineration and open burning of waste (4C)

- The amount of domestic hazardous solid waste landfilled was not estimated due to the absence of statistics.

- The amount of hazardous medical, industrial and agriculture solid waste were based only on the amount of waste reported in the National environmental status report 2017, and the AD on some typical incinerators provided by MONRE, thus, data was not sufficient for the whole country.

- GHG emissions from Liquid waste incineration were not taken into account in the Waste incineration sub-sector (4C1) due to the lack of AD collected.

- Some ratios, such as the rate of open landfill of waste and the open burning rate of waste, were still based on expert experience.

Wastewater treatment and discharge (4D)

GHG emission from sludge treatment was not calculated yet since no specific data was available on the amount of sludge treated and the current sludge treatment technology in Viet Nam.

Recommendations

For AD

- It is necessary to collect more complete data, particularly data on the amount of bio-treated waste and hazardous solid waste nation-wide.

- For the AD using expert assumptions and methods, specific investigations and collection methods are needed to obtain more accurate data.

For EFs / parameters

All most of the EFs and the parameters used for GHG generation estimates were default values according to the IPCC 2006 Guidelines. Therefore, in the future, to increase the accuracy of national GHG inventory, it is necessary to have studies to issue the country specific EFs for Viet Nam.

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ANNEXES

ANNEX 1: ENERGY BALANCE TABLE IN 2016

	Coal	Crude oil	Car gasoline	Aircraft gasoline	Diesel	DO	FO	LPG	Asphalt	Lubricant Oil	Other oil products	Natural gas	Mineral ethanol	Fuel wood	Bagasse	Straw	Rice husks	Agricultural by-products & other products	Charcoal	Solar energy (civil)	Hydroelectric	Wind power	Solar power	Electricity	Total
	KTOE																								
Domestic production	19,270.44	15,157.20										9,351.00	12.12	2,633.68	1,064.12	1,901.43	137.07	1,117.97		0.11	5,498.93				56,144.07
Import	7,391.29	443.70	2,611.98	1,584.51	51.36	6,849.89	876.75	1,342.32	563.22	134.04	135.27		0.04						8.28					235.30	22,227.95
Export	-696.30	-6,984.96	-225.50	-494.85		-522.69	-200.34	-296.96	-0.98	-22.92	-1.55		-0.21						-51.28					-121.20	-9,619.74
Inventory difference	-370.83	-433.50	-476.07	-733.86		240.72	-0.99																		-1,774.54
TOTAL PRIMARY ENERGY	**25,594.59**	**8,182.44**	**1,910.41**	**355.79**	**51.36**	**6,567.93**	**675.42**	**1,045.36**	**562.24**	**111.13**	**133.71**	**9,351.00**	**11.95**	**2,633.68**	**1,064.12**	**1,901.43**	**137.07**	**1,117.97**	**-42.99**	**0.11**	**5,498.93**			**114.09**	**66,977.74**
Petroleum refinery		-8,182.44	3,933.30	394.49		2,958.00	117.81	534.09			165.33														-79.42
Gas processing plant								334.85				-335.00													-0.15
Electric plant	-16,981.41					-41.82	-200.17					-7,591.50		-18.40	-1,051.31						-5,498.93			15,390.65	-15,992.89
Charcoal factory														-566.98					113.40						-453.58
Lost																								-1,173.71	-1,173.71
Self consumption																								-612.94	-612.94
TOTAL FINAL ENERGY CONSUMPTION	**8,613.18**	**0.00**	**5,843.71**	**750.28**	**51.36**	**9,484.10**	**593.06**	**1,914.30**	**562.24**	**111.13**	**299.04**	**1,424.50**	**11.95**	**2,048.31**	**12.81**	**1,901.43**	**137.07**	**1,117.97**	**70.40**	**0.11**				**13,718.09**	**48,665.05**
Industry	7,392.58					1,753.11	42.72	214.19				479.15		2,048.31		1,433.70		503.23						7,383.01	21,250.01
Mining	74.67					442.98	0.65																	573.01	1,091.30
Food processing, beverages and tobacco	325.96					64.84	9.95	12.49				9.18		560.86		242.51		503.23						1,353.49	3,082.53
Textile and leather	777.16					40.21	3.41	4.07				3.02		934.77		363.77								987.40	3,113.80

Wood and wood products	0.46					25.21	0.03	0.68				0.00		373.91		606.28								304.50	1,311.08
Pulp, paper and print	161.58					25.21	3.63	1.43				2.12												230.75	424.73
Chemical production	429.56					59.80	2.11	12.67				124.45												658.99	1,287.59
Metal and metal products manufacturing	1,942.76					69.85	7.82	39.83				176.40												1,120.88	3,357.54
Machine and equipment manufaturing	1.24					24.53	0.63	52.12				10.67												774.32	863.51
Other non-metal mineral production	3,260.62					151.72	14.22	44.94				147.94		178.77		221.14								830.81	4,850.16
Motor vehicle production	1.90					24.30	0.15	34.18				4.66												49.68	114.87
Construction	16.57					805.41		1.38				0.47												226.38	1,050.22
Other industries	400.10					19.04	0.12	10.40				0.23												272.78	702.68
Agriculture			639.96			1,708.71	332.65									318.76								312.09	3,312.17
Transportation			5,203.16	750.28		5,512.08	218.09					18.27	11.95												11,713.83
Road			5,203.16			4,745.04						18.27	11.95												9,978.42
River and seaway						727.26	218.09																		945.35
Railways						39.78																			39.78
Aviation				750.28																					750.28
Commercial sevice						510.60		190.75											13.80					1,563.48	2,278.63
Civil	701.96				39.06			1,509.36							12.81	148.96	137.07	614.73	56.60	0.11				4,459.53	7,680.20
Non-energy cônumption	518.64		0.59		12.31				562.24	111.13	299.04	927.22													2,431.17

