The Kingdom of Cambodia
Nation Religion King

National GHG Emissions Inventory Report

Prepare for submission to GSSD
by GDANCP

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Assignment details

Development of the national greenhouse gas inventory (GHG-I) and the GHG-I and the mitigation actions chapters of the first biennial update report of the Kingdom of Cambodia.

Project: Forest Carbon Partnership Facility II

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Key messages

- The 2019 edition of the GHG inventory of the Kingdom of Cambodia includes emissions for the years 1994-2016 of the gases CO_2, CH_4, N_2O and HFC and the sectors of Energy, Industrial Processes and Product Use (IPPU), Agriculture, Forestry and Other Land Use (AFOLU) and Waste.

- The inventory has been calculated following the methodologies of the 2006 IPCC Guidelines. The global warming potentials uses are those of the Fourth Assessment Report of IPCC, based on the effects of GHGs over a 100-year time horizon.

- The emissions of greenhouse gases estimated for the total of the inventory including Forestry and Other Land Use (FOLU) are 163 882 Gg of $CO_{2\text{-eq}}$ for year 2016, which is a 284 per cent higher than emissions in 1994. The main driver for this increase in GHG emissions is the deforestation reflected in the emissions of the FOLU sector.

- The major contributor to the GHG emissions during the entire period is the Forest and Other Land Use sector (FOLU), which is driven by the change in carbon stocks due to deforestation and other changes in the land use. The second largest emitter sector in the country is the Agriculture sector. Cambodia has an economy which is strongly marked by the contribution of agriculture to total GDP, and that is also reflected in the emission pattern. In the time span covered by the inventory, Cambodian GDP has experienced a significant expansion, along its population. This is reflected in the increasing trend of the emissions of the third and fourth largest emitter sectors in the country, the Energy and Waste sectors. The small size of the carbon intensive-industrial sector in the country makes the IPPU the fifth contributor the national total GHG emissions.

- Emissions (including FOLU) per capita have increased from 4.00 to 10.44 tonnes $CO_{2\text{-eq}}$/ inhabitant/year. This increase is mainly due to the high deforestation produced in the country. Without FOLU, emissions per capita have increased from 1.47 to 2.09 tonnes CO2-eq/ inhabitant/year due to increasing energy consumption and overall activity levels (GDP). Conversely, GHG emissions (including FOLU) per unit of GDP have been reduced from a 15.41 to 8.26 tonnes $Co_{2\text{-eq}}$/thousand USD/year. Without FOLU, emissions per unit of GDP have decreased from 5.65 to 1.66 tonnes $Co_{2\text{-eq}}$/thousand USD/year. This reduction is due to the fact that the expansion of GDP is significantly higher than the increase of GHG emissions.

1 - Introduction

The 2019 edition of the National Greenhouse Gas (GHG) emissions inventory of the Kingdom of Cambodia covers the GHG emissions of years 1994-2016.

This inventory addresses the estimation of the main direct greenhouse gases: Carbon Dioxide (CO2), Methane (CH4), Nitrous oxide (N2O) and Hydrofluorocarbons (HFC). Due to the lack of information on their occurrence, the emissions of Perfluorocarbons (PFC), Sulphur hexafluoride (SF6) and Nitrogen trifluoride (NF3) have not been estimated. The gases which are considered ozone precursors: carbon monoxide (CO), oxides of nitrogen (NOx), non-methane volatile organic compounds (NMVOCs), and Sulphur dioxide (SO2), which are also reported in national GHG emissions inventories, have not been estimated in an exhaustive manner in all the sectors

Greenhouse gas emission and removal estimates are divided into the main sectors of the 2006 IPCC Guidelines, which are groupings of related processes, sources and sinks:

- Energy
- Industrial Processes and Product Use (IPPU)
- Agriculture, Forestry and Other Land Use (AFOLU)
- Waste

Each sector comprises individual categories (e.g., transport) and sub-categories (e.g., cars). A national total is calculated by summing up emissions and removals for each gas.

Overall, the 2006 edition of the IPCC Guidelines has been followed for estimating the GHG emissions and removals of the inventory. For estimating the emissions of precursors, the Guidelines of EMEP/EEA 2016 have been used, as proposed by IPCC.

The activity data used for developing the inventory is mainly the information which is available at national level and was obtained by the inventory coordinator for the different categories of each sector from the national compilation team. Despite the efforts made, the scarcity of data has been the main challenge for developing estimates in all sectors and emission sources and removals.

In the cases in which the information available at national level was not enough for developing estimates in line with the IPCC guidelines, international sources of data have been used and assumptions made using expert judgment.

All sectors include an improvement plan for improving the quality of the inventory in the future. For all sectors the improvement plan is mainly focused on improving the information available from national sources.

2 - Institutional arrangements and the elaboration of the inventory for the Kingdom of Cambodia

The National Council for Sustainable Development (NCSD) is a high-level inter-ministerial mechanism created by the Royal Kingdom of Cambodia to prepare, coordinate, and monitor implementation of policies, strategies, plans and programmes related to sustainable development. The NCSD is chaired by minister of environment and is supported by the General Secretariat for Sustainable Development (GSSD). As part of the GSDD, The Department of Climate Change (DCC) is responsible for formulation of draft climate change plans and policies and serves as secretariat to the Cambodian Government's focal points for UNFCCC, the Intergovernmental Panel on Climate Change (IPCC), the Kyoto Protocol and the Clean Development Mechanism (CDM) and other mechanisms. DCC also coordinates inter-ministerial Technical Working Groups (TWGs) by sectors and themes (GHG inventory, mitigation, vulnerability and adaptation, and UNFCCC implementation). DCC also supports the climate change activities of the NCSD and acts as the coordinating agency for UNFCCC reporting.

Therefore, the NCSD through the GSSD and the DCC have the overall responsibility for the inventory preparation. Nevertheless, Cambodia does not count yet with a sustainable inventory compilation unit or exhaustive institutional arrangements for inventory planning, preparation and management.

For the development of the 2019 edition of the GHG inventory, the GSSD signed a letter of agreement (LoA) with the General Directorate of Administration for Nature Conservation and Protection (GDANCP) of the Ministry of Environment (MoE) to assist the DCC in the preparation of national greenhouse gas inventory and the inventory chapter of the BUR. Thought this letter, the GDANCP has acted as inventory coordinator for the preparation of the 2019 edition of the inventory. The detailed roles and responsibilities for the 2019 inventory development were the following:

Roles and responsibilities for the development of the GHG-I

Role	Responsibility
Climate Change lead agency	Validation of results, supervision and strategic oversight
Inventory coordinator	Coordinate and oversee the work of international and national consultants.
UNDP coordinator	Oversee the work of the international compilers and supports the coordination with the national inventory coordinator.
International inventory compilers	Estimate the GHG emission inventory, perform quality control processes, write the inventory report and provide capacity building to national compilers.
National inventory Compilers	Gathering activity data, supporting the compilation of GHG emissions estimates and perform quality checks in line with the QA/QC plan.
International QA experts	Carry out the quality assurance of the inventory, in line with the QA/QC plan.
Data providers	Provide the information available as needed for the development of the national inventory.

3 - Trend of emissions

The emissions of greenhouse gases estimated for the total of the inventory including Forestry and Other Land Use (FOLU) are 163 882 Gg of $CO_{2\text{-eq}}$ for year 2016, which is a 284 per cent higher than emissions in 1994. The main driver for this increase in GHG emissions is the deforestation reflected in the emissions of the FOLU sector. Without FOLU, the GHG emissions are 32 871 Gg of $CO_{2\text{-eq}}$ for year 2016, which is a 110 per cent higher than emissions in 1994.

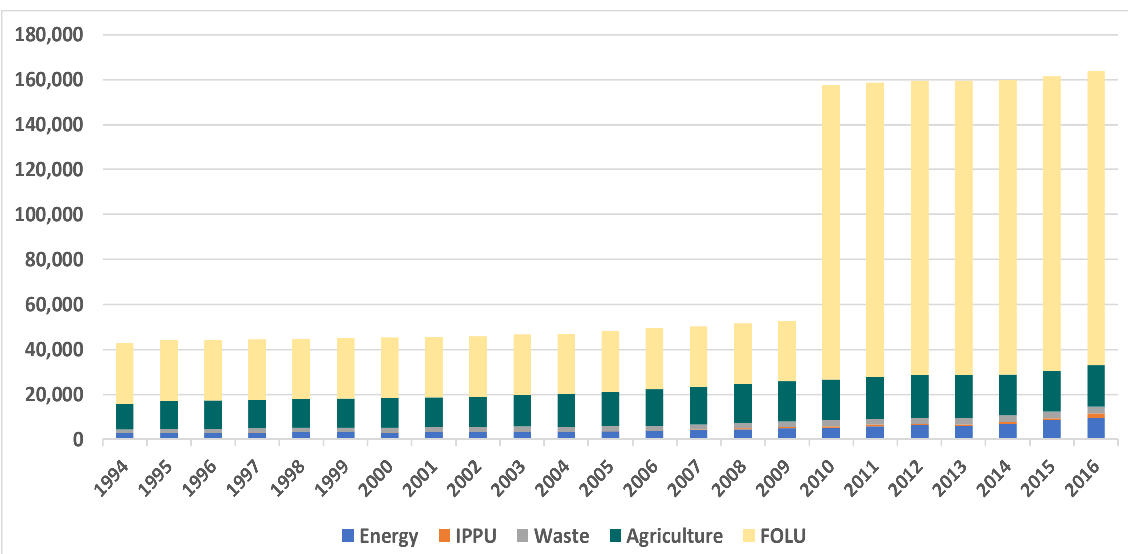
The next table provides an overview of the emissions of each inventory sector for the years 1994, 2000, 2005, 2010, 2015 and 2016.

Trend of emissions (GHG, Gg CO2-eq)

Inventory Sector	1994	2000	2005	2010	2015	2016
Energy	2690.95	3102.73	3454.41	5306.37	8356.31	601.61
IPPU	3.81	6.04	12.73	492.84	1001.38	821.15
Waste	1756.18	2111.61	2415.89	2633.62	2974.53	050.67
Agriculture (3A + 3C)	11202.58	13032.31	15336.38	18136.08	18068.35	8397.67
Forest and Other Land Use (FOLU) (3B)	27018.62	27018.62	27018.62	131011.24	131011.24	31011.24
Total (without FOLU)	15653.52	18252.70	21219.42	26568.91	30400.57	2871.10
Total (with FOLU)	42672.14	45271.32	48238.04	157580.15	161411.82	63882.35

As illustrated in the following figure, the emissions of all sectors present an increasing trend from 1994 to 2016.

GHG emissions; Years 1994-2016 (Gg of CO_2-eq)



The major contributor to the GHG emissions during the entire period is the Forest and Other Land Use sector (FOLU), which is driven by the change in carbon stocks due to deforestation and other changes in the land use.

The second largest emitter sector in the country is the Agriculture sector. Cambodia has an economy which is strongly marked by the contribution of agriculture to total GDP, and that is also reflected in the emission pattern. The main driver for the GHG emissions increase in the agriculture sector is the development of the rise cultivations, whose activity level and emissions increased by a rate of ~2.5 in the period 1994-2016.

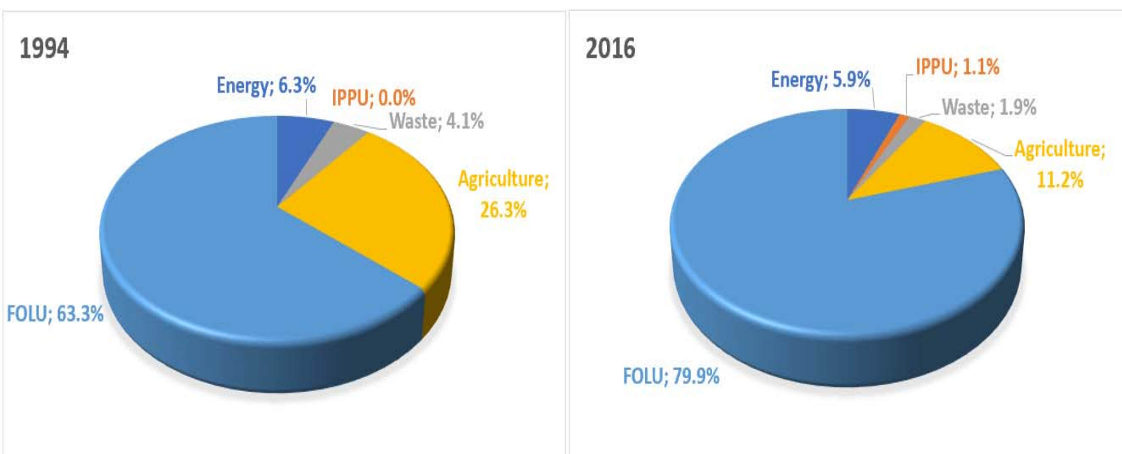
In the time span covered by the inventory, Cambodian GDP has experienced a significant expansion, along its population. This is reflected in the increasing trend of the emissions of the third and fourth largest emitter sectors in the country, the Energy and Waste sectors, respectively. The energy demand has experienced a significant increase, transport sector is expanding, and the population is migrating to cities; all these factors combined led to increasing fuel consumption and higher GHG emissions in the energy sector. The increased population and the changes in waste management and sanitation are the main drivers for the emissions of the waste sector.

Last but not least, the small size of the carbon intensive-industrial sector in the country makes the IPPU the fifth contributor the national total GHG emissions. Nevertheless, IPPU sector emissions experienced a growing expansion in the last period of the series, due to the raising contribution of cement production and the consumption of fluorinated gases.

Emissions (including FOLU) per cápita have increased from 4.00 to 10.44 tonnes CO2-eq/ inhabitant/year. This increase is mainly due to the high deforestation produced in the country. Conversely, GHG emissions (including FOLU) per unit of GDP have been reduced from a 15.41 to 8.26 tonnes Co2-eq/thousand USD/year. This reduction is due to the fact that the expansion of GDP is significantly higher than the increase of GHG emissions.

The following figure shows the percentage of emissions of each inventory sector for years 1994 and 2016.

Percentage of emissions by sector (as of % of CO_2-eq)



The previous figure shows the decreasing contribution to total national emissions in 2016 compared to 1994 in the sectors of energy, waste and agriculture, and the increase in the contribution of FOLU and IPPU.

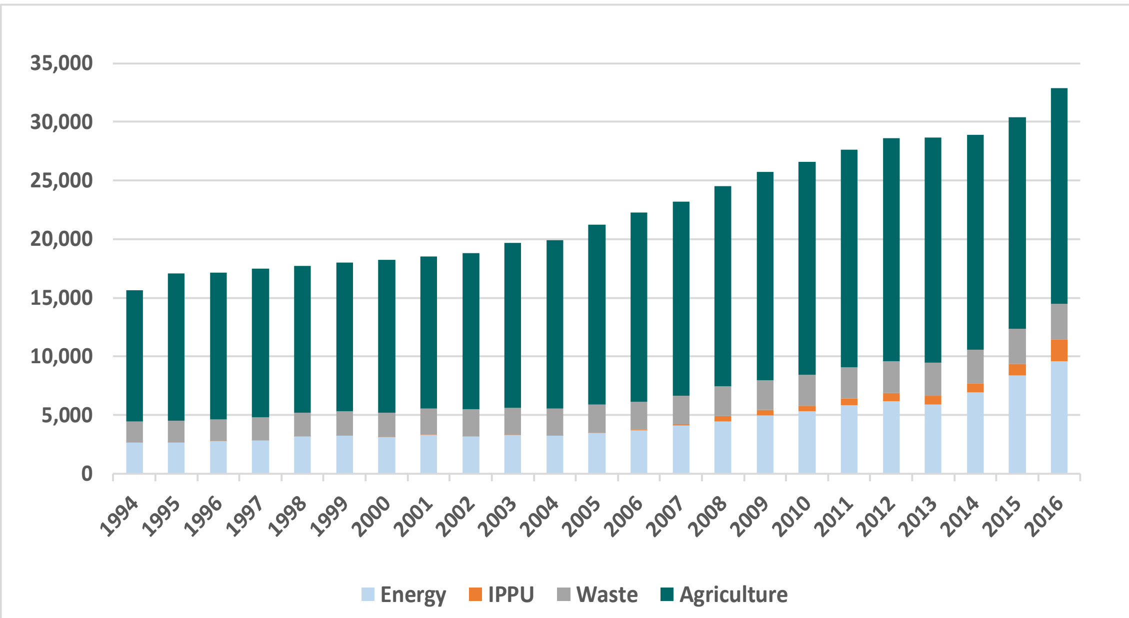
In terms of the contribution of each GHG to national total emissions, CO2 is the main gas emitted, driven by the large contribution of the FOLU sector to national total emissions, followed by CH4, N2O and HFC.

Contribution of each gas to national total emissions with FOLU (%)

Gas	1994	2000	2005	2010	2015	2016
CO_2	69.73%	66.49%	63.32%	86.81%	86.81%	86.73%
CH_4	25.52%	28.55%	31.57%	11.36%	11.30%	11.41%
N_2O	4.75%	4.96%	5.09%	1.76%	1.69%	1.63%
HFC	0.00%	0.00%	0.01%	0.07%	0.20%	0.23%

The following figure provides an overview of the contribution of each sector to national total GHG emissions without considering the FOLU sector.

GHG emissions without FOLU; Years 1994-2016 (Gg of CO_2-eq)



The GHG emissions without the FOLU sector are dominated by the contribution of the agriculture sector and the increasing contributions of the energy and waste sectors. In year 2016, the split of emissions without FOLU by sector is the following: Agriculture 56.0%, Energy 29.2%, Waste 9.3% and IPPU 5.5%.

Without FOLU, emissions per capita have increased from 1.47 to 2.09 tonnes CO2-eq/ inhabitant/year due to increasing energy consumption and overall activity levels (GDP). The emissions per unit of GDP have decreased from 5.65 to 1.66 tonnes Co2-eq/thousand USD/year. This reduction is due to the fact that the expansion of GDP is significantly higher than the increase of GHG emissions.

Without FOLU, the main GHG emitted is CH4, as a result of the large contribution of the agriculture sector, followed by CO2, N2O and HFC.