ANNEX 2: GHG EMISSIONS/ REMOVALS FOR 2016

Annex 2-1: GHG Emissions in energy sector for 2016

IPCC Code	Category	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	HFCs	HFCs	NMVOCs	SO_2
		kt			*kt CO_2eq*			*kt*			
1	**Energy**	**182,291.22**	**798.05**	**4.51**							
1A	Fuel combustion activities	180,767.38	46.13	4.50							
1A1	Energy industries	90,554.60	3.06	1.38				NE	NE	NE	NE
1A2	Manufacturing industries and Construction	37,701.55	8.36	1.18				NE	NE	NE	NE
1A3	Transport	35,193.17	8.12	1.60				NE	NE	NE	NE
1A4	Other Sectors	17,318.05	26.59	0.34				NE	NE	NE	NE
1A5	Non-specified	NE	NE	NE				NE	NE	NE	NE
1B	Fugitive emissions from fuels	1,523.84	751.92	0.01							
1B1	Solid fuels		107.38					NE	NE	NE	NE
1B2	Oil and natural gas	1,523.84	644.54	0.01				NE	NE	NE	NE
1B3	Other emissions from energy production	NE	NE	NE				NE	NE	NE	NE
1C	Carbon dioxide transport and storage										
1C1	Transport of CO_2	NO						NE	NE	NE	NE
1C2	Injections and storage	NO						NE	NE	NE	NE
1C3	Other	NO						NE	NE	NE	NE
MEMO ITEMS											
International bunkers											
Aviation		NE	NE					NE	NE	NE	NE
Marine		NE	NE					NE	NE	NE	NE
Multilateral operations		NE	NE					NE	NE	NE	NE

Annex 2-2: GHG Emissions in IPPU sector for 2016

IPCC Code	Category	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NOx	CO	NMVOCs	SO_2
		kt			*$ktCO_2eq$*			*kt*			
2	**IPPU**	**46,047.20**		**0.09**				**16.21**	**20.95**	**22.38**	**23.55**
2A	Mineral industry	40,917.20								7.56	22.34
2A1	Cement production	36,773.00						NE	NE	NE	22.34
2A2	Lime production	3,825.00						NE	NE	NE	NE
2A3	Glass production	319.20						NE	NE	NE	NE
2A4	Other process uses of carbonates	NE						NE	NE	NE	NE
2A5	Other mineral industries	NE						NE	NE	NE	NE
2B	Chemical industry	1,271.78		0.09					9.68	5.76	0.04
2B1	Ammonia production	1,271.78						NE	9.68	5.76	0.04
2B2	Nitric acid production			0.09				NE	NE	NE	NE
2B3	Adipic acid production			NO				NE	NE	NE	NE
2B4	Caprolactam, glyoxal and glyoxylic acid production			NO				NE	NE	NE	NE
2B5	Carbide production	NE	NE					NE	NE	NE	NE
2B6	Titanium dioxide production	NE						NE	NE	NE	NE
2B7	Soda ash production	NE						NE	NE	NE	NE
2B8	Petrochemical and carbon black production	NE	NE					NE	NE	NE	NE
2B9	Flourochemical production				NO			NE	NE	NE	NE

IPCC Code	Category	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NOx	CO	NMVOCs	SO_2
		kt			$ktCO_2eq$			kt			
2B10	Other	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2C	Metal industry	3,858.22			NO			16.21	11.27	9.06	1.17
2C1	Iron and steel production	3,858.22	NE	NO				16.21	11.27	9.06	1.17
2C2	Ferroalloys production	NE	NO	NO				NE	NE	NE	NE
2C3	Aluminium production	NO	NO			NO		NE	NE	NE	NE
2C4	Magnesium production	NO			NO	NO	NO	NE	NE	NE	NE
2C5	Lead production	NE						NE	NE	NE	NE
2C6	Zinc production	NE						NE	NE	NE	NE
2C7	Other	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2D	Non-energy products from fuels and solvent use										
2D1	Lubricant use	NE						NE	NE	NE	NE
2D2	Paraffin wax use	NE	NE	NE				NE	NE	NE	NE
2D3	Solvent use							NE	NE	NE	NE
2D4	Other	NE	NE	NE				NE	NE	NE	NE
2E	Electronics industry										
2E1	Integrated circuit or semiconductor	NE		NE	NE	NE	NE	NE	NE	NE	NE
2E2	TFT flat panel display				NE	NE	NE	NE	NE	NE	NE
2E3	Photovoltaics				NE	NE	NE	NE	NE	NE	NE
2E4	Heat transfer fluid							NE	NE	NE	NE

IPCC Code	Category	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NOx	CO	NMVOCs	SO_2
		kt			*$ktCO_2eq$*			*kt*			
2E5	Other	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2F	Product uses as substitutes for ozone depleting substances				23.32						
2F1	Refrigeration and air conditioning	NE			NE	NE		NE	NE	NE	NE
2F2	Foam blowing agents	NE			NE	NE		NE	NE	NE	NE
2F3	Fire protection	NE			23.32	NE		NE	NE	NE	NE
2F4	Aerosols				IE	NE		NE	NE	NE	NE
2F5	Solvents				NE	NE		NE	NE	NE	NE
2F6	Other applications	NE	NE	NE	NE	NE		NE	NE	NE	NE
2G	Other product manufacture and use										
2G1	Electrical equipment					NE	NE	NE	NE	NE	NE
2G2	SF_6 and PFCs from other product uses					NE	NE	NE	NE	NE	NE
2G3	N_2O from Product Uses			NE				NE	NE	NE	NE
2G4	Other	NE	NE		NE			NE	NE	NE	NE
2H	Other										
2H1	Pulp and paper industry	NE	NE					NE	NE	NE	NE
2H2	Food and beverages industry	NE	NE					NE	NE	NE	NE
2H3	Other	NE	NE	NE				NE	NE	NE	NE

Annex 2-3: GHG emissions/ removals in AFOLU sector for 2016

IPCC Code	Category	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NOx	CO	NMVOCs	SO_2
		kt			*$ktCO_2eq$*			*kt*			
3	**AFOLU**	**-37,489.34**	**2,376.59**	**56.66**				**38.64**	**1,461.39**		
3A	Livestock		555.47								
3A1	Enteric fermentation		443.63					NE	NE	NE	NE
3A2	Manure management		111.83	11.17				NE	NE	NE	NE
3B	Land	-39,491.24									
3B1	Forest land	-54,657.78						NE	NE	NE	NE
3B2	Cropland	3,637.60						NE	NE	NE	NE
3B3	Grassland	1,383.64						NE	NE	NE	NE
3B4	Wetlands	1,046.90						NE	NE	NE	NE
3B5	Settlements	1,919.14						NE	NE	NE	NE
3B6	Other land	7,179.27						NE	NE	NE	NE
3C	Aggregate sources and non-CO_2 emissions sources on land	2,001.90	1,821.13	45.49				38.64	1,461.39		
3C1	GHG emissions from biomass burning		46.38	1.23				NE	NE	NE	NE
3C2	Liming	565.79						NE	NE	NE	NE
3C3	Urea application	1,436.11						NE	NE	NE	NE
3C4	Direct N_2O emissions from managed soils			9.26				NE	NE	NE	NE
3C5	Indirect N_2O emissions from managed soils			4.16				NE	NE	NE	NE
3C6	Indirect N2O emissions from manure management			0.84				NE	NE	NE	NE
3C7	Rice cultivations		1,774.75					NE	NE	NE	NE
3D	Other										
3D1	Harvested wood products	NE						NE	NE	NE	NE
3D2	Other	NE	NE	NE				NE	NE	NE	NE

Annex 2-4: GHG emissions in waste sector for 2016

IPCC Code	Category	CO_2	CH_4	N_2O	HFC	HFCs	PFCs	NOx	CO	NMVOCs	SO_2
		kt			$ktCO_2eq$			kt			
4	**Waste**	**802.00**	**641.01**	**7.50**							
4A	Solid waste disposal sites		372.82								
4A1	Managed waste disposal sites		372.82					NE	NE	NE	NE
4A2	Unmanaged waste disposal sites		IE					NE	NE	NE	NE
4A3	Uncategorised waste disposal sites		IE					NE	NE	NE	NE
4B	Biological treatment of solid waste		2.48	0.15							
4C	Incineration and Open burning of waste	802.00	13.47	0.23							
4C1	Waste incineration	528.09	0.00	0.04				NE	NE	NE	NE
4C2	Open burning of waste	273.91	13.47	0.19				NE	NE	NE	NE
4D	Wastewater treatment and discharge		252.24	7.12							
4D1	Domestic wastewater treatment and discharge		171.63	7.12				NE	NE	NE	NE
4D2	Industrial wastewater treatment and discharge	NE	80.61					NE	NE	NE	NE
4E	Other	NE	NE	NE				NE	NE	NE	NE

ANNEX 3: RECALCULATION OF GHG EMISSIONS FOR 2010 AND 2014

Annex 3-1a: Recalculation of GHG emissions in energy sector for 2010

IPCC Code	Category	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NO_x	CO	NMVOCs	SO_2
		kt			*ktCO₂eq*			*kt*			
1	**Energy**	**125,514.57**	**895.54**	**4.87**							
1A	Fuel combustion activities	124,068.61	162.81	4.85							
1A1	Energy industries	40,077.12	0.68	0.34				NE	NE	NE	NE
1A2	Manufacturing industries and construction	38,538.63	6.65	0.95				NE	NE	NE	NE
1A3	Transport	33,591.23	7.45	1.66				NE	NE	NE	NE
1A4	Other sectors	11,861.64	148.03	1.90				NE	NE	NE	NE
1A5	Non-specified	NE	NE	NE				NE	NE	NE	NE
1B	Fugitive emissions from fuels	1,445.96	732.73	0.01							
1B1	Solid fuels	0.00	102.83	0.00				NE	NE	NE	NE
1B2	Oil and natural gas	1,445.96	629.90	0.01				NE	NE	NE	NE
1B3	Other emissions from energy production	NE	NE	NE				NE	NE	NE	NE
1C	Carbon dioxide transport and storage										
1C1	Transport of CO_2	NO						NE	NE	NE	NE
1C2	Injections and storage	NO						NE	NE	NE	NE
1C3	Other	NO						NE	NE	NE	NE
MEMO ITEMS											
International bunkers											
Aviation		NE	NE					NE	NE	NE	NE
Marine		NE	NE					NE	NE	NE	NE
Multilateral operations		NE	NE					NE	NE	NE	NE

Annex 3-1b: Recalculation of GHG emissions in energy sector for 2014

IPCC Code	Category	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NO_x	CO	NMVOCs	SO_2
		kt			*$ktCO_2eq$*			*kt*			
1	**Energy**	**148,435.33**	**920.89**	**4.98**							
1A	Fuel combustion activities	146,888.95	145.68	4.97							
1A1	Energy industries	54,714.32	0.82	0.59				NE	NE	NE	NE
1A2	Manufacturing industries and construction	49,638.22	9.01	1.28				NE	NE	NE	NE
1A3	Transport	30,665.71	7.29	1.47				NE	NE	NE	NE
1A4	Other sectors	11,870.71	128.56	1.63				NE	NE	NE	NE
1A5	Non-specified	NE	NE	NE				NE	NE	NE	NE
1B	Fugitive emissions from fuels	1,546.38	775.21	0.01							
1B1	Solid fuels	0.00	109.34	0.00				NE	NE	NE	NE
1B2	Oil and natural gas	1,546.38	665.87	0.01				NE	NE	NE	NE
1B3	Other emissions from energy production	NE	NE	NE				NE	NE	NE	NE
1C	Carbon dioxide transport and storage										
1C1	Transport of CO_2	NO						NE	NE	NE	NE
1C2	Injections and storage	NO						NE	NE	NE	NE
1C3	Other	NO						NE	NE	NE	NE
MEMO ITEMS											
International bunkers											
Aviation		NE	NE					NE	NE	NE	NE
Marine		NE	NE					NE	NE	NE	NE
Multilateral operations		NE	NE					NE	NE	NE	NE