Contribution of each gas to national total emissions without FOLU (%)

Gas	1994	2000	2005	2010	2015	2016
CO_2	17.47%	16.89%	16.61%	21.77%	29.98%	33.85%
CH_4	69.57%	70.80%	71.77%	67.37%	60.00%	56.88%
N_2O	12.95%	12.30%	11.58%	10.43%	8.96%	8.14%
HFC	0.00%	0.00%	0.03%	0.43%	1.05%	1.13%

As mentioned above, the GHG inventory of the Kingdom of Cambodia includes estimates of greenhouse gases as CO_2, CH_4, N_2O and HFC. Besides, other gases, known as precursors, have been estimated for the energy sector.

The following table shows the emissions estimated by gas and sector for year 2016.

Emissions by category and gas, year 2016

Inventory Sector	CO_2	CH_4	N_2O	HFC*	NO_X	CO	NMVOC	SOx
	(Gg)							
Energy	8845.29	23.04	0.61	NA	43.43	160.46	45.03	32.61
IPPU	1449.46	NA	NA	371.68	NE	NE	NE	NE
Waste	814.55	79.7	0.82	NA	NE	NE	NE	NE
Agriculture (3A + 3C)	17.42	645	7.56	NA	NE	NE	NE	
Forest and Other Land Use (FOLU) (3B)	131011.24	NA	NA	NA	NA	NA	NA	NA
Total (without FOLU)	11127.73	747.87	8.98	371.68	43.43	160.46	45.03	32.61
Total (With FOLU)	142137.97	747.87	8.98	371.68	43.43	160.46	45.03	32.61

Note – HFC data is provided in mass of $CO_{2\text{-}eq}$

The evolution of all gases estimated in the inventory is shown in the following table:

Emissions (with FOLU) by gas (Gg)

Inventory Sector	1994	2000	2005	2010	2015	2016
CO_2	29753.96	30102.41	30544.23	136796.33	140125.72	142137.97
CH_4	435.61	516.92	609.19	715.96	729.63	747.87
N_2O	6.80	7.54	8.25	9.30	9.14	8.98
HFC*	-	-	6.32	114.10	320.24	371.68
NOx	14.46	16.70	17.27	31.80	39.20	43.43
CO	68.62	69.85	66.27	138.80	137.61	160.46
NMVOC	23.44	25.22	23.11	54.04	43.99	45.03
SO_2	2.51	3.15	4.08	14.71	27.40	32.61

Note – Emissions of HFC are provided in terms of Gg $CO_{2\text{-}eq}$.

Preface

This document contains product 04 of the project “Development of the national greenhouse gas inventory (GHG-I) and the GHG-I and the Mitigation Actions chapters of Cambodia’s first Biennial Update Report”, funded by UNDP within the project Forest Carbon Partnership Facility II.

The Centre Interprofessional Technique d´Etudes de la Pollution Atmospherique (Citepa) subcontracting Gauss International Consulting S.L., was awarded the contract for developing the project, which started on the 01/08/2018 and will end on the 30/04/2018, as specified in the contract signed between the UNDP and CITEPA. For the development of the project, Citepa and Gauss (hereinafter international team) work in close collaboration with the National GHG-I Team and the Cambodian REDD+ taskforce and in consultation with relevant national stakeholders.

This document presents the revised draft of the edition 2019 of the GHG emissions inventory of Cambodia.

1. Introduction

This document presents the 2019 edition of the National Greenhouse Gas (GHG) emissions inventory of the Kingdom of Cambodia that covers the GHG emissions of years 1994-2016. This inventory has been estimated following the 2006 IPCC Guidelines, and has been compiled with the involvement of a national inventory compilation team and the focal points of the main line ministries of the country.

Gases

This inventory addresses the estimation of the main direct greenhouse gases: Carbon Dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O) and Hydrofluorocarbons (HFC). Due to the lack of information on their occurrence, the emissions of Perfluorocarbons (PFC), Sulfur hexafluoride (SF_6) and Nitrogen trifluoride (NF_3) have not been estimated.

The gases which are considered ozone precursors: carbon monoxide (CO), oxides of nitrogen (NOx), non-methane volatile organic compounds (NMVOCs), and Sulphur dioxide (SO_2), which are also reported in national GHG emissions inventories, have not been estimated in an exhaustive manner in all the sectors (the reasons are explained in the corresponding sections of this national inventory report).

Sectors and categories

Greenhouse gas emission and removal estimates are divided into the main sectors of the 2006 IPCC Guidelines, which are groupings of related processes, sources and sinks:

- Energy
- Industrial Processes and Product Use (IPPU)
- Agriculture, Forestry and Other Land Use (AFOLU)
- Waste

Each sector comprises individual categories (e.g., transport) and sub-categories (e.g., cars). A national total is calculated by summing up emissions and removals for each gas.

An exception is emissions from fuel use in ships and aircraft engaged in international transport which is not included in national totals but is reported separately.

Reporting of emission estimates is generally organised according to the sector actually generating emissions or removals. There are some exceptions to this practice, such as CO_2 emissions from biomass combustion for energy, which are reported in AFOLU Sector as part of net changes in carbon stocks.

Methodology

Overall, the 2006 edition of the IPCC Guidelines has been followed for estimating the GHG emissions and removals of the inventory. For estimating the emissions of precursors, the Guidelines of EMEP/EEA 2016[1] have been used, as proposed by IPCC.

The details of the methodology used for each category are specified in the corresponding methodological sections of the report.

Both the 2006 IPCC and the EMEP/EEA 2016 Guidelines provide methodologies of different complexity (tiers 1 to 3) which can be used in different circumstances and are generally based in linear models.

The basic equation for estimating the emission of one category is the following:

$$\{1\} \qquad Emissions_{c,g,t} = AD_{c,t} \cdot EF_{c,g,t}$$

Where

$Emissions_{c,g,t} = emissions\ of\ category\ c, gas\ g\ and\ year\ t$
$AD_{c,t} = activity\ data\ of\ category\ c, year\ t$
$EF_{c,g,t} = Emission\ factor\ of\ emissions\ of\ category\ c, gas\ g\ and\ year\ t$

The estimates of emissions and removals– in its simplest form- correspond to a direct relation between an emission factor (emission rate by unit of activity) and the activity data which represents the corresponding level of activity.

The activity data describes the annual magnitude of one activity (for instance, cement production, fuel consumption, etc, at national level, for one category and one year).

The emission factor is the amount of gas emitted by unit of activity (for instance, Gg of CH_4 by tonne of fuel consumed). Default emission factors are provided by the 2006 IPCC Guidelines for the direct GHGs and by EMEP/EEA 2016 Guidelines for the precursors.

In many cases, the activity data available do not correspond to the emission factor available or used. In these cases, the data need to be converted using conversion factors. In such cases, the equation is the following:

$$\{2\} \qquad Emissions_{c,g,t} = AD_{c,t} \cdot EF_{c,g,t} \cdot Conversión\ factor$$

All the equations require of a statistical value which needs to be obtained from the entities which collect regularly the data.

[1] https://www.eea.europa.eu/publications/emep-eea-guidebook-2016

There are several IPCC methods that can be used for estimating emissions and removals. The choice of one method depends on the availability of data, the current circumstances of the country and the human and financial resources to elaborate the inventory.

In the IPCC terminology, the simplest method is “tier 1”, while “tier 2” and “tier 3” are more advanced methods.

Tier 1 methods use default emission factors provided by 2006 IPCC Guidelines which require basic national activity data.

Tier 2 methods use more detailed methodologies using national specific emission factors, technology specific emission factors and/or regional emission factors and require data which certain level of disaggregation (higher breakdown than tier 1).

Tier 3 methods use models, data from surveys or direct measurements.

It is important to use higher tier methods for those categories which the country considers more important. For this reason, the first phase in the inventory development was to analyse the key categories using the results of inventories previously reported in the first and second national communication. In practice, tier 1 methodologies are used for categories with low impact in the inventory, tier 2 methodologies are used for categories with significant impact on the inventory, as much as the national circumstances allow it, and tier 3 methodologies are used in categories with very high impact on the inventory (improvement plans should focus in obtaining progressively more detailed and national specific data for enabling the country to use higher tiers and thus produce much more accurate and precise emissions and removals estimates).

Nevertheless, due to the lack of availability of data and the absence of national specific emission factors, the emissions and removals estimates have been performed using a tier 1 methodology for most categories, gases and years.

Specifically, the categories, gases and years for which a tier 2 methodology is applied are the following:

- Cement production CO_2 emissions for the years 2007-2015, as plant specific data on clinker production is available.
- Land CO_2 emissions for the years 1994-2016, as the calculations for the lands are based on a comprehensive monitoring of the land use and a country specific estimate for each type of land.

Data Sources

The activity data used for developing the inventory is mainly the information which is available at national level and was obtained by the inventory coordinator for the different categories of each sector from the national compilation team. Despite the efforts made, the scarcity of data has been the main challenge for developing estimates in all sectors and emission sources and removals.

In the cases in which the information available at national level was not enough for developing estimates in line with the IPCC guidelines, international sources of data have been used and assumptions made using expert judgment.

All sectors include an improvement plan for improving the quality of the inventory in the future. For all sectors the improvement plan is mainly focused on improving the information available from national sources.

Regarding the emission factors and other coefficients, the 2006 IPCC Guidelines were used as a primary source of information. Nevertheless, the Guidelines have been complemented with other sources when necessary. All the cases in which the 2006 IPCC Guidelines have not been used are specified in the report.

Global Warming Potentials

The Global Warming Potential (GWP) was developed to allow comparisons of the global warming impacts of different gases. The larger the GWP, the more that a given gas warms the Earth compared to CO_2 over a time period. The time period usually used for GWPs is 100 years. GWPs provide a common unit of measure, which allows to add up emissions estimates of different gases and thus to compile a national GHG inventory.

In the Conference of the Parties (COP) decisions, Parties may use GWPs to reflect their inventories and projections in CO_2 eq terms. In such cases, the 100-year time-horizon values provided by the IPCC in its Special Reports should be used.

In 2002 the COP by its decision 17/CP.8 decided that non-Annex I Parties wishing to report on aggregated GHG emissions and removals expressed in CO_2 eq should use the “1995 IPCC GWP Values” based on the effects of GHGs over a 100-year time horizon. At the same time, by its decision 18/CP.8, it decided that Annex I Parties should report aggregate emissions and removals of GHGs, expressed in CO2 eq using the same “1995 IPCC GWP Values” based on the effects of GHGs over a 100-year time horizon.

In 2013, under the framework of the UNFCCC reporting guidelines on annual inventories for Annex I Parties, the COP, by decision 24/CP.19, decided that, from 2015, the GWPs used to calculate the CO_2 equivalence of emissions and removals of GHGs shall be, also those listed in the column entitled “Global warming potential for given time horizon” in table 2.14 of the errata to the contribution of Working Group I to the Fourth Assessment Report of the IPCC, based on the effects of GHGs over a 100-year time horizon.

Under the Convention, the Subsidiary Body for Scientific and Technological Advice (SBSTA) 44 (2016) noted that the COP requested the Ad Hoc Working Group on the Paris Agreement (APA) to elaborate guidance for accounting for Parties’ nationally determined contributions which ensures that accounting is in accordance with common metrics assessed by the IPCC (1/CP.21, paragraph 31). Therefore, the SBSTA agreed to defer the consideration of common metrics to SBSTA 46 (May 2017) so as to be able to take into account deliberations under the APA. During SBSTA 47 (November 2017) Parties recognized that further consideration of common metrics by the APA was necessary and agreed to resume consideration of common metrics at SBSTA 50 (June 2019), so as to be able to take into account the deliberations under the APA on this matter. The APA concluded its deliberations at CMA 1 (December 2018), and Parties agreed that Parties account for anthropogenic emissions and removals in accordance with common metrics assessed by the IPCC and in accordance with decision 18/CMA.1 (decision 4/CMA.1, annex II, paragraph 1(a)). Pursuant the modalities, procedures and guidelines (MPGs) for the transparency framework for action and support adopted by decision 18/CMP.1, Parties agreed to use the 100-year time-horizon GWP values from the Fifth Assessment Report of the IPCC, or 100-year time-horizon GWP values from a subsequent IPCC assessment report as agreed upon by the CMA, to report aggregate emissions and removals of GHGs, expressed in CO2 eq. (decision 18/CMA.1, annex, paragraph 37).

In order to prepare an inventory aligned with the second commitment period of the Kyoto protocol of Annex I Parties using 2006 IPCC Guidelines, the GWP used for the 2019 Edition of the Cambodian GHG inventory are the 100-year time-horizon GWP values from the errata table of the Fourth Assessment Report of the IPCC.

Notation keys

The use of Notation keys is a good practice for fulfilling the reporting tables contained in inventory reports. Notation keys are needed when the estimates of emissions and sinks are not made or if there is any clarification needed for a specific source when a numeric value is not provided. Notation keys are used to account for completeness and transparency in reporting.

Table 1 – Notation keys

Notation Key	Definition	Explanation
NE	Not estimated	Emissions and/or removals occur but have not been estimated or reported.
IE	Included elsewhere	Emissions and/or removals for this activity or category are estimated and included in the inventory but not presented separately for this category. The category where these emissions and removals are included should be indicated (for example in the documentation box in the correspondent table).
C	Confidential information	Emissions and/or removals are aggregated and included elsewhere in the inventory because reporting at a disaggregated level could lead to the disclosure of confidential information.
NA	Not applicable	The activity or category exists but emissions and removals are considered never to occur.
NO	Not occurring	An activity or process does not exist within a country.

Source: Chapter 8; volume 1, 2006 IPCC Guidelines

2. National system

In the context of national GHG emission inventories, a national system is the way in which a country prepares its inventory. The design and establishment of an inventory national system is a requirement for developed countries (Annex I Parties) under the Convention. The guidelines for national systems for Annex I parties[2] provides the following definition:

"*A national system includes all institutional, legal and procedural arrangements made within a Party included in Annex I for estimating anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, and for reporting and archiving inventory information*".

Developing countries (non-Annex I Parties) under the Convention are not required to establish GHG emissions inventory national systems. However, the guidelines for the preparation of national communications and biennial update reports for non-annex I parties include similar information provisions, as follows:

Decision 17/CP.8, annex, paragraph 13: "*Non-Annex I Parties are encouraged to describe procedures and arrangements undertaken to collect and archive data for the preparation of national GHG inventories, as well as efforts to make this a continuous process, including information on the role of the institutions involved*".

Aiming at fulfilling the information provision for the Biennial Update Report (BUR) and National Communication (NC), this section includes a description of the institutional arrangements in place in Cambodia for the preparation of the GHG emissions inventory, as well as a description of the inventory preparation and management procedures established that have enabled the preparation of the inventory.

The development of GHG emission inventory is framed under the preparation of the First BUR of the country. Hence, references are made to the arrangements in place for the development of the first BUR of Cambodia.

2.1. Institutional arrangements for compiling GHG inventory

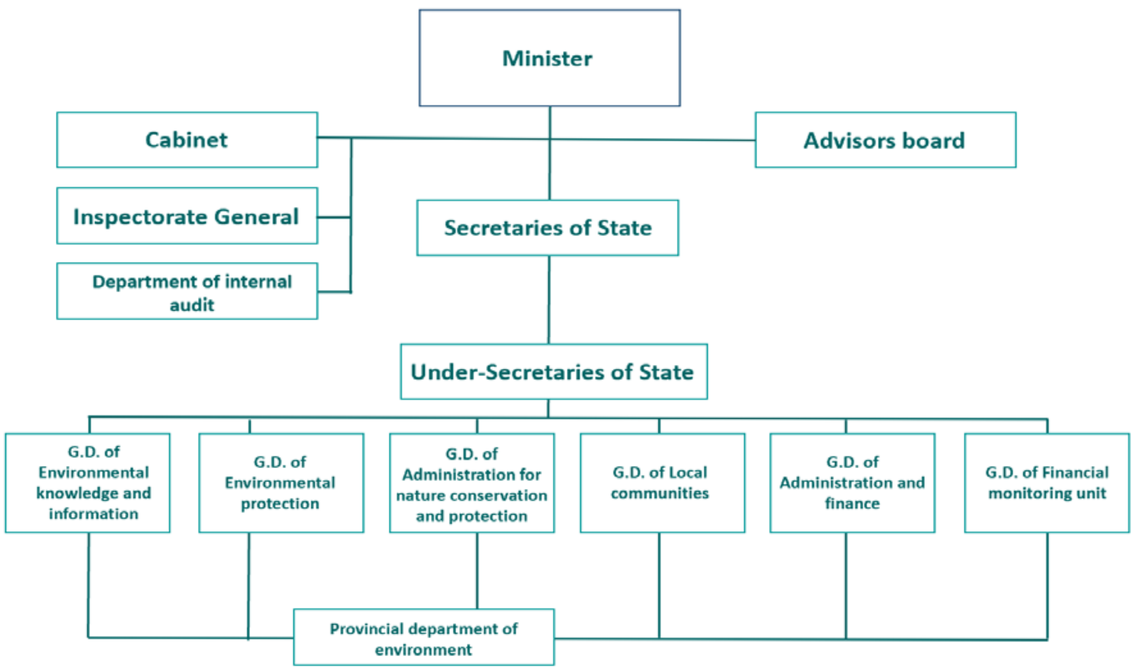
In the fifth mandate of the Royal Government of Cambodia, the Ministry of Environment (MoE) was officially reformed aiming at strengthening the function of natural resource management and ensuring environmental quality management in the context of sustainable development. Along the reform of the MoE, the National Council for Sustainable Development (NCSD) was established by the sub-decree No. 59 dated 18 May 2015 with the objective of improving the inter-ministerial coordination for addressing the sustainable development challenge. Thus, the NCSD is a high-level inter-ministerial mechanism created to prepare, coordinate, and monitor the implementation of policies, strategies, plans and programmes related to sustainable development. The NCSD is chaired by minister of environment and is supported by the General Secretariat for Sustainable Development (GSSD). As part of the GSDD, The Department of Climate Change (DCC) is responsible for formulation of draft climate change plans and policies and serves as secretariat to the Cambodian Government's focal points for UNFCCC, the

[2] Decision 19/CMP.1

Intergovernmental Panel on Climate Change (IPCC), the Kyoto Protocol and the Clean Development Mechanism (CDM) and other mechanisms. DCC also coordinates inter-ministerial Technical Working Groups (TWGs) by sectors and themes (GHG inventory, mitigation, vulnerability and adaptation, and UNFCCC implementation). DCC also supports the climate change activities of the NCSD and acts as the coordinating agency for UNFCCC reporting.