Annex 3-2a: Recalculation of GHG emissions in IPPU sector for 2010

IPCC Code	Category	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NO_x	CO	NMVOCs	SO_2
		kt			*$ktCO_2eq$*			*kt*			
2	**IPPU**	**25,844.05**						**NE**	**NE**	**NE**	**NE**
2A	Mineral industry	24,816.94								NE	
2A1	Cement production	23,221.03						NE	NE	NE	NE
2A2	Lime production	1,446.00						NE	NE	NE	NE
2A3	Glass production	149.91						NE	NE	NE	NE
2A4	Other process uses of carbonates	NE						NE	NE	NE	NE
2A5	Other mineral industries	NE						NE	NE	NE	NE
2B	Chemical industry	681.99									
2B1	Ammonia production	681.99						NE	NE	NE	NE
2B2	Nitric acid production			NE				NE	NE	NE	NE
2B3	Adipic acid production			NO				NE	NE	NE	NE
2B4	Caprolactam, glyoxal and glyoxylic acid production			NO				NE	NE	NE	NE
2B5	Carbide production	NE	NE					NE	NE	NE	NE
2B6	Titanium dioxide production	NE						NE	NE	NE	NE
2B7	Soda ash production	NE						NE	NE	NE	NE
2B8	Petrochemical and carbon black production	NE	NE					NE	NE	NE	NE
2B9	Flourochemical production				NO			NE	NE	NE	NE

IPCC Code	Category	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NO_x	CO	NMVOCs	SO_2
		kt			*$ktCO_2eq$*			*kt*			
2B10	Other	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2C	Metal industry	345.12									
2C1	Iron and steel production	345.12	NE	NO				NE	NE	NE	NE
2C2	Ferroalloys production	NE	NO	NO				NE	NE	NE	NE
2C3	Aluminium production	NO	NO			NO		NE	NE	NE	NE
2C4	Magnesium production	NO			NO	NO	NO	NE	NE	NE	NE
2C5	Lead production	NE						NE	NE	NE	NE
2C6	Zinc production	NE						NE	NE	NE	NE
2C7	Other	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2D	Non-energy products from fuels and solvent use										
2D1	Lubricant use	NE						NE	NE	NE	NE
2D2	Paraffin wax use							NE	NE	NE	NE
2D3	Solvent use							NE	NE	NE	NE
2D4	Other	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2E	Electronics industry										
2E1	Integrated circuit or semiconductor	NE		NE	NE	NE	NE	NE	NE	NE	NE
2E2	TFT flat panel display				NE	NE	NE	NE	NE	NE	NE
2E3	Photovoltaics				NE	NE	NE	NE	NE	NE	NE

IPCC Code	Category	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NO_x	CO	NMVOCs	SO_2
		kt			*$ktCO_2eq$*			*kt*			
2E4	Heat transfer fluid							NE	NE	NE	NE
2E5	Other	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2F	Product uses as substitutes for ozone depleting substances										
2F1	Refrigeration and air conditioning	NE			NE	NE		NE	NE	NE	NE
2F2	Foam blowing agents	NE			NE	NE		NE	NE	NE	NE
2F3	Fire protection	NE			NE	NE		NE	NE	NE	NE
2F4	Aerosols				IE	NE		NE	NE	NE	NE
2F5	Solvents				NE	NE		NE	NE	NE	NE
2F6	Other applications				NE	NE		NE	NE	NE	NE
2G	Other product manufacture and use										
2G1	Electrical equipment					NE	NE	NE	NE	NE	NE
2G2	SF_6 and PFCs from other product uses					NE	NE	NE	NE	NE	NE
2G3	N_2O from product uses			NE				NE	NE	NE	NE
2G4	Other	NE	NE		NE			NE	NE	NE	NE
2H	Other										
2H1	Pulp and paper industry	NE	NE					NE	NE	NE	NE
2H2	Food and Beverages Industry	NE	NE					NE	NE	NE	NE
2H3	Other	NE	NE	NE				NE	NE	NE	NE

Annex 3-2b: Recalculation of GHG emissions in IPPU sector for 2014

IPCC Code	Category	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NO_x	CO	NMVOCs	SO_2
		kt			$ktCO_2eq$			kt			
2	**IPPU**	**38,637.70**			**95.01**			**NE**	**NE**	**NE**	**NE**
2A	Mineral industry	35,222.29						NE		NE	NE
2A1	Cement production	32,440.38						NE	NE	NE	NE
2A2	Lime production	2,442.00						NE	NE	NE	NE
2A3	Glass production	339.91						NE	NE	NE	NE
2A4	Other process uses of carbonates	NE						NE	NE	NE	NE
2A5	Other mineral industries	NE						NE	NE	NE	NE
2B	Chemical industry	1,737.39									
2B1	Ammonia production	1,737.39						NE	NE	NE	NE
2B2	Nitric acid production			NE				NE	NE	NE	NE
2B3	Adipic acid production			NO				NE	NE	NE	NE
2B4	Caprolactam, glyoxal and glyoxylic acid production			NO				NE	NE	NE	NE
2B5	Carbide production	NE	NE					NE	NE	NE	NE
2B6	Titanium dioxide production	NE						NE	NE	NE	NE
2B7	Soda ash production	NE						NE	NE	NE	NE
2B8	Petrochemical and carbon black production	NE	NE					NE	NE	NE	NE
2B9	Flourochemical production				NO			NE	NE	NE	NE

IPCC Code	Category	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NO_x	CO	NMVOCs	SO_2
		kt			*$ktCO_2eq$*			*kt*			
2B10	Other	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2C	Metal industry	1,678.02									
2C1	Iron and steel production	1,678.02	NE	NO				NE	NE	NE	NE
2C2	Ferroalloys production	NE	NO	NO				NE	NE	NE	NE
2C3	Aluminium production	NO	NO			NO		NE	NE	NE	NE
2C4	Magnesium production	NO			NO	NO	NO	NE	NE	NE	NE
2C5	Lead production	NE						NE	NE	NE	NE
2C6	Zinc production	NE						NE	NE	NE	NE
2C7	Other	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2D	Non-energy products from fuels and solvent use										
2D1	Lubricant use	NE						NE	NE	NE	NE
2D2	Paraffin wax use	NE	NE	NE				NE	NE	NE	NE
2D3	Solvent use							NE	NE	NE	NE
2D4	Other	NE	NE	NE				NE	NE	NE	NE
2E	Electronics industry										
2E1	Integrated circuit or semiconductor	NE		NE	NE	NE	NE	NE	NE	NE	NE
2E2	TFT flat panel display				NE	NE	NE	NE	NE	NE	NE
2E3	Photovoltaics				NE	NE	NE	NE	NE	NE	NE

IPCC Code	Category	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NO_x	CO	NMVOCs	SO_2
		kt			*$ktCO_2eq$*			*kt*			
2E4	Heat transfer fluid							NE	NE	NE	NE
2E5	Other	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2F	Product uses as substitutes for ozone depleting substances				95.01						
2F1	Refrigeration and air conditioning	NE			NE	NE		NE	NE	NE	NE
2F2	Foam blowing agents	NE			NE	NE		NE	NE	NE	NE
2F3	Fire protection	NE			95.01	NE		NE	NE	NE	NE
2F4	Aerosols				IE	NE		NE	NE	NE	NE
2F5	Solvents				NE	NE		NE	NE	NE	NE
2F6	Other applications	NE	NE	NE	NE	NE		NE	NE	NE	NE
2G	Other product manufacture and use										
2G1	Electrical equipment					NE	NE	NE	NE	NE	NE
2G2	SF6 and PFCs from other product uses					NE	NE	NE	NE	NE	NE
2G3	N2O from product uses			NE				NE	NE	NE	NE
2G4	Other	NE	NE		NE			NE	NE	NE	NE
2H	Other										
2H1	Pulp and paper industry	NE	NE					NE	NE	NE	NE
2H2	Food and beverages industry	NE	NE					NE	NE	NE	NE
2H3	Other	NE	NE	NE				NE	NE	NE	NE

Annex 3-3a: Recalculation of GHG emissions/ removals in AFOLU sector for 2010

IPCC Code	Category	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NOx	CO	NMVOCs	SO_2
		kt			$ktCO_2eq$			kt			
3	**AFOLU**	**-19,499.85**	**2,687.79**	**48.88**				**60.96**	**2,319.50**		
3A	Livestock		590.74	7.92							
3A1	Enteric fermentation		469.41					NE	NE	NE	NE
3A2	Manure management		121.32	7.92				NE	NE	NE	NE
3B	Land	-20,696.41									
3B1	Forest land	-55,660.57						NE	NE	NE	NE
3B2	Cropland	10,615.14						NE	NE	NE	NE
3B3	Grassland	1,475.51						NE	NE	NE	NE
3B4	Wetlands	1,168.90						NE	NE	NE	NE
3B5	Settlements	2,268.60						NE	NE	NE	NE
3B6	Other Land	19,436.01						NE	NE	NE	NE
3C	Aggregate sources and non-CO_2 emissions sources on land	1,196.56	2,097.05	40.96				60.96	2,319.50		
3C1	GHG emissions from biomass burning		74.83	1.99				60.96	NE	NE	NE
3C2	Liming	47.67						NE	47.67	NE	NE
3C3	Urea application	1,148.89						NE	1,148.89	NE	NE
3C4	Direct N_2O emissions from managed soils			25.71				NE	NE	NE	NE
3C5	Indirect N_2O emissions from managed soils			12.51				NE	NE	NE	NE
3C6	Indirect N_2O emissions from manure management			0.74				NE	NE	NE	NE
3C7	Rice cultivations		2,022.22					NE	NE	NE	NE
3D	Other										
3D1	Harvested wood products	NE						NE	NE	NE	NE
3D2	Other	NE	NE	NE				NE	NE	NE	NE

Annex 3-3b: Recalculation of GHG emissions/ removals in AFOLU sector for 2014

IPCC Code	Category	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NOx	CO	NMVOCs	SO_2
		kt			$ktCO_2eq$			kt			
3	**AFOLU**	**-35,936.97**	**2,403.74**	**51.43**				**62.27**	**2,335.88**		
3A	Livestock		530.07	10.36							
3A1	Enteric fermentation		425.77					NE	NE	NE	NE
3A2	Manure management		104.29	10.36				NE	NE	NE	NE
3B	Land	-37,254.91									
3B1	Forest land	-54,326.53						NE	NE	NE	NE
3B2	Cropland	6,905.15						NE	NE	NE	NE
3B3	Grassland	0						NE	NE	NE	NE
3B4	Wetlands	1,469.67						NE	NE	NE	NE
3B5	Settlements	1,419.03						NE	NE	NE	NE
3B6	Other land	7,277.77						NE	NE	NE	NE
3C	Aggregate sources and non-CO_2 emissions sources on land	1,317.94	1,873.67	41.07				2.27	2,335.88		
3C1	GHG emissions from biomass burning		72.43	1.91				NE	NE	NE	NE
3C2	Liming	54.16						62.27	2,335.88	NE	NE
3C3	Urea application	1,263.78						NE	NE	NE	NE
3C4	Direct N_2O emissions from managed soils			25.63				NE	NE	NE	NE
3C5	Indirect N_2O emissions from managed soils			12.76				NE	NE	NE	NE
3C6	Indirect N_2O emissions from manure management			0.78				NE	NE	NE	NE
3C7	Rice cultivations		1,801.23					NE	NE	NE	NE
3D	Other										
3D1	Harvested wood products	NE						NE	NE	NE	NE
3D2	Other	NE	NE	NE				NE	NE	NE	NE

Annex 3-4a: Recalculation of GHG emissions in waste sector for 2010

IPCC Code	Category	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NOx	CO	NMVOCs	SO_2
		kt			*$ktCO_2eq$*			*kt*			
4	**Waste**	**694.48**	**552.43**	**6.09**							
4A	Solid waste disposal sites		299.58								
4A1	Managed waste disposal sites		299.58					NE	NE	NE	NE
4A2	Unmanaged waste disposal sites		IE					NE	NE	NE	NE
4A3	Uncategorised waste disposal sites		IE					NE	NE	NE	NE
4B	Biological treatment of solid waste		0	0							
4C	Incineration and Open burning of waste	694.48	9.49	0.17							
4C1	Waste incineration	501.50	0.00	0.03				NE	NE	NE	NE
4C2	Open burning of waste	192.99	9.49	0.13				NE	NE	NE	NE
4D	Wastewater treatment and discharge		243.36	5.92							
4D1	Domestic wastewater treatment and discharge		157.80	5.92				NE	NE	NE	NE
4D2	Industrial wastewater treatment and discharge		85.56	NE				NE	NE	NE	NE
4E	Other	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