It is also worth highlighting that the Cambodia REDD+ programme was transferred from Ministry of Agriculture, Forestry and Fisheries to the MoE and is now under direct management and implementation of the General Directorate of Administration for Nature Conservation and Protection (GDANCP) within the MoE. The Cambodia REDD+ programme and its secretariat have key responsibilities in formulating forest policies, strategic and action plans aligning with Cancun decision and Warsaw framework on REDD+.

Figure 1 – Simplified organization chart of the Ministry of Environment

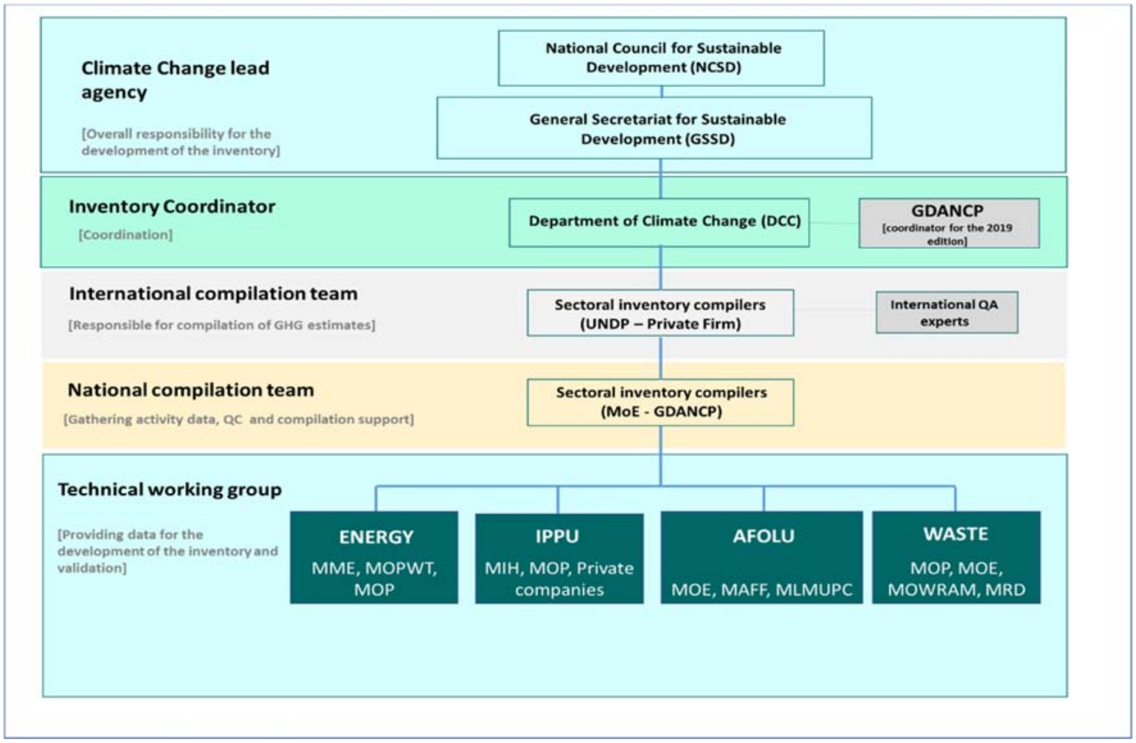


Note – G.D. General Directorate

The NCSD through the GSSD and the DCC have the overall responsibility for the inventory preparation. Nevertheless, Cambodia does not count yet with a sustainable inventory compilation unit or exhaustive institutional arrangements for inventory planning, preparation and management.

For the development of the 2019 edition of the GHG inventory, the GSSD signed a letter of agreement (LoA) with the GDANCP to assist the DCC in the preparation of national greenhouse gas inventory and the inventory chapter of the BUR. Thought this letter, the GDANCP has acted as inventory coordinator for the preparation of the 2019 edition of the inventory. A national and an international compilation team were temporally contracted for the preparation of the inventory.

Figure 2 – Structural arrangements for the GHG inventory compilation 2016



(Note: this diagram is designed for this third GHG-I only)

For the development of the 2019 edition of the GHG emission inventory, which covers the years 1994-2016, the detailed roles and responsibilities for the inventory development are the following:

Table 2 – Roles and responsibilities for the development of the GHG-I

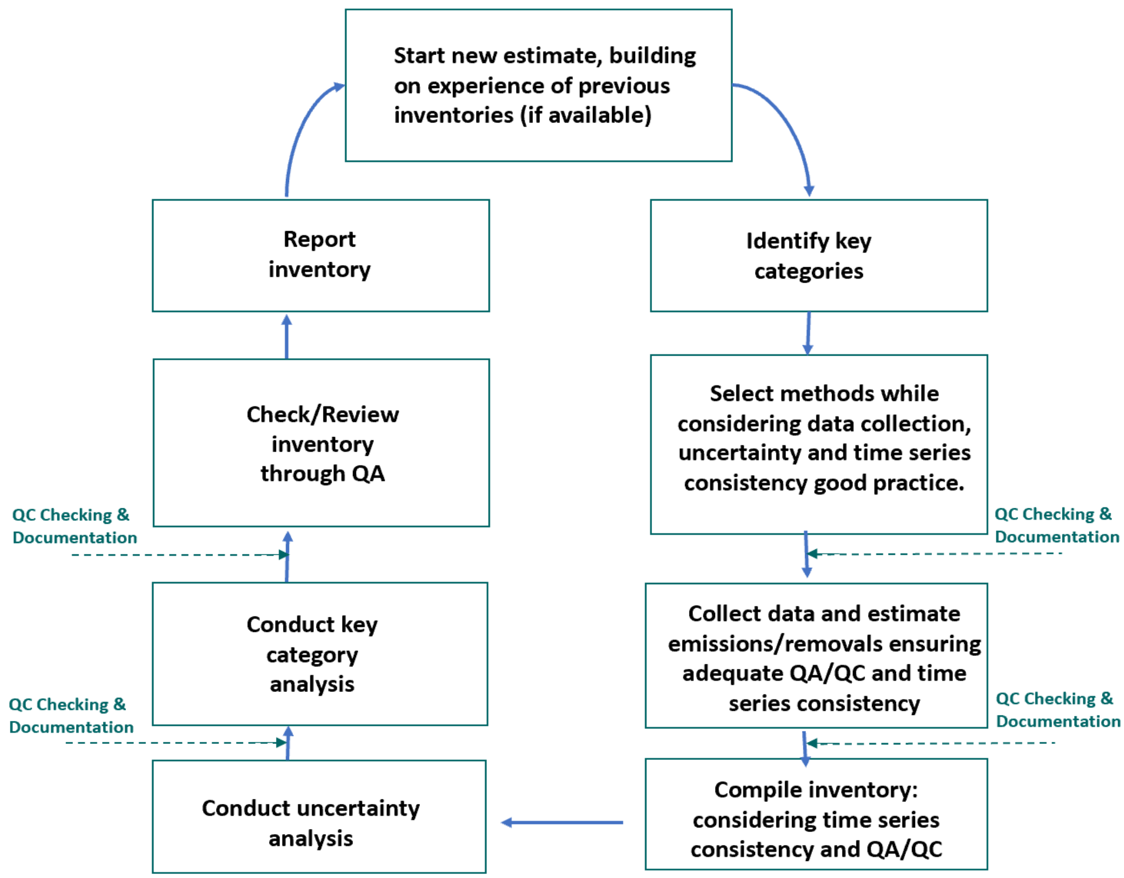
Role	Responsibility
Climate Change lead agency	Validation of results, supervision and strategic oversight
Inventory coordinator	Coordinate and oversee the work of international and national consultants.
UNDP coordinator	Oversee the work of the international compilers and supports the coordination with the national inventory coordinator.
International inventory compilers	Estimate the GHG emission inventory, perform quality control processes, write the inventory report and provide capacity building to national compilers.
National inventory Compilers	Gathering activity data, supporting the compilation of GHG emissions estimates and perform quality checks in line with the QA/QC plan.
International QA experts	Carry out the quality assurance of the inventory, in line with the QA/QC plan.
Data providers	Provide the information available as needed for the development of the national inventory.

2.2. Inventory planning, inventory preparation and inventory management

The 2006 IPCC Guidelines for the development of national GHG emission inventories recommend a set of steps to follow for the inventory compilation. These steps are the *inventory development cycle*, which encompass all the tasks needed to produce a national GHG emission inventory in line with good practice.

The following figure illustrates the inventory development cycle for Cambodia, based on the steps proposed by 2006 IPCC Guidelines.

Figure 3- Inventory development cycle in Cambodia



Source: Adapted to Cambodia based on 2006 IPCC Guidelines, Volume 1, Chapter 1.

A description of all tasks developed within each of the steps of the inventory cycle for the inventory edition of 2019 is provided below.

Identification of key categories

Key category analysis is the IPCC's method for deciding which emissions or removals categories to prioritize in GHG inventory estimation (categories that should use progressively higher tier methods to increase accuracy and decrease uncertainty of the estimates).

A category is key if, when categories are ordered by magnitude, it is one of the categories contributing to 95% of total national emissions or removals, or to 95% of the trend in national emissions or removals.

Key category analysis may need to be iterative; the initial ordering may need to be undertaken using Tier 1 methods, since it is not yet known which categories are keys.

The inventories reported in the First and the Second National Communications were analysed for a preliminary identification of key categories.

The first National Communication was submitted in 2002 and included the emissions of the inventory year of 1994. The second National Communication was submitted in 2016 and included the emissions of the inventory year 2000.

Based on the most updated NC, total national GHG emissions of the country for year 2000 are -456.81kt CO_2-eq. Energy sector emissions are 2,767.30 kt CO_2-eq, Agriculture 21,112.16 kt CO_2-eq, Land Use, Land Use Change and Forestry (LULUCF) -24,565.50 kt CO_2-eq and waste 229.24 kt CO_2-eq. These figures illustrate that the AFOLU sector (Agriculture plus LULUCF, as of 2006 IPCC Guidelines) is dominant for explaining national total GHG emissions of the country. The IPPU sector was not reported in the Second National Communication, but it was in the First National Communication.

For their contribution to the level of emissions, the categories of transport, energy industries and forestry and other land use were identified as key categories.

For its possible contribution to the trend (i.e. the change of emissions from the first to the second national communication), the categories of solid waste disposal, rice cultivation, cement production and manufacturing industries were identified as key categories.

Data Collection

The development of the GHG emission inventory was based on the information available at national level that could be used for estimating the emissions of the different emission sources of the Common Reporting Format (CRF) and the 2006 IPCC Guidelines.

The 2019 inventory edition started from an initial planning phase for developing a detailed work plan for the development of the inventory, considering the prospective information requirements for implementing tier 1 methodologies. Accordingly, data questionnaires by sector (for the Energy, Industrial Processes and Product Use, Waste and Agriculture, Forestry and Other Land Use sectors) were generated and presented to possible data providers and stakeholders.

These questionnaires were used for gathering information from official sources.

The data gathered from official sources was complemented by international sources or assumptions. All data sources and assumptions are specified in the calculation files and in this national inventory report to ensure the transparency of the estimates.

Finally, the cases in which there was no data from national sources, proposals were performed in the improvement plans at sectoral level.

The following table shows all the data sources by emission source as used for the 2019 GHG emission inventory edition.

Table 3 – Main sources of information used for the development of the inventory

Sector	Description of the data	Data Provider
Energy	Energy statistics for the period 2010-2015	Economic Research Institute for ASEAN and East Asia (ERIA)
	Energy balances 2010-2016	Ministry of Mines and Energy
	Energy statistics for the period 1995-2012	Association of South East Nations (ASEAN)
IPPU	Production data for years 2014-2017	Ministry of Industry and Handicrafts
	Cement Production capacity and plant year of installation	Different sources online such as industrial papers and news on starting industrial operations
	Production data from one cement production plant	One producer company
	Fuel (Lubricant) consumption data	Cambodia Energy Statistics – ERIA and the Ministry of Mines and Energy
	Cambodia HFC inventory for the period 2012-2015	The National Ozone Unit of the Ministry of Environment
	Population and GDP data sources from period 1950-2016	CDB data, NCDD, Socio-economic survey and World bank data
AFOLU	Crops data	Animal populations, crop areas and productions from Ministry of Agriculture, Forestry and Fisheries (MAFF).
	Livestock	
	Land activity data for period 2006-2010 and 2010-2014	Cartography matrix from the work developed under the preparation of the Forest Reference Level
	Biomass burning from rice cultivation	Vibol, S., & Towprayoon, S. (2010). Estimation of methane and nitrous oxide emissions from rice field with rice straw management in Cambodia. Environmental monitoring and assessment, 161(1-4), 301-313.
	Rice cultivation data period before 2004	MAFF publications for both wet and dry seasons
	Rice cultivation data period since 2005	FAOSTAT
Waste	Population data	Data from the National Committee for sub-national Democratic Development complemented with the world bank database
	GDP data	GDP from the MOP complemented with the world bank database
	Waste composition	Study “State of Waste Management in Phnom Penh, Cambodia”, UNEP 2018. Available at

Sector	Description of the data	Data Provider
	Waste generation	Ministry of Environment
	Amount of dung used for producing biogas	Hyman, J., & Bailis, R. (2018). Assessment of the Cambodian National Biodigester Programme. Energy for Sustainable Development, 46, 11-22.
		Energy balance of the Ministry of Mines and Energy
	Protein consumption	FAO data
	Percentage of people open burning waste	Yut S. and Seng B., 2018. KAP on waste management (data of 2012)

Inventory compilation

The inventory compilation was performed using Excel worksheets, which include the raw information used for the estimation of the GHG emissions of each category, the coefficients used, the results obtained, and the QA/QC procedures followed. These Excel files were developed to be self-explanatory and can be used as a starting point for developing future national inventories. These are at the same time working files and an inventory excel database.

The 2006 IPCC Software was used only as a complimentary approach, just for QA purposes. The reason for doing that is the limited flexibility of the software for developing national tier2/tier3 approaches, the limitations for being used as a database (for instance, for including raw data as provided by data providers) and also for its constraints regarding national specific calculations to be done on the parameters used such as activity data, emission factors or other coefficients.

Several worksheets were developed by sector. In general, the worksheets follow the structure proposed by IPCC in its calculation worksheets, available at https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html.

The overall structure of the worksheets is the following:

- Sheet “Introduction”: this sheet includes a description of the objective of the file, the categories or emission sources considered in the file, the description of the activity data used and the list of sheets in the file.
- Sheet “Summary table”: This sheet includes the sectoral report table for the sector.
- Sheet “Results”: this sheet provides the results for all the time series for the different gases estimated in both CO_2-eq and mass.

The calculation sheets include links to the raw data used in the calculations, so it can be easily tracked. To the extent possible, a system of colors has been used: sheets coloured in light red and light yellow are raw data as provided by different data providers. Sheets coloured in green contain the calculations, results and key methodological variables used for the development of the inventory.

QA/QC Plan

A QA/QC plan has been developed to describe the Quality Assurance and Quality Control procedures in place to ensure the datasets meet the quality requirements and to explain the data processing steps required for producing the datasets.

The QA/QC plan covers the following processes:

- GHG inventory management, comprising all activities that are necessary for the planning and preparation of the inventory in order to ensure the accomplishment of the above-mentioned objectives and principles.
- Quality control that is directly related to the estimation of emissions. The process includes activities related to (a) data inquiry, collection and documentation, (b) methodological choice in accordance with the 2006 IPCC Guidelines, (c) quality control checks for data from secondary sources and (d) record keeping.
- Archiving inventory information, comprising activities related to centralised archiving of inventory information and the compilation of the national inventory report.
- Quality assurance, comprising activities related to the different levels of review processes including the review of input data from experts, if necessary, and comments from the validation workshop with all relevant national stakeholders.
- Estimation of uncertainties, defining procedures for estimating and documenting uncertainty estimates per source / sink category and for the whole inventory.
- Inventory improvement that is related to the preparation and the justification of any recalculations or the generation of new estimates.

The objectives of the QA/QC Plan are the following:

1. Compliance with the 2006 IPCC guidelines and the UNFCCC reporting guidelines while estimating and reporting emissions/removals.
2. Continuous improvement of GHG emissions/removals estimates.
3. Timely submission of necessary information in compliance with relevant requirements defined in international conventions, protocols and agreements.

The five principles for this QA/QC plan are shown in the table below. These principles are interrelated and apply at various levels in the data compilation and reporting processes.

Table 4 – Guiding principles of the QA/QC

Principles	Procedures in place to quality check if the principle is implemented
Transparency means clear documentation and reporting at a level of disaggregation that sufficiently allows individuals other than the compiler of the inventory to understand how the inventory was compiled. The transparency of emission reporting is fundamental to the effective use, review and continuous improvement of the inventory.	Check if documentation within the spreadsheets shows data inputs, calculations and outputs. Check if the chapters and sections within the NIR provide the activity data and emission factors with the sources used, explain the methods used and summarise the data set.

Principles	Procedures in place to quality check if the principle is implemented
Consistency means that estimates for any different inventory years, gases and source categories are made in such a way that differences in the results between years and source categories reflect real differences in emissions. Annual emissions, as far as possible, should be calculated using the same method and data sources for all years, and resultant trends should reflect real fluctuations in emissions and not the changes resulting from methodological differences.	Check if the same methods and the same data sources are used for the whole time series.
Comparability means that the national inventory is reported in such a way that allows it to be compared with national inventories of other Parties. This can be achieved by using accepted methodologies and by using the reporting templates such as those provided in the 2006 IPCC Guidelines.	Check if the same IPCC guidelines for the methodologies and reporting templates have been used for the whole inventory and for the same group of gases (GHG or precursors).
Completeness means that estimates are reported for all gases, all relevant source categories and all years and for the entire territorial areas of Parties covered by the reporting requirements set forth in the provisions of the Convention and its protocols.	Specific checks have to be made to ensure that estimates are provided for all gases, all source categories existing in the country and the whole national territory. Check if emissions from international transport are not part of the totals but provided as memo items.
Accuracy means that emissions are neither overestimated nor underestimated, as far as can be judged and with uncertainties reduced as far as practicable. This implies that Parties will endeavour to remove bias from the inventory estimates and minimize uncertainty.	Check if uncertainty analysis is undertaken and improvement plans proposed. Check if the most appropriate and up to date data sources and methods are used.

The accomplishment of the above-mentioned objectives can only be ensured by the implementation, from all the members of the Inventory Team and the external peer reviewers, of the QA/QC procedures included in the plan for:

- data collection and processing,
- applying methods consistent with 2006 IPCC Guidelines for calculating / recalculating emissions or removals,
- making quantitative estimates of inventory uncertainty,
- archiving information and record keeping and
- compiling national inventory reports.

Section Results of the QA/QC presents the results of the quality control and quality assurance carried out for the 2019 edition of the Cambodian GHG inventory.

Documentation and archiving

For the development of the 2019 edition of the inventory, an electronic platform was dedicated specifically for archiving the information used, the files generated and all the reports and supporting information used for the preparation of the inventory. This platform was managed and oversee by the coordinator of the GHG inventory.

The main objectives of the archiving system are preventing information loss, and facilitate the update of future inventories. The information archives will be also used for providing information in the technical analysis of the BUR.

3. GHG emissions inventory – edition 2019

The following sections provide information about the results obtained, data used, methodology followed by category of emissions and removals. This information corresponds to the 2019 edition of the national GHG inventory of the Kingdom of Cambodia. The nomenclature followed is the one used by the 2006 IPCC Guidelines, as follows:

Table 5 – Nomenclature used

Inventory sector	Code
Energy	1
Industrial Process and Products Use (IPPU)	2
Agriculture, Forest and Other Land Use (AFOLU)	3
Waste	4

Each sector comprises individual categories (in capital letter), sub-categories (number) and sources/sinks (lowercase letter). A complete list of codes, categories and emissions, are provided in the reporting tables in each section of the report.

Overall, the 2006 IPCC Guidelines have been followed for estimating the GHG emissions and removals of the inventory. For estimating the emissions of precursors, the EMEP/EEA 2016 Guidelines have been used, as proposed by IPCC.

The global warming potentials used for the calculation of the total GHG emissions are those of the AR4, as follows:

Table 6 - Global Warming Potentials (GWP) used

Global Warming Potential	
Gas	GWP
CO_2	1
CH_4	25
N_2O	298
HFC134a	1 430
HFC125	3 500
HFC143a	4 470
HFC32	675
HFC-227ea	3 220

Source: IPCC Fourth Assessment Report (AR4)

3.1. Emissions trends (1994-2016)

This report presents the results, methodologies and information used for estimating the GHG emissions of the Kingdom of Cambodia for the years 1994-2016 for the sectors of Energy, Industrial process and Products Use (IPPU), Agriculture, Forestry and Other Land Use (AFOLU) and Waste.

The emissions of direct Greenhouse gases are pondered using the global warming potentials extracted from the IPCC Fourth Assessment Report (AR4), in terms of gigagrams (Gg) or kilotonnes (kt) of CO2-eq for the CO2, CH4, N2O and HFC. PFC, SF6 and NF3 have not been estimated due to the lack of information available.

The emissions of greenhouse gases estimated for the total of the inventory including Forestry and Other Land Use (FOLU) are 163 882 Gg of CO2-eq for year 2016, which is a 284 per cent higher than emissions in 1994. The main driver for this increase in GHG emissions is the deforestation reflected in the emissions of the FOLU sector. Without FOLU, the GHG emissions are 32 871 Gg of CO2-eq for year 2016, which is a 110 per cent higher than the emissions in 1994.

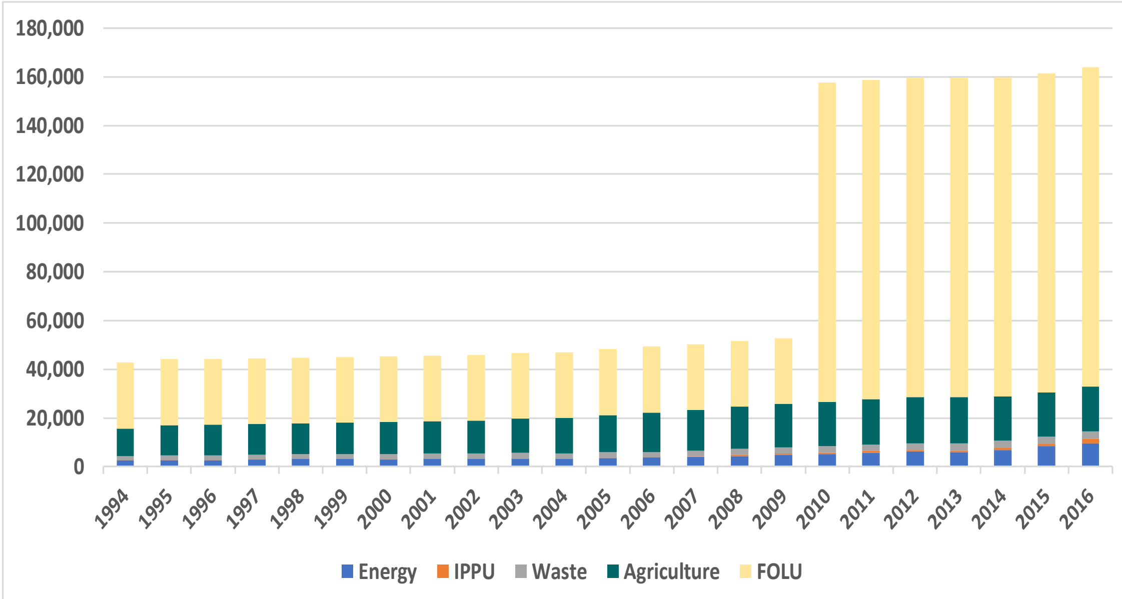
The next table provides an overview of the emissions of each inventory sector for the years 1994, 2000, 2005, 2010, 2015 and 2016.

Table 7- Trend of emissions (GHG, Gg CO2-eq)

Inventory Sector	1994	2000	2005	2010	2015	2016
Energy	2 690.95	3102.73	3454.41	5306.37	8356.31	9601.61
IPPU	3.81	6.04	12.73	492.84	1001.38	1821.15
Waste	1756.18	2111.61	2415.89	2633.62	2974.53	3050.67
Agriculture (3A + 3C)	11202.58	13032.31	15336.38	18136.08	18068.35	18397.67
Forest and Other Land Use (FOLU) (3B)	27018.62	27018.62	27018.62	131011.24	131011.24	131011.24
Total (without FOLU)	15653.52	18252.70	21219.42	26568.91	30400.57	32871.10
Total (with FOLU)	42672.14	45271.32	48238.04	157580.15	161411.82	163882.35

As illustrated in the following figure, the emissions of all sectors present an increasing trend from 1994 to 2016.

Figure 4 - GHG emissions; Years 1994-2016 (Gg of CO_2-eq)



The major contributor to the GHG emissions during the entire period is the Forest and Other Land Use sector (FOLU), which is driven by the change in carbon stocks due to deforestation and other changes in the land use.

The second largest emitter sector in the country is the Agriculture sector. Cambodia has an economy which is strongly marked by the contribution of agriculture to total GDP, and that is also reflected in the emission pattern. The main driver for the GHG emissions increase in the agriculture sector is the development of the rise cultivations, whose activity level and emissions increased by a rate of ~2.5 in the period 1994-2016.

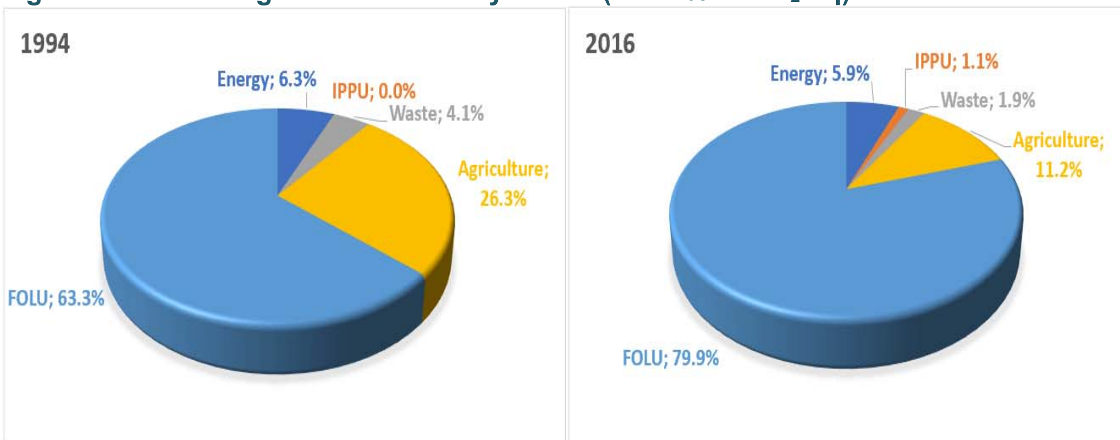
In the time span covered by the inventory, Cambodian GDP has experienced a significant expansion, along its population. This is reflected in the increasing trend of the emissions of the third and fourth largest emitter sectors in the country, the Energy and Waste sectors, respectively. The energy demand has experienced a significant increase, transport sector is expanding, and the population is migrating to cities; all these factors combined led to increasing fuel consumption and higher GHG emissions in the energy sector. The increased population and the changes in waste management and sanitation are the main drivers for the emissions of the waste sector.

Last but not least, the small size of the carbon intensive-industrial sector in the country makes the IPPU the fifth contributor the national total GHG emissions. Nevertheless, IPPU sector emissions experienced a growing expansion in the last period of the series, due to the raising contribution of cement production and the consumption of fluorinated gases.

Emissions (including FOLU) per cápita have increased from 4.00 to 10.44 tonnes CO2-eq/inhabitant/year. This increase is mainly due to the high deforestation produced in the country. Conversely, GHG emissions (including FOLU) per unit of GDP have been reduced from a 15.41 to 8.26 tonnes Co2-eq/thousand USD/year. This reduction is due to the fact that the expansion of GDP is significantly higher than the increase of GHG emissions.

The following figure shows the percentage of emissions of each inventory sector for years 1994 and 2016.

Figure 5 – Percentage of emissions by sector (as of % of CO_2-eq)



The previous figure shows the decreasing contribution to total national emissions in 2016 compared to 1994 in the sectors of energy, waste and agriculture, and the increase in the contribution of FOLU and IPPU.

In terms of the contribution of each GHG to national total emissions, CO_2 is the main gas emitted, driven by the large contribution of the FOLU sector to national total emissions, followed by CH_4, N_2O and HFC.

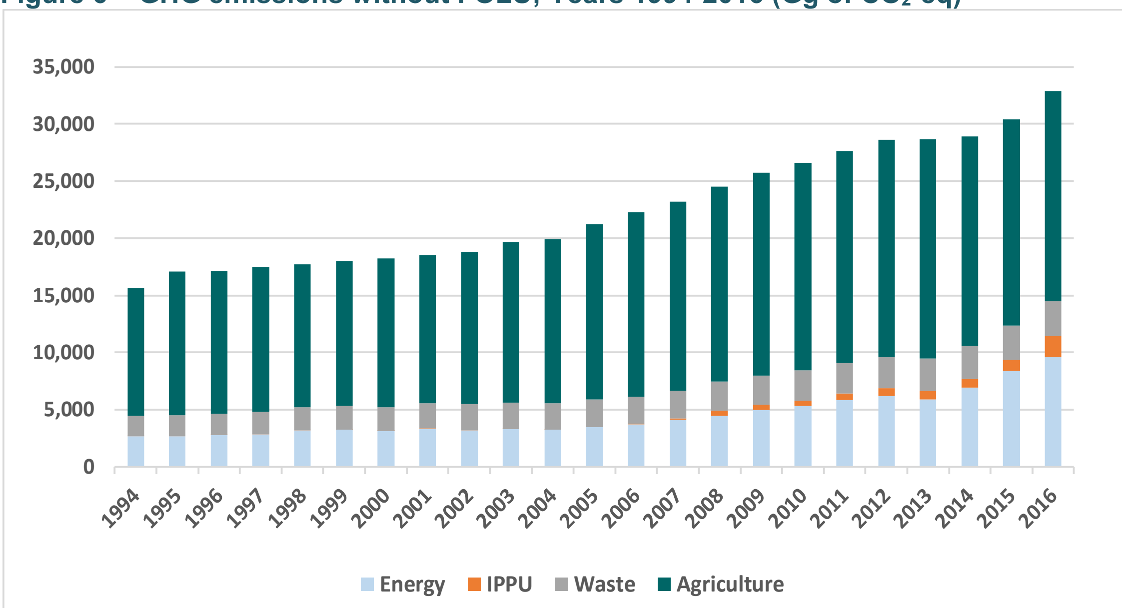
Table 8 - Contribution of each gas to national total emissions with FOLU (%)

Gas	1994	2000	2005	2010	2015	2016
CO_2	69.73%	66.49%	63.32%	86.81%	86.81%	86.73%
CH_4	25.52%	28.55%	31.57%	11.36%	11.30%	11.41%
N_2O	4.75%	4.96%	5.09%	1.76%	1.69%	1.63%
HFC	0.00%	0.00%	0.01%	0.07%	0.20%	0.23%

Note – This contribution is calculated converting first the emissions of each gas to CO2-eq using global warming potentials

The following figure provides an overview of the contribution of each sector to national total GHG emissions without considering the FOLU sector.

Figure 6 – GHG emissions without FOLU; Years 1994-2016 (Gg of CO_2-eq)



The GHG emissions without the FOLU sector are dominated by the contribution of the agriculture sector and the increasing contributions of the energy and waste sectors. In year 2016, the split of emissions without FOLU by sector is the following: Agriculture 56.0%, Energy 29.2%, Waste 9.3% and IPPU 5.5%.

Without FOLU, the main GHG emitted is CH_4, as a result of the large contribution of the agriculture sector, followed by CO_2, N_2O and HFC.

Table 9 - Contribution of each gas to national total emissions without FOLU (%)

Gas	1994	2000	2005	2010	2015	2016
CO_2	17.47%	16.89%	16.61%	21.77%	29.98%	33.85%
CH_4	69.57%	70.80%	71.77%	67.37%	60.00%	56.88%
N_2O	12.95%	12.30%	11.58%	10.43%	8.96%	8.14%
HFC	0.00%	0.00%	0.03%	0.43%	1.05%	1.13%

Note – This contribution is calculated converting first the emissions of each gas to CO2-eq using global warming potentials

As mentioned above, the GHG inventory of the Kingdom of Cambodia includes estimates of greenhouse gases as CO_2, CH_4, N_2O and HFC. Besides, other gases, known as precursors, have been estimated for the energy sector.

The following table shows the emissions estimated by gas and sector for year 2016. Complete reporting tables for all sectors are provided in section "Reporting tables".

Table 10 - Emissions by category and gas, year 2016

Inventory Sector	CO_2	CH_4	N_2O	HFC*	NOx	CO	NMVOC	SOx
	(Gg)							
Energy	8845.29	23.04	0.61	NA	43.43	160.46	45.03	32.61
IPPU	1449.46	NA	NA	371.68	NE	NE	NE	NE
Waste	814.55	79.7	0.82	NA	NE	NE	NE	NE
Agriculture (3A + 3C)	17.42	645	7.56	NA	NE	NE	NE	
Forest and Other Land Use (FOLU) (3B)	131011.24	NA	NA	NA	NA	NA	NA	NA
Total (without FOLU)	11127.73	747.87	8.98	371.68	43.43	160.46	45.03	32.61
Total (With FOLU)	142137.97	747.87	8.98	371.68	43.43	160.46	45.03	32.61

Note – HFC data is provided in mass of CO2-eq

The evolution of all gases estimated in the inventory is shown in the following table:

Table 11 - Emissions (with FOLU) by gas (Gg)

Inventory Sector	1994	2000	2005	2010	2015	2016
CO_2	29 753.96	30 102.41	30 544.23	136 796.33	140 125.72	142 137.97
CH_4	435.61	516.92	609.19	715.96	729.63	747.87
N_2O	6.80	7.54	8.25	9.30	9.14	8.98
HFC*	NO	NO	6.32	114.10	320.24	371.68
NOx	14.46	16.70	17.27	31.80	39.20	43.43
CO	68.62	69.85	66.27	138.80	137.61	160.46
NMVOC	23.44	25.22	23.11	54.04	43.99	45.03
SO_2	2.51	3.15	4.08	14.71	27.40	32.61

Note – Emissions of HFC are provided in terms of Gg $CO_{2\text{-}eq}$. Detailed information by gas is provided under the IPPU sector.

Complete reporting tables are provided in section *Reporting tables*.

3.2. Energy sector

3.2.1. Characterization of the sector

The energy sector includes all the GHG emissions arising from combustion and fugitive releases of fuels. Based on the IPCC 2006 Guidelines, GHG emissions in the energy sector are split into three main sub-sectors: 1A Fuel Combustion Activities, 1B Fugitive emissions from fuels and 1C CO_2 transport and storage. The description of the nature of the emissions included in each sub-sector is provided in the following table:

Table 12 - Emissions included under the energy sector

Sector/sub-sector	GHG emissions included
1. Energy sector	All GHG emissions arising from combustion and fugitive releases of fuels. Emissions from the non-energy uses of fuels are generally not included here but reported under Industrial Processes and Product Use sector.
1A. Fuel combustion activities	Emissions from the intentional oxidation of materials within an apparatus that is designed to raise heat and provide it either as heat or as mechanical work to a process or for use away from the apparatus
1B. Fugitive emissions from fuels	Includes all intentional and unintentional emissions from the extraction, processing, storage and transport of fuel to the point of final use.
1C. CO_2 transport and storage	Carbon dioxide (CO2) capture and storage (CCS) involves the capture of CO2, its transport to a storage location and its long-term isolation from the atmosphere.

Source: IPCC 2006 guidelines

The official energy balance of the Kingdom of Cambodia[3] describes an energy sector significantly dependent on energy imports. From a total of 7 365 ktoes of primary energy supply for year 2016, only an amount of 4 336 ktoes were produced in the country, of which 4 107 ktoes corresponds to biomass. The remaining energy supply for year 2016 was fulfilled by hydrogeneration (225 ktoes) and other renewables (4 ktoes).

Regarding final energy consumption, the energy balance shows a total amount for year 2016 of 6 164 ktoes. The fuel which is more consumed in the country is biomass (3 530 ktoes), followed by oil products (2 111 ktoes), electricity (506 ktoes) and coal (17 ktoes).