Annex 3-4b: Recalculation of GHG emissions in waste sector for 2014

IPCC Code	Category	CO	CH_4	N_2O	HFCs	PFCs	SF_6	NOx	CO	NMVOCs	SO_2
		kt			*$ktCO_2eq$*			*kt*			
4	**Waste**	**794.66**	**598.33**	**6.95**							
4A	Solid waste disposal sites		347.04								
4A1	Managed waste disposal sites		347.04					NE	NE	NE	NE
4A2	Unmanaged waste disposal sites		IE					NE	NE	NE	NE
4A3	Uncategorised waste disposal sites		IE					NE	NE	NE	NE
4B	Biological treatment of solid waste		0	0							
4C	Incineration and Open burning of waste	794.66	14.53	0.24							
4C1	Waste incineration	499.23	0.00	0.03				NE	NE	NE	NE
4C2	Open burning of waste	295.43	14.53	0.21				NE	NE	NE	NE
4D	Wastewater treatment and discharge		236.76	6.71							
4D1	Domestic wastewater treatment and discharge		166.87	6.71				NE	NE	NE	NE
4D2	Industrial wastewater treatment and discharge		69.89					NE	NE	NE	NE
4E	Other	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

ANNEX 4: UNCERTAINTIES OF 158 EMISSIONS/REMOVALS FOR 2016

No.	IPCC Code	Category	Gas	Emissions/ Removals	Emissions/ Removals uncertainty	AD uncertainty	EF uncertainty
				$ktCO_2eq$	%		
1	1A1ai	Energy industries: Electricity generation	CO_2	88,482.75	10.3	7.5	7.0
2	1A1ai	Energy industries: Electricity generation	CH_4	67.28	100.3	7.5	82.2
3	1A1ai	Energy industries: Electricity generation	N_2O	340.12	505.1	7.5	476.9
4	1A1b	Energy industries: Petroleum fefining	CO_2	2,008.90	10.3	7.5	7.0
5	1A1b	Energy industries: Petroleum refining	CH_4	2.3	100.3	7.5	100.0
6	1A1b	Energy industries: Petroleum fefining	N_2O	4.36	505.1	7.5	505.0
7	1A1ci	Energy industries: Manufacture of solid fuels	CH_4	15.95	100.3	7.5	100.0
8	1A1ci	Energy industries: Manufacture of solid fuels	N_2O	20.13	505.1	7.5	505.0
9	1A1cii	Energy industries: Gas extraction	CO_2	62.95	10.3	7.5	7.0
10	1A1cii	Energy industries: Gas extraction	CH_4	0.03	100.3	7.5	100.0
11	1A1cii	Energy industries: Gas extraction	N_2O	0.03	505.1	7.5	505.0
12	1A2a	Manufacturing industries and construction: Iron and steel	CO_2	8,757.59	18.8	17.5	7.0
13	1A2a	Manufacturing industries and construction: Iron and steel	CH_4	23.30	101.5	17.5	100.0
14	1A2a	Manufacturing industries and construction: Iron and steel	N_2O	33.09	505.3	17.5	505.0
15	1A2c	Manufacturing industries and construction: Chemicals and petroleum refining	CO_2	2,286.29	18.8	17.5	7.0
16	1A2c	Manufacturing industries and construction: Chemicals and Petroleum refining	CH_4	5.41	101.5	17.5	100.0
17	1A2c	Manufacturing industries and construction: Chemicals and petroleum refining	N_2O	7.71	505.3	17.5	505.0
18	1A2d	Manufacturing industries and construction: Pulp, paper and print	CO_2	760.45	18.8	17.5	7.0
19	1A2d	Manufacturing industries and construction: Pulp, paper and print	CH_4	1.99	101.5	17.5	100.0
20	1A2d	Manufacturing industries and construction: Pulp, paper and print	N_2O	2.87	505.3	17.5	505.0

21	1A2e	Manufacturing industries and construction: Food processing, beverages and tobacco	CO_2	1,629.60	18.8	17.5	7.0
22	1A2e	Manufacturing industries and construction: Food processing, beverages and tobacco	CH_4	50.06	101.5	17.5	100.0
23	1A2e	Manufacturing industries and construction: Food processing, beverages and tobacco	N_2O	63.93	505.3	17.5	505.0
24	1A2f	Manufacturing industries and construction: Non-metallic minerals	CO_2	14,402.77	18.8	17.5	7.0
25	1A2f	Manufacturing industries and construction: Non-metallic minerals	CH_4	53.10	101.5	17.5	100.0
26	1A2f	Manufacturing industries and construction: Non-metallic minerals	N_2O	73.33	505.3	17.5	505.0
27	1A2g	Manufacturing industries and construction: Transport equipment	CO_2	194.48	18.8	17.5	7.0
28	1A2g	Manufacturing Industries and construction: Transport equipment	CH_4	0.16	101.5	17.5	100.0
29	1A2g	Manufacturing industries and construction: Transport equipment	N_2O	0.24	505.3	17.5	505.0
30	1A2h	Manufacturing industries and construction: Machinery	CO_2	246.51	18.8	17.5	7.0
31	1A2h	Manufacturing industries and construction: Machinery	CH_4	0.18	101.5	17.5	100.0
32	1A2h	Manufacturing industries and construction: Machinery	N_2O	0.26	505.3	17.5	505.0
33	1A2i	Manufacturing industries and construction: Mining (excluding fuels) and quarrying	CO_2	1,683.71	18.8	17.5	7.0
34	1A2i	Manufacturing industries and construction: Mining (excluding fuels) and quarrying	CH_4	2.44	101.5	17.5	100.0
35	1A2i	Manufacturing industries and construction: Mining (excluding fuels) and quarrying	N_2O	4.20	505.3	17.5	505.0
36	1A2j	Manufacturing industries and construction: wood and wood products	CO_2	82.01	18.8	17.5	7.0
37	1A2j	Manufacturing industries and construction: Wood and wood products	CH_4	34.57	101.5	17.5	100.0
38	1A2j	Manufacturing industries and construction: Wood and wood products	N_2O	43.68	505.3	17.5	505.0
39	1A2k	Manufacturing industries and construction: Construction	CO_2	2,571.69	18.8	17.5	7.0
40	1A2k	Manufacturing industries and construction: Construction	CH_4	3.03	101.5	17.5	100.0