In a more detailed analysis of the energy consumption of the country by sector using the latest data available on the sectoral split of fuel consumption (year 2015)[4], shows the transport sector as the main consumer of energy, with a 45% of total final energy consumption, followed by the residential/institutional/commercial sector, with a 39% of total final energy consumption, and Industry, with a 45%.

As a result of the energy profile of Cambodia, only the emissions of fuel combustion activities (1A Fuel Combustion activities) are estimated in the current inventory[5].

Several categories are included within fuel combustion, as follows:

Table 13 - Emissions included under 1A Fuel Combustion activities

Category	GHG emissions included
1A1. Energy industries	Comprises emissions from fuels combusted by the fuel extraction or energy-producing industries. This includes emissions from main activity producers of electricity generation, combined heat and power generation, and heat plants; auto

[3] Provided by the Ministry of Energy and Mines

[4] This analysis is made using the data from the ERIA report for year 2015, which provides data with certain level of disaggregation regarding fuel consumption

[5] As Cambodia is mainly an importer or fuels, fugitive emissions from fuels produce minor GHG emissions. CO2 transport and storage does not occur in the country.

Category	GHG emissions included
	producers; and All combustion activities supporting the refining of petroleum products.
1A2. Manufacturing Industries and Construction	Emissions from combustion of fuels in industry. Non-energy consumption of fuels is not included here by in the IPPU sector.
1A3. Transport	Emissions from the combustion and evaporation of fuel for all transport activity (excluding military transport). Emissions from fuel sold to any air or marine vessel engaged in international transport are excluded from national totals
1A4. Other Sectors	Emissions from combustion activities in the commercial and institutional buildings, in the residential sector and emissions from fuel combustion in agriculture, forestry, fishing and fishing industries.

The following table provides a summary of the emissions for the energy sector in year 2016. Complete reporting tables are provided in section Reporting tables.

Table 14 - Summary of emissions – Energy sector –GHG emissions of year 2016

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	HFC	SF6	NO_X	CO	NMVOC	SO_2
	(Gg)								
Total Energy	8 866.28	22.87	0.61	NA	NA	43.43	160.46	45.03	32.61
A. Fuel combustion activities (sectoral approach)	8 866.28	22.87	0.61	NA	NA	43.43	160.46	45.03	32.61
1. Energy industries	2 990.41	10.05	0.05	NA	NA	9.23	3.47	0.29	25.14
2. Manufacturing industries and construction	710.77	1.14	0.16	NA	NA	6.95	23.32	11.39	3.12
3. Transport	4 993.03	1.21	0.24	NA	NA	19.61	86.54	8.61	3.25
4. Other sectors	172.07	10.46	0.17	NA	NA	7.64	47.14	24.73	1.09
5. Other *(as specified in table 1.A(a) sheet 4)*	NO	NO	NO	NO	NO	NO	NO	NO	NO
B. Fugitive emissions from fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO
Memo items: (1)									
International bunkers	236.49	0.00	0.01	NA	NA	0.83	94.44	1.50	0.08
Aviation	236.49	0.00	0.01	NA	NA	0.83	94.44	1.50	0.08
Navigation	NE	NE	NE	NE	NE	NE	NE	NE	NE
CO_2 emissions from biomass	13 694.77								
CO_2 captured	NO								

3.3.2. Data sources

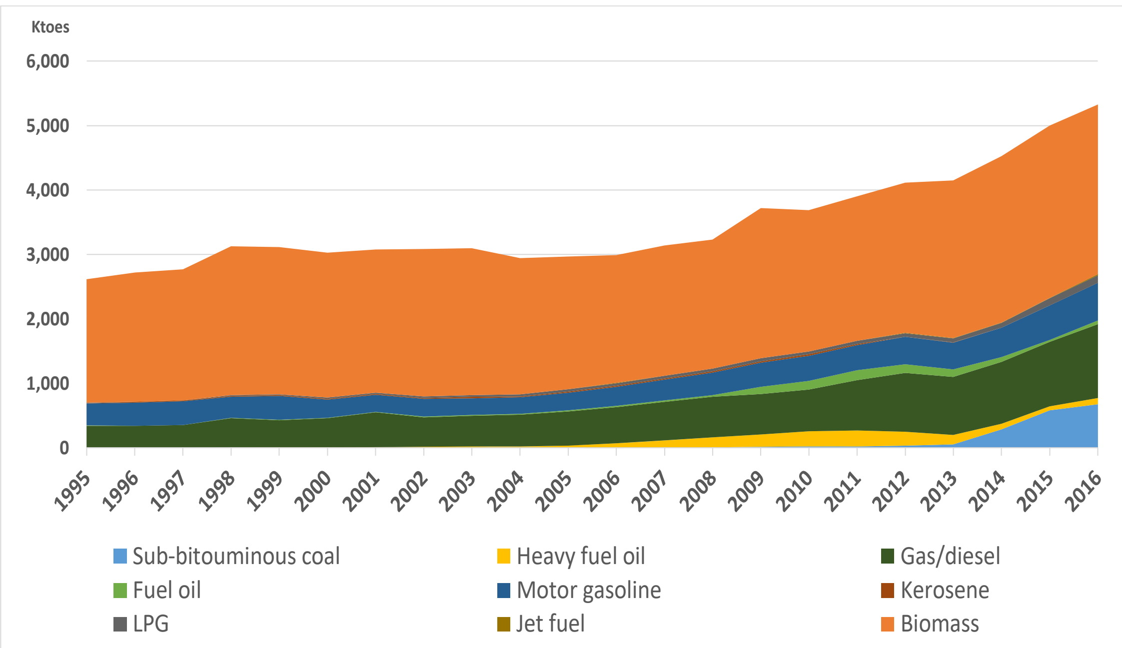
There are three data sources for the energy sector:

- **Economic Research Institute for ASEAN and East Asia (ERIA) – ERIA statistics –** complete energy statistics for the period 2010-2015, and partial data for 2007-2010.
- **Energy balance 2010-2016 of the Ministry of Mines and Energy**
- **Association of South East Nations (ASEAN) database**: Energy statistics for the period 1995-2012

ERIA statistics are considered by national stakeholders a more exhaustive and complete source of data. These statistics were produced as a result of surveys developed to fill the existent data gaps; and was developed by a team of experts which combined international and national expertise. The dataset of ERIA was validated by national stakeholders. Nevertheless, the ERIA dataset was only complete for years 2010-2015, with year 2015 being only preliminary. For this reason and aiming at providing a complete and consistent time series for years 1995-2016, the three data sources have been combined for producing the activity data series of each emission category. Year 1995 is subrogated (1994) to provide time series up to the year presented in the first national communication.

The following figure shows the evolution of fuel consumption which has been used for estimating the emissions of the inventory. This time series has been estimated by the inventory team based on the data provided by the aforementioned sources of information.

Figure 7– Fuel consumption of Cambodia 1994-2016 – Data in ktoes



The previous figure shows that the fuel consumption of the country is driven by the consumption of biomass, the fuel with higher contribution to national total fuel consumption. Biomass consumption occurs in the residential sector, in the energy industries (production of electricity and charcoal) and industry. Biomass is followed by gas/diesel and motor gasoline, primarily used in the transport sector.

3.3.3. Energy emissions by category

Regarding methodologies, the most detailed data available in the country has been used to estimate through a sectoral approach the emissions of category 1A Fuel Combustion activities.

In the sectoral approach, the emissions are estimated using a bottom-up procedure, from the most disaggregated data available by sector. Data with a certain level of sectoral breakdown was available in the ERIA report for years 2010-2015. This data has been the main data used for building the activity data series used in the sectoral approach of the inventory, complemented with data from the Ministry of Mines and Energy for the period 2010-2015 and the ASEAN database for years 1995-2012.

The data has been provided primarily in ktoes of fuel consumed and transformed to GJ using the conversion factors provided by the international energy agency[6]. The following table shows the low calorific value of the fuels, which have been used where appropriate:

Table 15 – Low calorific values of Cambodian fuels

Fuel	Low Calorific Content	
	TOE/t	TJ/kt
Sub-bituminous coal	0.50	20.76
Additives/Oxygenates	1.21	50.51
Motor gasolina	1.04	43.72
Naphtha	1.05	44.12
Kerosene type jet fuel	1.00	42.03
Kerosene	1.06	44.38
Gas/Diesel oil	1.01	42.35
Fuel oil	1.01	42.17
LPG	0.66	27.78
Lubricants	0.96	40.19
Bitumen	1.00	41.87
Fuelwood & woodwaste	0.37	15.50
Charcoal	0.70	29.31
Electricity	0.09	3.60
Biogas*		50.40

Source: ERIA report, edition 2016. Note –Biogas LHV has been extracted from 2006 IPCC Guidelines.

The emission of the sectoral approach of the energy sector has been estimated using a tier 1 approach for all categories of the energy sector, using fuel-specific emission factors provided by 2006 IPCC guidelines (also EMEP/EEA 2016 Guidelines were used for estimating non-GHG emissions).

In the following sub-sections, information on the activity data, emission factors and emissions obtained for each category included in the sectoral approach of the energy sector is provided in more detail. Subsequently, a comparison between the sectoral approach and reference approach is provided to illustrate the quality of the data used by the inventory.

1A1. Energy Industries

The category 1A1 Energy Industries comprises emissions from fuels combusted by the fuel extraction or energy-producing industries. In Cambodia, energy industry emissions include the emissions which occur in the combustion of fuels for electricity generation as well as the emissions which occur in the manufacture of solid fuels (i.e. production of charcoal). Other

[6] Available at https://www.iea.org/statistics/resources/unitconverter/

emissions that should be accounted for in this category (such as petroleum refining) do not occur in the country.

Activity data

The following table shows the activity data used for the estimation of emissions:

Table 16 - Activity data energy industries. Data in GJ

Year	Sub-bituminous coal	Heavy fuel oil	Diesel	Biomass used for the production of electricity	Charcoal Production
1994	0	253 536	386 703	129 372	10 007 289
2005	0	1 482 873	615 567	181 620	14 048 807
2010	727 365	9 784 326	347 730	293 076	10 552 676
2011	832 194	10 212 245	338 491	293 076	9 788 023
2012	1 206 671	9 039 517	464 519	293 076	9 023 370
2013	1 907 466	6 214 607	191 197	167 472	9 408 091
2014	11 693 483	3 522 334	120 182	251 208	9 847 354
2015	24 032 232	2 429 302	82 778	544 284	9 995 269
2016	27 716 616	4 089 326	139 342	586 152	9 995 269

From 2014 there is a significant increase in coal consumption due to the operation of new coal power plants (Sihanoukville 100 MW coal power plant and the first 270 MW coal power plants of the CIIDG Erdos Hongjun Electric Power Co.Ltd.). The increase in coal consumption is reflected in lower levels of heavy fuel oil and diesel consumption.

For coal, the data from ERIA has been used for years 2008-2014 and the Ministry of mines for years 2015 and 2016. In the historical period there was no consumption of coal.

Regarding oil products, ERIA figures should be higher than the figure provided by the Ministry of Mines and Energy, as the data included in ERIA statistics completes the coverage of the data of the Ministry of Mines for years 2010-2015. Nevertheless, the amount of fuel consumed as contained in the data provided by the Ministry of Mines and Energy is higher than the corresponding figures of ERIA. For this reason and aiming at ensuring the consistency of the time series, the inventory has been calculated for this category and years 2010-2015 using the total amount of “oil” consumption from the Ministry of Mines and the split between the different oil products of ERIA. In the historical period there is data available in ASEAN on heavy fuel oil, but there is a sharp decrease in the consumption in years 2008-2009. The series has been smoothed for those years by considering 2008 and 2009 as outliers and interpolating between years 2007-2010.

Methodology and emission factors

The following are the emission factors used for estimating the emissions for the entire time series:

Table 17 - Emission factors category 1A1. Energy industries

	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_x
	Kg/TJ			g/GJ			
Fuel							
Coal	96 100	1	1.5	209	8.7	1	820
Heavy fuel oil	77 400	3	0.6	142	15.1	2.3	495
Diesel	74 100	3	0.6	65	16.2	0.8	46.5
Biomass	112 000	30	4	81	90	7.31	10.8
Charcoal*	NA	1 000	NA	NA	NA	NA	NA

Source for GHG: Table 2.2. Chapter 2 Stationary combustion
Source for other gases: Tables 3.2 - 3.7, EMEP/EEA 2016 Chapter 1A1
Source for charcoal: Table I-14 IPCC 1996; volumen III for energy

CH_4 emissions from the production of charcoal has been estimated using an emission factor from the Revised 1996 Guidelines, as there is no emission factor specific for charcoal production in the 2006 IPCC Guidelines. The emission factor is to be applied to the amount of charcoal produced. This issue will be addressed in the 2019 refinement of the guidelines, so the inventory of Cambodia will consider it in the next inventory submission.

The CO2 emissions of biomass are not included in the total emissions of the sector. CO2 emissions from the consumption of biomass for the production of electricity are estimated by applying the biomass emission factor of the previous table to the amount of biomass consumed. Nevertheless, the CO2 emissions which occur in the production of charcoal cannot be estimated by applying a biomass emission factor to the total amount of firewood used for the production of charcoal, as not all the carbon is combusted in the process. Instead, the carbon content of the biomass is transformed into charcoal. For this reason, the activity data used for calculating CO2 emissions from charcoal is estimated by subtracting the amount of charcoal produced to the total amount of biomass which is used for the production of charcoal. A CO2 emission factor is applied to this amount of biomass calculated as a differential. CO2 emissions from biomass are reported as a memo item.

The remaining emissions are estimated by applying the emission factors to the corresponding activity data.

Results

Table 18 - Emissions in energy industries. Data in Gg

Year	CO_2	CH_4	N_2O	NO_X	CO	NMVOC	SO_X
1994	48.28	10.01	0.00	1.22	1.29	0.11	0.30
2005	160.39	14.06	0.00	1.87	1.83	0.15	0.98
2010	852.97	10.59	0.00	4.03	2.90	0.25	5.78
2011	895.48	9.83	0.01	4.22	3.02	0.26	6.10
2012	850.04	9.06	0.01	4.24	3.13	0.26	5.84
2013	678.49	9.43	0.01	4.07	3.20	0.27	5.02
2014	1 405.28	9.88	0.01	5.87	3.39	0.28	11.73
2015	2 503.66	10.04	0.02	8.35	3.56	0.30	21.31
2016	2 990.41	10.05	0.04	9.23	3.47	0.29	25.14

CO_2 emissions do not include biomass CO_2, which is reported as a memory item. The trend of emissions is driven by the decreasing consumption of oil products (diesel and heavy fuel oil) and the significant increase of coal consumption in years 2014-2016.

The emissions of CH_4 of the category are strongly driven by the contribution of charcoal production. This effect is not seen in CO_2 and N_2O emissions, because Co2 is not accounted in the total emissions and N_2O emissions from charcoal are not applicable, as specified in the 1996 IPCC Guidelines. The emission trend of these gases is there driven by the increasing consumption of coal for electricity generation.