41	1A2k	Manufacturing industries and construction: Construction	N_2O	5.64	505.3	17.5	505.0
42	1A2l	Manufacturing industries and construction: Textile and leather	CO_2	3,352.31	18.8	17.5	7.0
43	1A2l	Manufacturing industries and construction: Textile and leather	CH_4	54.94	101.5	17.5	100.0
44	1A2l	Manufacturing industries and construction: Textile and leather	N_2O	70.86	505.3	17.5	505.0
45	1A2m	Manufacturing industries and construction: Non-specified industry	CO_2	1,734.14	18.8	17.5	7.0
46	1A2m	Manufacturing industries and construction: Non-specified industry	CH_4	4.77	101.5	17.5	100.0
47	1A2m	Manufacturing industries and construction: Non-specified industry	N_2O	6.80	505.3	17.5	505.0
48	1A3a	Transport: Civil aviation	CO_2	2,246.01	5.6	5.0	2.5
49	1A3a	Transport: Civil aviation	CH_4	0.44	50.2	5.0	50.0
50	1A3a	Transport: Civil aviation	N_2O	16.56	75.2	5.0	75.0
51	1A3b	Transport: Road transportation	CO_2	29,860.73	4.3	2.5	3.5
52	1A3b	Transport: Road transportation	CH_4	224.95	20.2	2.5	20.0
53	1A3b	Transport: Road transportation	N_2O	390.66	25.1	2.5	25.0
54	1A3c	Transport: Railways	CO_2	123.41	2.9	2.5	1.5
55	1A3c	Transport: Railways	CH_4	0.19	20.2	2.5	20.0
56	1A3c	Transport: Railways	N_2O	2.62	100.0	2.5	100.0
57	1A3d	Transport: Water borne navigations	CO_2	2,963.01	25.0	25.0	1.5
58	1A3d	Transport: Water borne navigations	CH_4	1.79	35.4	25.0	25.0
59	1A3d	Transport: Water borne navigations	N_2O	4.84	103.1	25.0	100.0
60	1A4a	Other sectors: Commercial/institusional	CO_2	2,088.03	21.2	20.0	7.0
61	1A4a	Other sectors: Commercial/institusional	CH_4	10.34	121.7	20.0	120.0
62	1A4a	Other sectors: Commercial/institusional	N_2O	3.76	505.4	20.0	505.0
63	1A4b	Other sectors: Residential	CO_2	6,994.11	21.2	20.0	7.0
64	1A4b	Other sectors: Residential	CH_4	590.75	121.7	20.0	120.0
65	1A4b	Other sectors: Residential	N_2O	54.79	505.4	20.0	505.0

66	1A4c	Other sectors: Agriculture, foresty and fishing farm	CO_2	8,235.91	21.2	20.0	7.0
67	1A4c	Other sectors: Agriculture, foresty and fishing farm	CH_4	143.54	121.7	20.0	120.0
68	1A4c	Other sectors: Agriculture, foresty and fishing farm	N_2O	32.00	505.4	20.0	505.0
69	1B1ai	Fugitive emissions from coal: Underground mines	CH_4	2,652.99	39.4	3.6	39.2
70	1B1aii	Fugitive emissions from coal: Surface mines	CH_4	353.73	92.5	4.6	92.3
71	1B2a	Fugitive emissions from oil	CO_2	767.48	41.8	11.3	40.3
72	1B2a	Fugitive emissions from oil	CH_4	14,270.02	327.3	9.2	327.2
73	1B2a	Fugitive emissions from oil	N_2O	2.88	600.1	12.5	600.0
74	1B2b	Fugitive emissions from natural gas	CO_2	756.36	116.5	11.6	115.9
75	1B2b	Fugitive emissions from natural gas	CH_4	3,777.10	118.2	11.8	117.6
76	1B2b	Fugitive emissions from natural gas	N_2O	0.18	600.1	12.5	600.0
77	2A1	Mineral industry: Cement production	CO_2	36,773.00	33.5	15.0	30.0
78	2A2	Mineral industry: Lime production	CO_2	3,825.00	15.1	15.0	2.0
79	2A3	Mineral industry: Glass production	CO_2	319.20	42.7	5.0	42.4
80	2B1	Chemical industry: Ammonia production	CO_2	1,271.78	28.6	4.0	28.3
81	2B2	Chemical industry: Nitric acid production	N_2O	24.12	25.1	2.0	25.0
82	2C1	Metal Industry: Iron and Steel Production	CO_2	3,858.22	24.1	8.9	22.3
83	2F3	Product uses as substitutes for ozone depleting substances: Fire protection	HFCs	23.32	16.1	9.6	12.8
84	3A1ai	Enteric fermentation: Dairy cows	CH_4	538.81	41.2	10.0	40.0
85	3A1aii	Enteric fermentation: Non-dairy cattle	CH_4	6,861.05	41.2	10.0	40.0
86	3A1b	Enteric fermentation: Buffalo	CH_4	3,879.89	41.2	10.0	40.0
87	3A1c	Enteric fermentation: Sheep	CH_4	17.66	41.2	10.0	40.0
88	3A1d	Enteric fermentation: Goats	CH_4	282.94	41.2	10.0	40.0
89	3A1f	Enteric fermentation: Horses	CH_4	27.27	41.2	10.0	40.0
90	3A1h	Enteric fermentation: Swine	CH_4	814.11	41.2	10.0	40.0