Figure 8 - Emissions of CO_2 in energy industries. Data in Gg

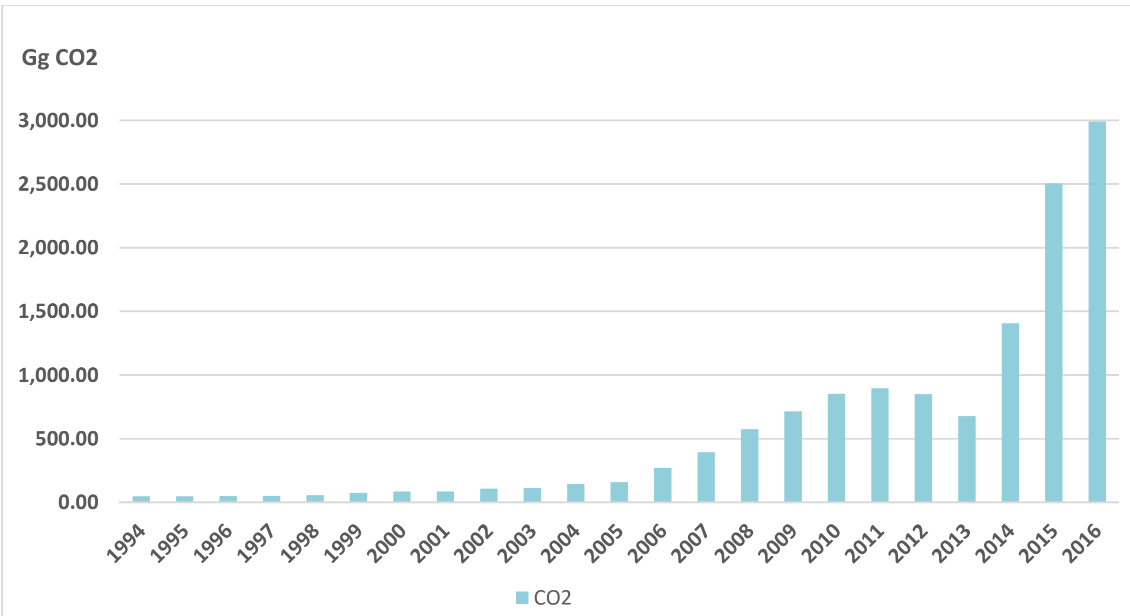


Figure 9 - Emissions of CH_4 in energy industries. Data in Gg

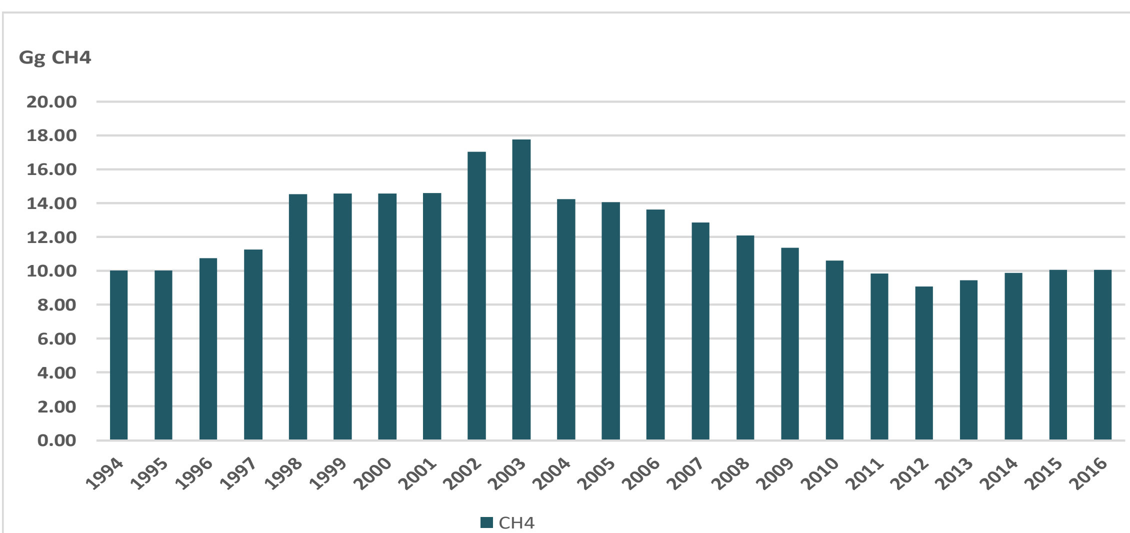
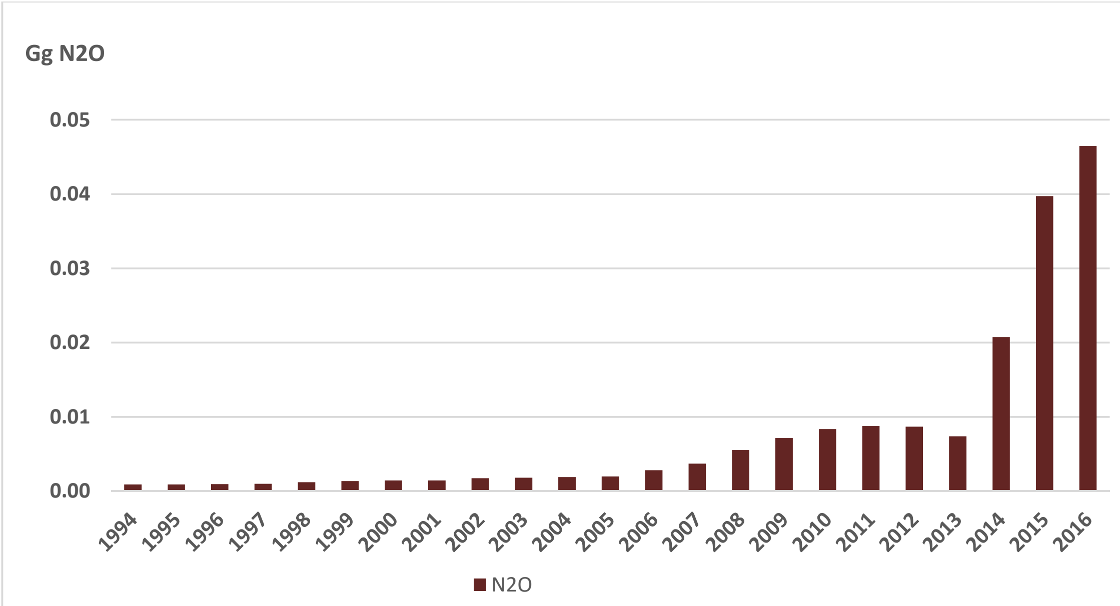


Figure 10 - Emissions of N_2O in energy industries. Data in Gg



1A2. Manufacturing Industry and construction

The category 1A2 Manufacturing Industry and construction includes emissions from fuels combusted in industries. If possible, the emissions of this category should be dissagregated by sub-category. The availability of data has not allowed to breakdown the emissions by sub-category. Therefore, the activity and emissions are provided for the manufacturing industry as a whole.

Activity data

Table 19 - Activity data manufacturing industries. Data in GJ

Year	Sub-bituminous coal	Fuel oil	Diesel	LPG	Biomass
1994	0	122 877	1 421 414	0	36 638 977
2005	0	718 679	2 221 763	0	33 999 127
2010	211 526	5 191 632	2 763 288	0	27 507 276
2011	246 815	5 400 972	2 888 892	0	28 051 560
2012	270 271	4 856 688	3 223 836	0	30 103 092
2013	278 782	4 103 064	3 098 232	41 868	32 363 964
2014	392 952	2 763 288	3 433 176	41 868	34 624 836
2015	553 620	1 130 436	3 223 836	83 736	37 095 048
2016	711 756	2 058 246	5 869 814	152 462	36 843 840

For coal, the data from the Ministry of Mines and Energy is the same as ERIA for years 2010-2015. Therefore, the data from both sources has been used. For year 2016 there is only data from the Ministry of Mines and Energy. There is no coal consumption for the historical period (before 2010).

For oil products (fuel oil and diesel) in the manufacturing industry, there is a significant difference between the figures provided by ERIA and the ministry of Mines. The data of ERIA has been used, as it has been considered more complete and more consistent (with the exception of a significant decrease of fuel consumption in year 2015). The data used for year 2016 comes from the Ministry of mines. For the historical period, the interannual variation rate of the data provided by ASEAN on fuel oil and diesel has been applied to year 2010.

For biomass, the data of the ministry of Mines is used for the entire time period. ERIA is supposed to be more complete, but the figures for this specific consumption are lower. Therefore, the inventory has used the data from the Ministry of Mines aiming at being conservative, but this issue should be addressed in the future. For the historical period (data from ASEAN), we split the amount (provided at an aggregated level), between 1A2 and 1A4, using the split of year 2010.

Methodology and emission factors

The following are the emission factors used for estimating the emissions for the entire time series:

Table 20 - Emissions factors in the manufacturing industry.

	CO_2	CH_4	N_2O	NO_X	CO	NMVOC	SO_X
	Kg/TJ			g/GJ			
Fuel							
Heavy fuel oil	77 400	3	0.6	513	66	25	47
Diesel	74 100	3	0.6	513	66	25	47
Biomass	112 000	30	4	91	570	300	11
Coal	96 100	10	1.5	173	931	88.8	900
Lubricants	73 300	3	0.6	513	66	25	47
LPG	63 100	1	0.1	513	66	25	47

Results

Table 21 - Emissions in the manufacturing industry. Data in Gg

Year	CO_2	CH_4	N_2O	NO_X	CO	NMVOC	SO_X
1994	117.14	1.10	0.15	4.08	21.09	11.04	0.58
2005	233.70	1.03	0.14	4.36	20.20	10.32	1.13
2010	724.00	0.89	0.12	4.86	20.70	8.78	5.28
2011	756.82	0.90	0.12	5.02	21.21	8.97	5.51
2012	731.59	0.96	0.13	5.29	21.90	9.54	5.08
2013	653.32	1.02	0.14	5.32	22.48	10.15	4.42
2014	560.35	1.08	0.15	5.49	22.54	10.72	3.35
2015	406.01	1.13	0.15	5.38	22.42	11.31	2.03
2016	710.77	1.14	0.16	6.95	23.32	11.39	3.12

CO_2 emissions do not include biomass CO_2, which is reported as a memory item. The trend of emissions is driven by the increasing manufacturing industry. The emissions of all gases show a strong increasing trend, along the increasing figures for industrial GDP. Nevertheless, the consistency of the consumption values available for year 2016 shall be ensured in the future.

Figure 11 - Emissions of CO_2 in energy industries. Data in Gg

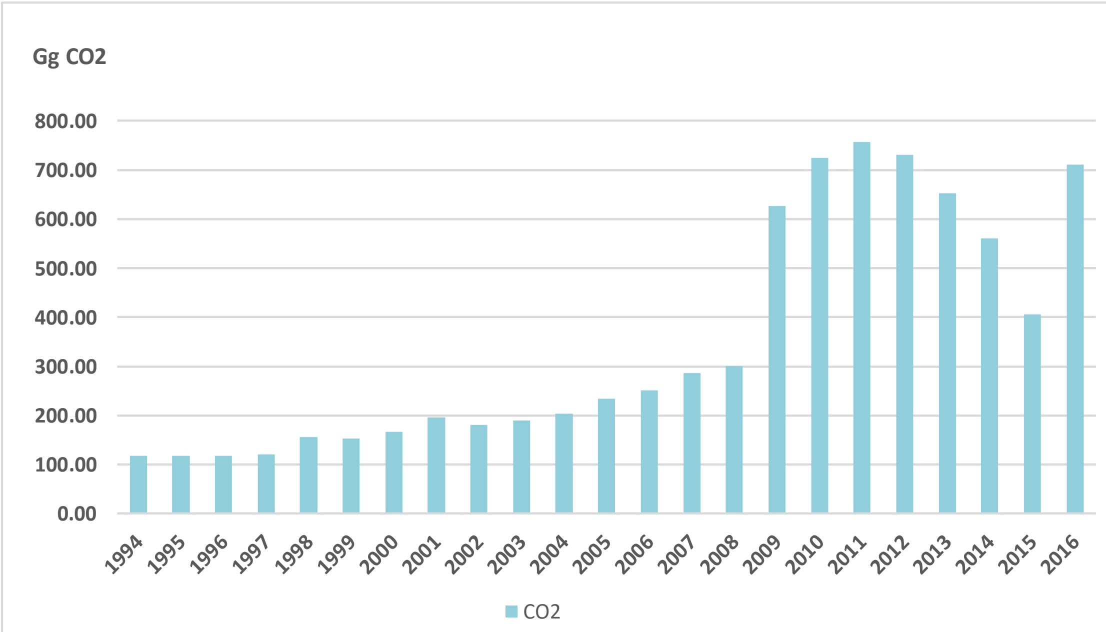


Figure 12 - Emissions of CH_4 in energy industries. Data in Gg

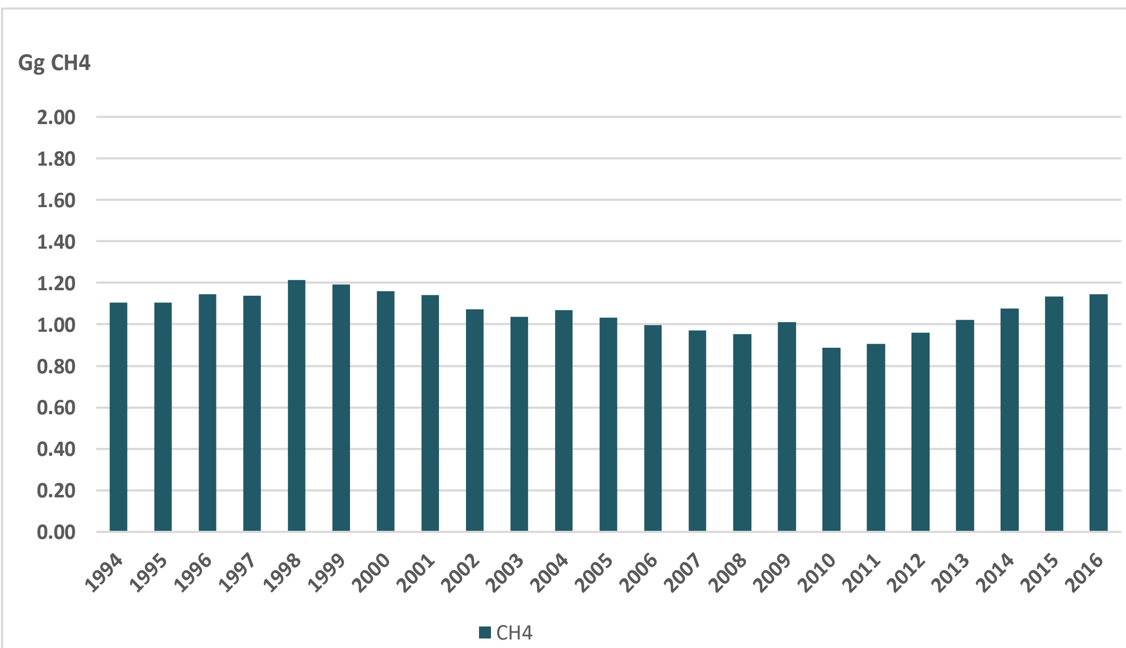
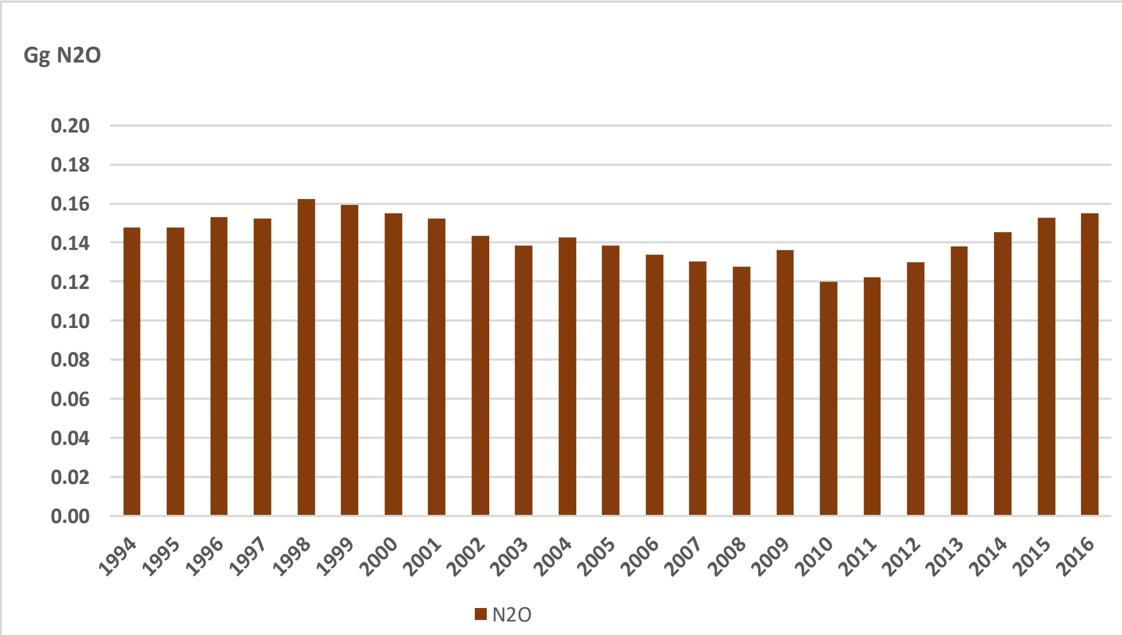


Figure 13 - Emissions of N_2O in energy industries. Data in Gg



1A3. Transport

The category 1A3 Transport comprises emissions from the combustion and evaporation of fuel for all transport activity (excluding military transport), regardless of the sector. In the Inventory of Cambodia, there are two big sub-categories within the transport sector: civil aviation and road transportation. International bunkers (fuels consumed for international transportation) are not included in the totals but reported separately. Other sub-categories emissions to be allocated here, as railways (not occurrence) and domestic water born navigation (lack of data), have not been estimated in this edition.

Activity data

Table 21 - Activity data air transport. Data in GJ

Year	Jet fuel – International aviation	Jet fuel – Domestic aviation	Motor gasoline	Diesel	LPG
1995	473 622	34 655	14 178 229	11 694 366	7 476
2005	851 662	62 317	11 488 989	18 279 058	105 089
2010	1 716 588	125 604	16 412 256	22 734 324	125 604
2011	1 925 928	167 472	16 328 520	28 051 560	460 548
2012	2 428 344	167 472	17 626 428	32 573 304	1 423 512
2013	2 847 024	125 604	17 458 956	32 740 776	1 758 456
2014	3 558 780	209 340	19 008 072	34 750 440	2 386 476
2015	3 307 572	251 208	22 357 512	36 927 576	3 642 516
2016	3 307 572	837 360	24 425 173	40 342 701	3 979 382

The fuel consumption of international aviation is provided separately from domestic aviation, as the emissions of international bunkers are not included in national total GHG emissions.

The data on international aviation is only provided by ERIA. Year 2015 is subrogated to 2016 as there is no information for that year.

For domestic aviation, the data from the ASEAN database is used for the period 1995-2010; for the time period 2010-2015 the data from the Ministry of Mines and Energy is equal to ERIA. Hence, both data sources have been used for this time span. Finally, for year 2016 only data from the ministry of Mines and Energy is available. Regarding this value, as can be noted from the previous table, there is a significant interannual increase in year 2016 which affects the consistency of the time series. This issue needs to be addressed in the future.

For road transport, the data for the period 2010-2015 from ERIA is more disaggregated than the one provided by the ministry of Mines, but the aggregated figures are similar. ERIA has been used for 2010-2015 and the Ministry of Mines and Energy for year 2016, applying the fuel split of the data for year 2015.

For the historical period (ASEAN), there is data directly available for moto gasoline but there is a big gap between series (2010-2016 vs 1995-2009), so the interannual variation rate of the historical series time series (1995-2009) was applied to the figure of 2010 to ensure the consistency of the series. The same approach was followed for diesel. Conversely, the historical series of LPG, provided for the national total (national total consumption of LPG), was split between 1A2 and 1A4 using the proportions of 2010.

Methodology and emission factors

Table 22 - Emission factor in transport category

	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_x
	Kg/TJ						
Fuel							
Jet fuel	71 500	0,5	2	250	28 553	452	24
Motor gasoline	69 300	33	3.2	200	1 937	230	47
Gas/diesel	74 100	3.9	3.9	306	79	17	47
LPG	63 100	62	0.2	547	3 049	491	47
Lubricants	73 300	3	0.6	513	66	25	47

Source for jet fuel GHG: Table 3.6.4 and 3.6.5. chapter Mobile Combustion

Source for motor gasoline GHG: Tables 3.2.1 and 3.2. from chapter Mobile Combustion

Source for other gases: Tables 3.2 - 3.7, EMEP/EEA 2016 Chapter 1A3

Results

Table 23 - Emissions in the transport sector. Data in Gg

Year	CO_2	CH_4	N_2O	NO_X	CO	NMVOC	SO_X
1994	1 852.05	0.51	0.09	6.42	29.40	3.47	1.22
2005	2 161.75	0.46	0.11	7.96	25.80	3.02	1.41
2010	2 838.89	0.64	0.14	10.33	37.55	4.27	1.85
2011	3 251.22	0.68	0.16	12.14	40.03	4.52	2.11

2012	3 736.99	0.80	0.18	14.31	45.83	5.36	2.43
2013	3 755.94	0.81	0.18	14.50	45.35	5.47	2.45
2014	4 057.82	0.91	0.20	15.79	52.81	6.21	2.64
2015	4 533.51	1.11	0.22	17.82	64.50	7.65	2.96
2016	4 993.03	1.21	0.24	19.61	86.54	8.61	3.25

The main driver of GHG emissions in the transport sector is the increased consumption of fuels due to the increasing fleet of private vehicles. This is, in turn, due to the economic development of the country, the demographic expansion and the migration of population from rural to urban areas.

Table 24 - Emissions in international bunkers. Data in Gg

Year	CO_2	CH_4	N_2O	NO_X	NMVOC	CO	SO_X
1994	33.86	0.0002	0.0009	0.12	0.21	13.52	0.01
2005	60.89	0.0004	0.0017	0.21	0.39	24.32	0.02
2010	122.74	0.0009	0.0034	0.43	0.78	49.01	0.04
2011	137.70	0.0010	0.0039	0.48	0.87	54.99	0.05
2012	173.63	0.0012	0.0049	0.61	1.10	69.34	0.06
2013	203.56	0.0014	0.0057	0.71	1.29	81.29	0.07
2014	254.45	0.0018	0.0071	0.89	1.61	101.61	0.08
2015	236.49	0.0017	0.0066	0.83	1.50	94.44	0.08
2016	236.49	0.0017	0.0066	0.83	1.50	94.44	0.08

Figure 11 - Emissions of CO_2 in Transport. Data in Gg

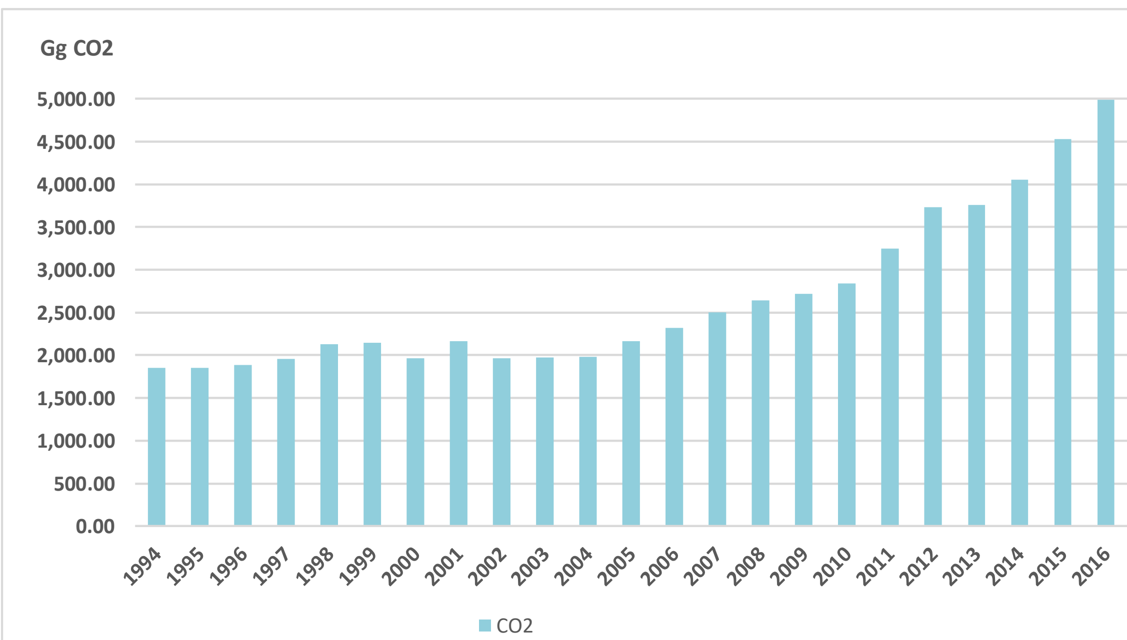


Figure 12 - Emissions of CH_4 in Transport. Data in Gg

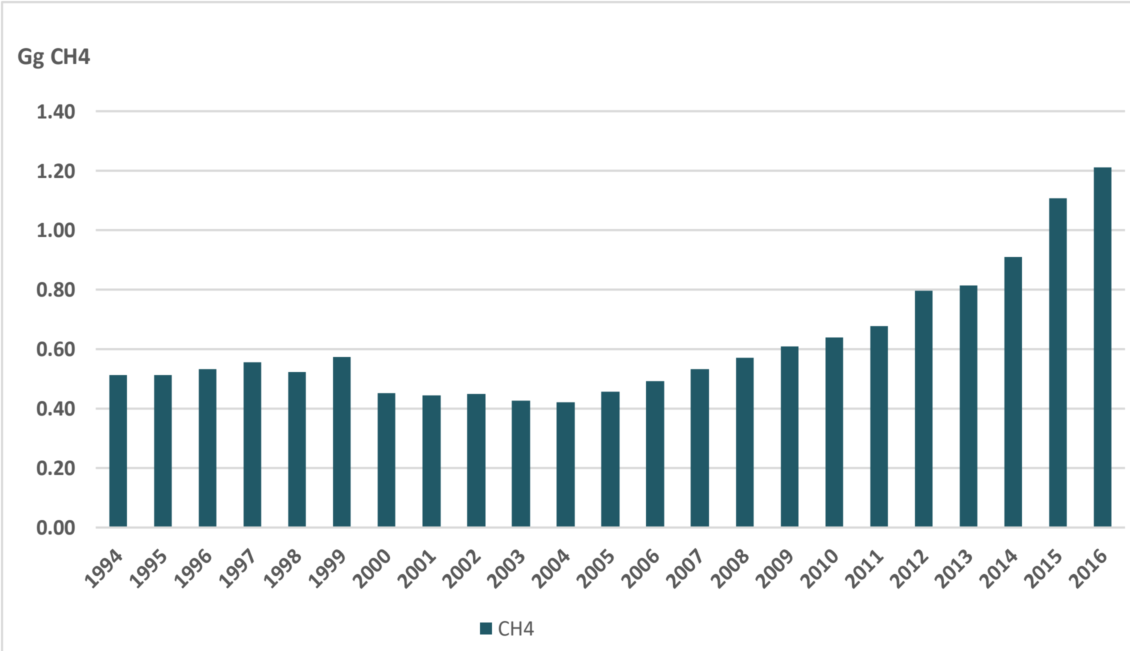
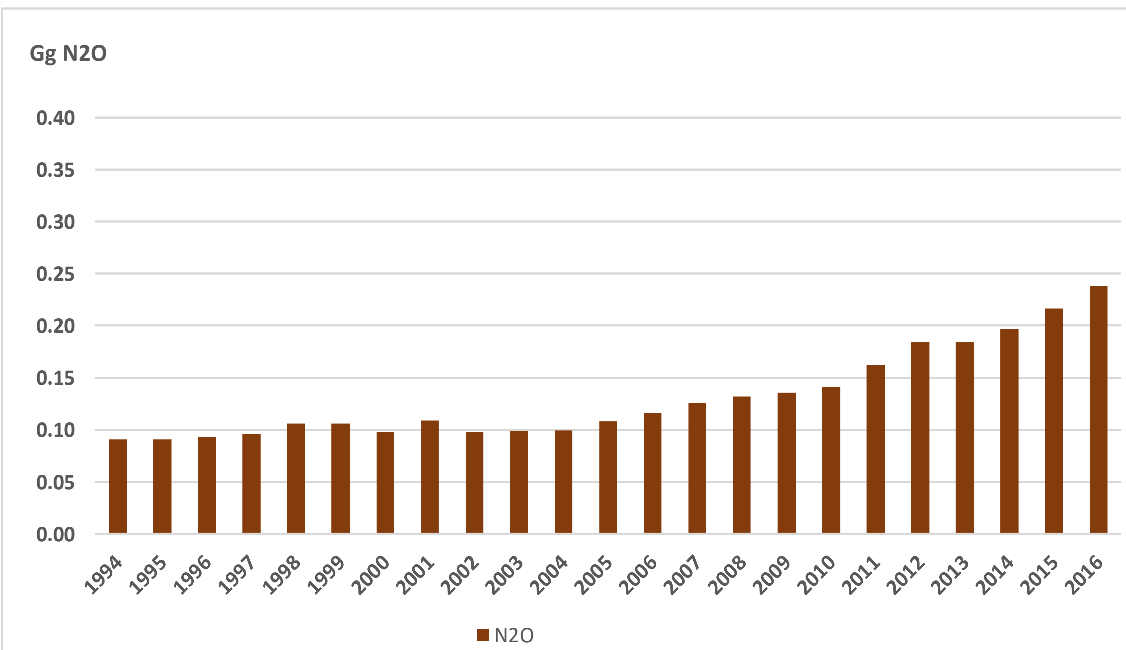


Figure 13 - Emissions of N_2O in Transport. Data in Gg



1A4. Other

The category 1A4 *Other* comprises emissions from the combustion of fuels in other sectors. These sectors are the commercial/institutional sector, the residential sector and the agriculture/forestry/ fishing sector. The inventory of Cambodia includes estimates for all these sectors.

Activity data

Table 25 - Activity data Commerce and public services sector. Data in GJ

Year	Kerosene	Fuel oil	LPG
1994	284 334	9 909	79 749
2005	398 908	57 958	1 120 946
2010	586 152	418 680	1 339 776
2011	293 076	1 004 832	1 256 040
2012	125 604	962 964	711 756
2013	41 868	628 020	753 624
2014	0	334 944	502 416
2015	0	209 340	669 888
2016	0	209 340	669 888

The data from ERIA has been used for the period 2010-2015. For years 1995-2009 for kerosene and fuel oil, the interannual variation rate of the original data from ASEAN has been applied to the value of ERIA of year 2010. It is also worth highlighting that for years 1995-2009 the amount of LPG (which is provided by ASEAN for the national total consumption) is split between categories 1A2 and 1A4 using the proportions of 2010.

As the value for oil consumption from the Ministry of Mines and Energy for year 2016 increases by a factor of 6 compared to the figure of 2015 (fuel oil plus LPG consumption), and would affect the consistency of the time series, the value for year 2016 from this source has not been used. Alternatively, the amount of year 2015 of ERIA has been subrogated to 2016. For future updates of the inventory, this issue should be addressed.

Table 26 - Activity data Residential. Data in GJ

Year	Kerosene	LPG	Biomass		
			Firewood	Charcoal	Biogas
1994	182 786	17 445	19 394 014	10 007 289	0
2005	256 441	245 207	17 996 669	14 048 807	0
2010	376 812	293 076	23 265 265	10 552 676	101 989
2011	272 142	334 944	24 287 428	9 788 023	131 464
2012	83 736	125 604	25 280 638	9 023 370	114 439
2013	83 736	125 604	26 358 522	9 408 091	30 374
2014	0	167 472	27 589 170	9 847 354	44 430
2015	0	209 340	28 003 550	9 995 269	44 430
2016	0	209 340	28 003 550	9 995 269	44 430

For oil products, the figures from the ministry of mines are significantly high compared to ERIA. However, ERIA is generally more robust regarding oil data (see section data sources above for a description of the sources), so the data from ERIA has been used. Nevertheless, this discrepancy between sources should be addressed for future editions of the inventory.

Regarding biomass products, the degree of detail of ERIA is very high compared to the ministry of mines, but the differences of the total amount of biomass consumed between sources (ERIA vs Ministry of Mines) are significant. The data from ERIA has been used for years 2010-2015 and for year 2016, when the data was subrogated. Even within the statistics provided by ERIA there are also differences in the data provided at different level of aggregation. The data provided at the most disaggregated level in the ERIA statistics has been used in the inventory.

For the historical period (1995-2019), the biomass fuel consumption provided by ASEAN is differentiated by "charcoal" and "firewood" and is not allocated in sectors. Therefore, the firewood quantities provided have been split between categories 1A4 and 1A2 using the proportions of 2007. For charcoal, it was assumed that the figures provided for the historical series is charcoal production, and all charcoal was consumed in the residential sector.

Lastly, biogas data was compiled in the ERIA statistics and was originally gathered by the national biodigester program, which started in year 2007. For future editions of the inventory, the data gathering collection process for biomass within the Ministry of Mines and Energy could be improved by using the same disaggregation as the ERIA statistics.

Table 27 - Activity data agriculture. Data in GJ

Year	Diesel
1994	689 171
2005	1 077 219
2010	1 339 776
2011	1 590 984
2012	1 842 192
2013	1 758 456
2014	2 093 400
2015	1 590 984
2016	1 590 984

Methodology and emission factors

Table 28 - Emission factors used for the Commercial and institutional sub-sectors

	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_x
	Kg/TJ						
Fuel							
Kerosene	71 900	10	0.6	51	57	0.7	70
Fuel oil	77 400	10	0.6	51	57	0.7	70
LPG	63 100	5	0.1	51	57	0.7	70

Source for jet fuel GHG: Table 3.6.4 and 3.6.5. chapter Mobile Combustion
Source for GHG: Table 2.2. Chapter 2 Stationary combustion
Source for other gases: Tables 3.1 - 3.5, EMEP/EEA 2016 Chapter 1A14

Table 29 - Emission factors used for the Residential and agricultural sub-sectors

	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_x
	Kg/TJ						
Fuel							
Kerosene	71 900	10	0.6	51	57	0.7	70
LPG	77 400	10	0.6	51	57	0.7	70
Gas/diesel	74 100	10	0.6	51	57	0.7	70
Firewood	112 000	300	4	91	570	300	11
Charcoal	112 000	200	1	91	570	300	11
Biogas	54 600	5	0.1	74	29	23	0.67

Source for GHG: Table 2.2. Chapter 2 Stationary combustion
Source for other gases: Tables 3.1 - 3.5, EMEP/EEA 2016 Chapter 1A14
Air quality gases EFs for firewood and charcoal extracted from table 3.10
Air quality gases EFs for biogas extracted from table 3.8

Results

Table 30 - Emissions in the other sectors. Data in Gg

Year	CO_2	CH_4	N_2O	NO_X	NMVOC	CO	SO_X
1994	83.97	7.83	0.09	2.74	8.82	16.83	0.41
2005	205.78	8.23	0.09	3.08	9.62	18.45	0.57
2010	289.22	9.22	0.21	12.58	40.75	77.66	1.80
2011	319.20	9.41	0.24	15.31	49.67	94.63	2.15
2012	258.66	9.53	0.23	13.73	44.63	85.00	1.91
2013	224.08	9.84	0.15	6.19	19.84	37.89	0.96
2014	200.29	10.31	0.17	7.61	24.56	46.84	1.12
2015	172.07	10.46	0.17	7.64	24.73	47.14	1.09
2016	172.07	10.46	0.17	7.64	24.73	47.14	1.09