91	3A2ai	Manure management: Dairy cows	CH_4	61.68	18.9	10.0	16.0
92	3A2ai	Manure management: Dairy cows	N_2O	65.91	138.6	17.3	137.5
93	3A2aii	Manure management: Non-dairy cattle	CH_4	688.27	18.9	10.0	16.0
94	3A2aii	Manure management: Non-dairy cattle	N_2O	658.76	138.6	17.3	137.5
95	3A2b	Manure management: Buffalo	CH_4	464.20	18.9	10.0	16.0
96	3A2b	Manure management: Buffalo	N_2O	379.51	138.6	17.3	137.5
97	3A2c	Manure management: Sheep	CH_4	2.49	18.9	10.0	16.0
98	3A2c	Manure management: Sheep	N_2O	5.48	138.6	17.3	137.5
99	3A2d	Manure management: Goats	CH_4	34.62	18.9	10.0	16.0
100	3A2d	Manure management: Goats	N_2O	102.90	138.6	17.3	137.5
101	3A2f	Manure management: Horses	CH_4	6.11	18.9	10.0	16.0
102	3A2f	Manure management: Horses	N_2O	5.55	138.6	17.3	137.5
103	3A2h	Manure management: Swine	CH_4	1,034.78	18.9	10.0	16.0
104	3A2h	Manure management: Swine	N_2O	756.37	138.6	17.3	137.5
105	3A2i	Manure management: Poultry	CH_4	839.20	18.9	10.0	16.0
106	3A2i	Manure management: Poultry	N_2O	985.80	138.6	17.3	137.5
107	3B1a	Forest land remaining forest land	CO_2	-42,704.93	59.6	10.2	68.4
108	3B1bi	Cropland converted to forest land	CO_2	-793.85	77.2	15.0	75.7
109	3B1bii	Grassland converted to forest land	CO_2	-11,030.95	77.2	15.0	75.7
110	3B1biii	Wetlands converted to forest land	CO_2	-65.85	18.1	15.0	10.2
111	3B1biv	Settlements converted to forest land	CO_2	-9.59	52.2	15.0	50.0
112	3B1bv	Other land converted to forest land	CO_2	-52.62	52.2	15.0	50.0
113	3B2a	Cropland remaining cropland	CO_2	-1,026.04	118.0	14.1	117.2
114	3B2bi	Forest land converted to cropland	CO_2	5,623.33	146.1	14.1	145.4
115	3B2bii	Grassland converted to cropland	CO_2	-891.27	134.2	15.0	133.2

116	3B2biii	Wetlands converted to cropland	CO_2	-53.32	111.2	15.0	110.2
117	3B2biv	Settlements converted to cropland	CO_2	-8.93	118.2	15.0	117.3
118	3B2bv	Other land converted to cropland	CO_2	-6.17	118.2	15.0	117.3
119	3B3bi	Forest land converted to grassland	CO_2	1,168.70	115.2	15.0	114.2
120	3B3bii	Cropland converted to grassland	CO_2	216.13	134.2	15.0	133.3
121	3B3biii	Wetlands converted to grassland	CO_2	-0.79	117.2	15.0	110.2
122	3B3biv	Settlements converted to grassland	CO_2	-0.35	118.2	15.0	117.3
123	3B3bv	Other land converted to grassland	CO_2	-0.05	118.2	15.0	117.3
124	3B4bi	Forest land converted to wetlands	CO_2	526.56	33.5	15.0	30.0
125	3B4biii	Cropland converted to wetlands	CO_2	513.90	76.5	15.0	75.0
126	3B4biii	Grassland converted to wetlands	CO_2	6.43	76.5	15.0	75.0
127	3B5bi	Forest land converted to wettlements	CO_2	890.65	96.6	18.0	94.9
128	3B5bii	Cropland converted to wettlements	CO_2	1,016.12	76.5	15.0	75.0
129	3B5biii	Grassland converted to Settlements	CO_2	12.37	76.5	15.0	75.0
130	3B6bi	Forest land converted to other land	CO_2	5,335.51	33.5	15.0	30.0
131	3B6bii	Cropland converted to other land	CO_2	1,350.75	76.5	15.0	75.0
132	3B6biii	Grassland converted to other land	CO_2	493.00	76.5	15.0	75.0
133	3C1a	Emissions from biomass burning in forest lands	CH_4	11.35	100.8	10.0	100.3
134	3C1a	Emissions from biomass burning in Forest lands	N_2O	3.16	72.0	10.0	71.3
135	3C1b	Emissions from biomass burning in croplands	CH_4	1,244.59	133.8	53.2	122.7
136	3C1b	Emissions from biomass burning in croplands	N_2O	309.49	113.6	53.2	100.4
137	3C1c	Emissions from Biomass Burning in Grasslands	CH_4	31.78	147.0	53.2	137.0
138	3C1c	Emissions from Biomass Burning in Grasslands	N_2O	9.95	125.1	53.2	113.3
139	3C1d	Emissions from Biomass Burning in Other Land	CH_4	10.80	112.5	51.0	100.3
140	3C1d	Emissions from Biomass Burning in Other Land	N_2O	3.01	87.7	51.0	71.3

141	3C2	Emission from Liming	CO_2	565.79	82.5	106.1	70.7
142	3C3	Emission fromUrea Fertilization	CO_2	1,436.11	53.9	20.0	50.0
143	3C4	Direct N2O Emissions from Managed Soils	N_2O	7,754.11	135.4	50.0	125.8
144	3C5	Indirect N2O Emissions from Managed Soils	N_2O	3,752.55	160.5	50.0	152.5
145	3C6	Indirect N2O Emissions from Manure Management	N_2O	221.90	110.3	12.0	109.7
146	3C7	Rice Cultivations	CH_4	49,693.02	63.2	30.0	55.6
147	4A	Solid Waste Disposal	CH_4	10,438.86	26.8	17.3	20.6
148	4B	Biological Treatment of Solid Waste	CH_4	69.45	40.2	40.0	4.0
149	4B	Biological Treatment of Solid Waste	N_2O	39.44	72.1	40.0	60.0
150	4C1	Waste Incineration	CO_2	528.09	64.0	50.0	40.0
151	4C1	Waste Incineration	CH_4	0.13	94.3	50.0	80.0
152	4C1	Waste Incineration	N_2O	11.38	94.3	50.0	80.0
153	4C2	Open Burning of Waste	CO_2	273.91	66.1	50.0	43.3
154	4C2	Open Burning of Waste	CH_4	377.15	98.6	50.0	85.0
155	4C2	Open Burning of Waste	N_2O	50.70	98.6	50.0	85.0
156	4D1	Domestic Wastewater Treatment and Discharge	CH_4	4,805.66	23.6	19.5	13.2
157	4D1	Domestic Wastewater Treatment and Discharge	N_2O	1,886.55	142.8	142.5	10.0
158	4D2	Industrial Wastewater Treatment and Discharge	CH_4	2,257.05	45.5	32.0	32.4