Figure 14 - Emissions of CO_2 in other sectors. Data in Gg

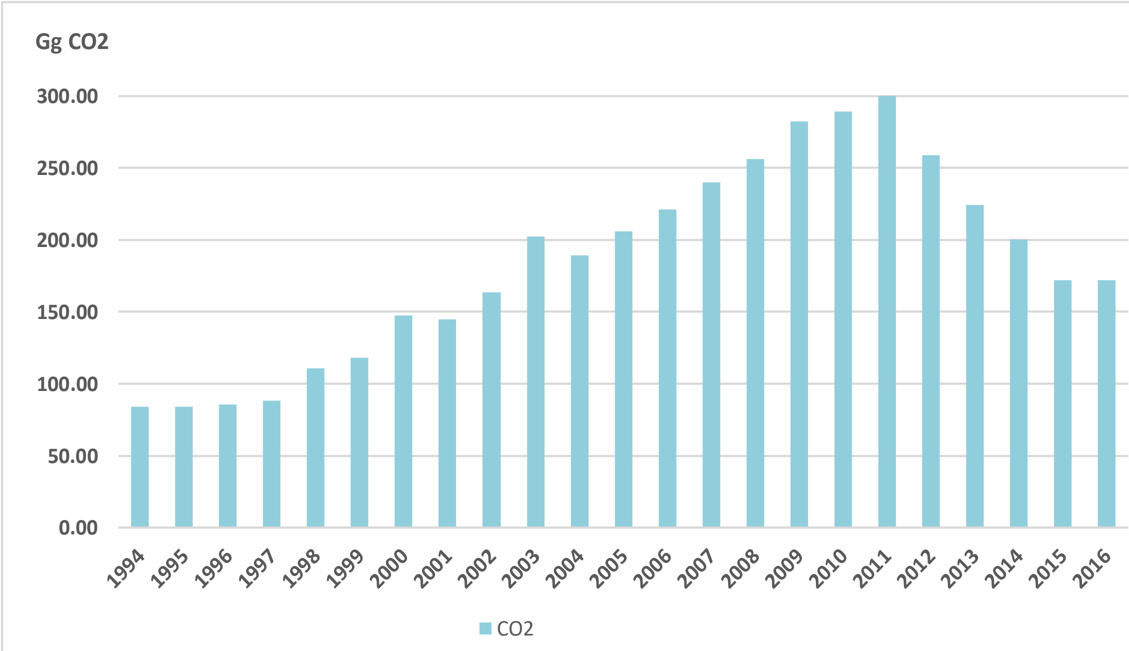


Figure 15 - Emissions of CH_4 in other sectors. Data in Gg

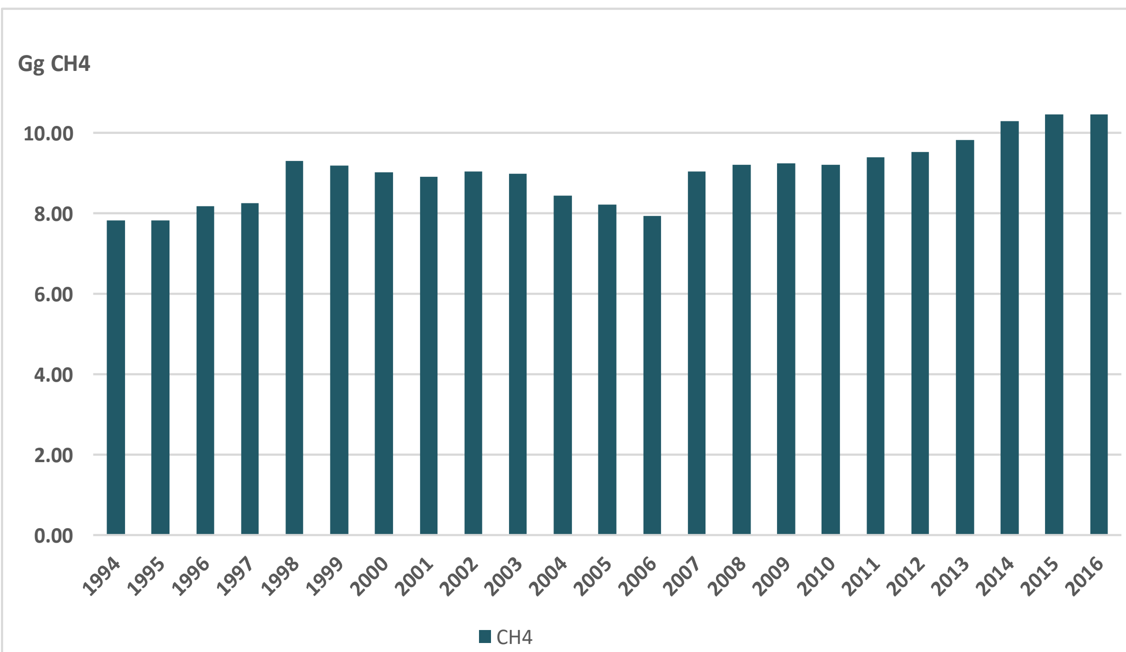
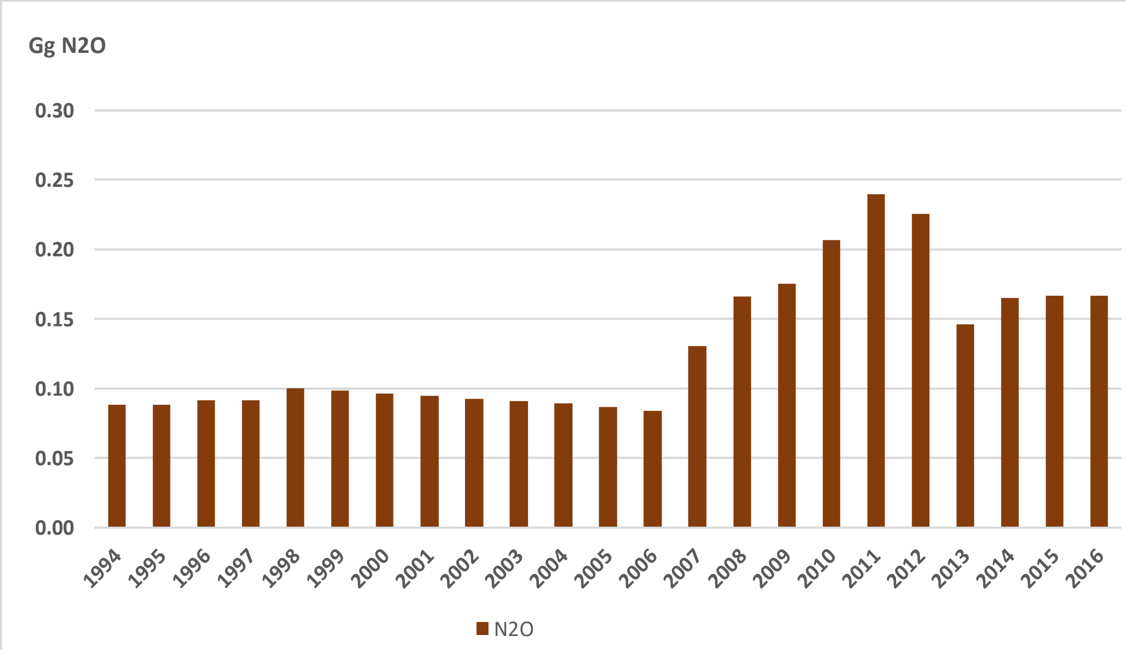


Figure 16 - Emissions of N_2O in other sectors. Data in Gg



3.3.4. Comparison between the Reference and Sectoral Methods

IPPC guidelines recommend applying a Sectoral approach and a Reference approach to estimate country's CO_2 emissions from fuel combustion and to compare the results of these two independent estimates. The Sectoral approach uses values bounded to each category that together add up the national total of the Energy sector while the Reference approach uses the total values of the national energy statistics.

The Reference approach is a top-down approach, using a country's energy supply data to calculate the emissions of CO_2 from combustion of mainly fossil fuels. Therefore, the Reference approach is designed to calculate the emissions of CO_2 from fuel combustion, starting from high level energy supply data.

The assumption is that carbon is conserved so that, for example, carbon in crude oil is equal to the total carbon content of all the derived products.

The Reference approach does not distinguish between different source categories within the energy sector and only estimates total CO_2 emissions from Source category 1A, Fuel Combustion.

For estimating CO_2 emissions using the reference approach, the following 5 steps methodology needs to be followed:

- Step 1: Estimate Apparent Fuel Consumption in Original Units
- Step 2: Convert to a Common Energy Unit
- Step 3: Multiply by Carbon Content to Compute the Total Carbon
- Step 4: Compute the Excluded Carbon

- Step 5: Correct for Carbon Unoxidized and Convert to CO_2 Emissions

These steps are expressed in the following equation:

$$CO_2 = \sum_{all\,fuels} \left[\left(\left(AC_{fuel} * CFactor_{fuel} * CC_{fuel} \right) * 10^{-3} - ECarbon_{fuel} \right) * COF_{fuel} * 44/12 \right]$$

Where:

AC= Apparent Consumption = production + imports – exports – international bunkers – stock change
CFactor = conversion factor for the fuel to energy units (TJ) on a net calorific value basis
CC = carbon content (tonne C/TJ (= kg C/GJ))
ECarbon = carbon in feedstocks and non-energy use excluded from fuel combustion emissions (Gg C)

The data used for calculating the reference approach is the energy balance provided by the Ministry of Mines and Energy. The differences between the sectoral and reference approach are the following:

Table 31 – Differences between the sectoral and reference approaches (%)

2010	2011	2012	2013	2014	2015	2016
6.01	3.41	6.05	0.88	0.57	7.34	7.73

There was no official energy balance before year 2010. The sectoral approach uses the most disaggregated data available that for years 2010-2015 is generally available in ERIA statistics.

The data sources used in both approaches (ERIA statistics and the energy balance form the ministry of Mines) are official. Nevertheless, no information is available to explain these differences between data sources. The data from ERIA statistics is more disaggregated and was found to be more consistent than the data from the Ministry of Mines. For this reason, it is the main data source used by the inventory. For the future, Cambodia will need to address the improvement of its energy statistics and ensure the consistency of the fuel consumption data. For years 2010 and 2012 the difference is found in solid fuels, while for years 2015 and 2016 the difference is encountered in liquid fuels. A detailed explanation of the inconsistencies found between data sources is provided at category level in the methodological section of the inventory.

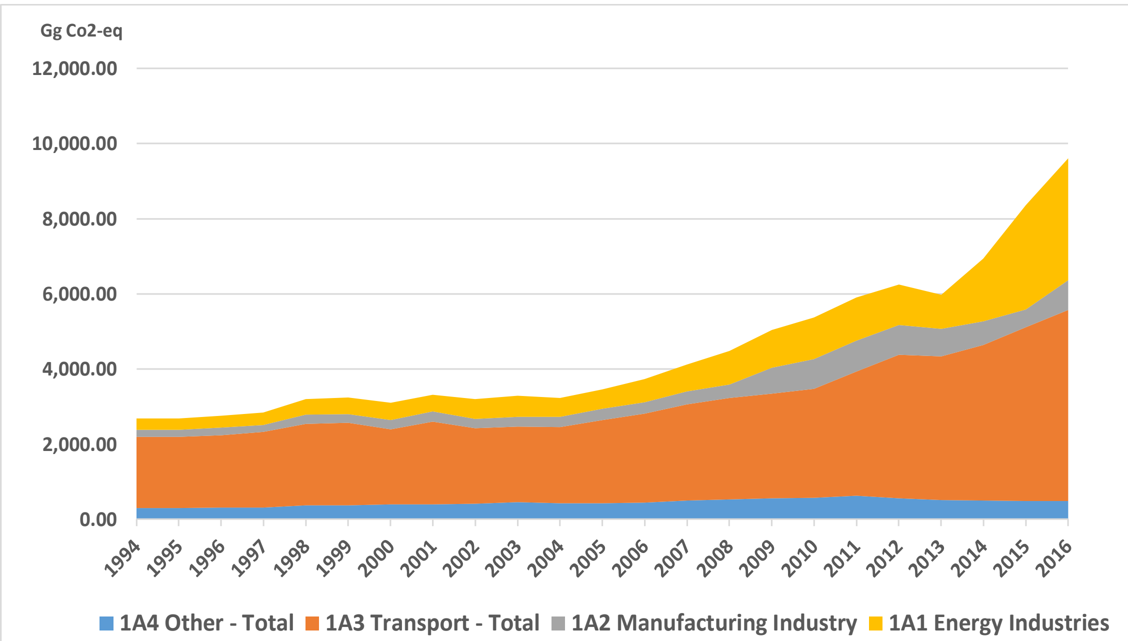
3.3.5. Energy emissions trend

In the time span covered by the inventory, Cambodian GDP has experienced a significant expansion, along its population. This is reflected in the increasing trend of the emissions of the Energy sector. The energy demand has experienced a significant increase, transport sector is expanding, and the population is migrating to cities; all these factors combined led to increasing fuel consumption and higher GHG emissions in the energy sector.

Table 32 - Trend of emissions (GHG, Gg CO_2-eq)

Inventory Sector	1994	2000	2005	2010	2015	2016
1A1. Energy Industries	298.87	450.75	512.49	1 120.27	2 766.58	3 255.58
1A2. Manufacturing Industry	188.73	242.25	300.79	781.84	479.92	785.59
1A3. Transport	1 892.04	2 003.53	2 205.42	2 897.00	4 625.81	5 094.21
1A4. Other	305.89	401.64	437.32	581.34	483.26	501.19
Total	2 685.53	3 098.17	3 456.03	5 380.45	8 355.57	9 636.58

Figure 17 – GHG emissions in the energy sector - 1994-2016 (Gg CO_2-eq)



As illustrated in the figure above, the main contributor to energy sector emissions is transport (category 1A3), with a contribution that ranges from a 70.5% in 1994, to a 52.9% in 2016. The second contributor to GHG emissions of the energy sector is energy industries (category 1A1), with a contribution that ranges from a 11.1% in 1994 to a 33.8% in 2016.

The sharp interannual variation of emissions in the energy industry in year 2013 is due to the effect produced by the trade-off in electricity production from oil products to coal (a sharp decrease in oil products consumption were registered in 2013, while coal consumption only starts to raise in year 2014, producing this fall in consumption in year 2013) added to an overall slowdown in fuel consumption produced this year. The third contributor to the emissions is the sector other (category 1A4), with a contribution that ranges from a 11.4% in 1994 to a 5.2% in 2016. Lastly, the manufacturing and construction industry contributes with a 7.0% of emissions in 1994 and increased up to 8.2 in year 2016. The following table shows the contribution of each category to the energy GHG emissions for the entire time period.

Table 33 - Percentage of contribution to energy GHG emissions by category

Inventory Sector	1994	2000	2005	2010	2015	2016
1A1. Energy Industries	11.1%	14.5%	14.8%	20.8%	33.1%	33.8%
1A2. Manufacturing Industry	7.0%	7.8%	8.7%	14.5%	5.7%	8.2%
1A3. Transport	70.5%	64.7%	63.8%	53.8%	55.4%	52.9%
1A4. Other	11.4%	13.0%	12.7%	10.8%	5.8%	5.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Regarding the contribution of each gas to total GHG emissions, the following table show the detailed evolution of the split of greenhous gases for the entire time period.

Table 34 - Percentage of emissions by gas

Inventory Sector	1994	2000	2005	2010	2015	2016
CO_2	78.3%	76.3%	79.9%	87.4%	91.1%	92.2%
CH_4	18.1%	20.3%	17.2%	9.9%	6.8%	5.9%
N_2O	3.6%	3.4%	2.9%	2.6%	2.1%	1.9%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note – This contribution is calculated converting first the emissions of each gas to CO2-eq using global warming potentials

The gas which is predominant in the sector is CO_2, followed by CH_4. The lower contribution of CH4 is explained by the decreasing contribution of biomass to total energy consumption, which in turn produces an increase in the contribution of CO_2. This effect is intesified in the last period of the series by the increase of coal consumption for production of electricity.

Apart from GHG, the estimates of the energy sector included GHG precursors, which has been calculated using the EMEP/EEA guidelines. The following figure shows the temporal evolution of the emissions estimated for all gases, including precursors.

Table 35 - Emissions by gas (Gg)

Inventory Sector	1994	2000	2005	2010	2015	2016
CO_2	2 101.44	2 363.53	2 590.02	4 705.08	7 615.25	8 866.28
CH_4	19.46	25.21	25.09	21.34	22.74	22.87
N_2O	0.33	0.35	0.36	0.48	0.58	0.61
NOx	14.46	16.70	17.69	31.80	39.20	43.43
CO	68.62	69.85	68.25	138.80	137.61	160.46
NMVOC	23.44	25.22	24.82	54.04	43.99	45.03
SO_2	2.51	3.15	3.26	14.71	27.40	32.61

3.3. Industrial Processes and Product Use (IPPU) sector

3.4.1. Characterization of the sector

The industrial Processes and Product Use (IPPU) sector includes the emissions which occur in the production and the consumption of products, except those due to the combustion of fuels, which are included in the energy sector, and the generation and treatment of waste, which are included in the waste sector. Considering that exclusion, GHG emissions are produced from a wide variety of industrial activities. The main emission sources are releases from industrial processes that chemically or physically transform materials where many different GHG, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs), are produced during these processes. Based on the 2006 IPCC Guidelines, the IPPU sector comprises eight categories:

- 2.A - Mineral Industry
- 2.B - Chemical Industry
- 2.C - Metal Industry
- 2.D - Non-Energy Products from Fuels and Solvent Use
- 2.E - Electronics Industry
- 2.F - Product Uses as Substitutes for Ozone Depleting Substances
- 2.G - Other Product Manufacture and Use
- 2.H – Other

Nevertheless, the information available in the country points out that in Cambodia only the production of cement, the consumption of lubricants and the use of fluorinated gases occur. Consequently, the inventory includes emissions estimates for 2.A.1 Cement Production, 2.D.1 Lubricant Use, 2F1 Refrigeration and Air Conditioning and 2.F.3 Fire Protection.

Aiming at providing an overview of the industrial structure of the country, the following table shows the percentual contribution of each economic sector to national total Gross Domestic product (GDP).

Table 36 – GDP distribution by economic sector – Cambodia, 2016

Sector/subsector	Percentage of total GDP
Agriculture	25%
Services	40%
Other	7%
Industry	29%
Mining	3.21%
Manufacturing	33.65%
Food, Beverages & Tobacco	4.86%
Textile,Wearing Apparel & Footwear	22.15%
Wood, Paper & Publishing	1.08%
Rubber Manufacturing	1.17%
Other Manufacturing	4.39%
Non-Metallic Manufacturing	1.12%
Basic Metal and Metal Products	0.63%
Other manufacturing	2.64%
Electricity, Gas & Water	1.17%
Construction	23.94%

Source: own elaboration based on https://www.nis.gov.kh/nis/NA/NA2016_Tab.htm

The data available on the production and consumption of products in the country is scarce. This has been a significant challenge for estimating the emissions of this category. This is, in fact, the reason for not estimating the emissions of NMVOC, which are potentially a big source of indirect GHG emissions, given the industrial characteristics of the country.

The following table provides a summary of the emissions for the energy sector in year 2016. A complete reporting table is provided in the section *Reporting tables*.

Table 37 - Sectoral reporting table – IPPU sector –GHG emissions of year 2016

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3	NO_x	CO	NMVOC	SO_2
Total industrial processes	1449.46	NA, NE, NO	NA, NE, NO	371.68	NA, NE, NO	NA, NE, NO	NA, NE, NO	NA, NE, NO	NA, NE, NO	NE, NO	NA, NE, NO
A. Mineral industry	1420.96							NA	NA	NA	NA
1. Cement production	1420.96										
2. Lime production	NE										
3. Glass production	NE										
4. Other process uses of carbonates	NE							NA	NA	NA	NA
B. Chemical industry	NA, NO	NA, NO	NA, NO	NA, NO	NA, NO	NA, NO	NA, NO	NA, NO	NA, NO	NA, NO	NA, NE, NO
C. Metal industry	NE, NO	NE, NO	NO	NO	NO	NO	NO	NE, NO	NE, NO	NE, NO	NE, NO
D. Non-energy products from fuels and solvent use	NA, NE	NA, NE	NA, NE					NA	NA	NE	NE
1. Lubricant use	28.50	NE	NE					NA	NA	NE	NA
2. Paraffin wax use	NE	NE	NE					NA	NA	NE	NA
3. Other	NA	NA	NA					NA	NA	NE	NA
E. Electronics industry				NE, NO	NE, NO	NE, NO	NE, NO				
F. Product uses as substitutes for ODS[(2)]				371.68	NA, NE, NO	NA, NO	NA, NO				
1. Refrigeration and air conditioning				371.50	NE	NA	NA				
2. Foam blowing agents				NO	NA	NA	NA				
3. Fire protection				0.19	NE	NA	NA				
4. Aerosols				NO	NA	NA	NA				
5. Solvents				NO	NO	NO	NO				
6. Other applications				NO	NO	NO	NO				
G. Other product manufacture and use	NO	NO	NO	NA, NO	NA, NO	NA, NO	NA, NO	NO	NO	NO	NO
H. Other (as specified in tables 2(I).A-H and 2(II))[(3)]	NE	NA	NA	NA	NA	NA	NA	NA	NA	NE	NA

Note: NO: not occurring NA: not applicable NE: not estimated

3.4.2. Data sources

The table 38 below summarises the information used for the estimation of emission in the IPPU sector:

Table 38 - IPPU source of information

Source of information	Description of information
Ministry of Industry and Handicraft	Production data for years 2014-2017
Different sources compiled by the national team	Cement Production capacity and year of installation
One cement production company	Production data from one cement production plant
Cambodia Energy Statistics – ERIA and the Ministry of Mines and Energy.	Fuel consumption data
The National Ozone Unit Ministry of Environment the Royal Government of Cambodia	CAMBODIA HFC INVENTORY

3.4.3. Industrial emissions by category

2A. Mineral Industry

This category includes the CO_2 emissions due to the consumption of carbonates in the production and use of mineral industrial products. As described by IPCC 2006, There are two broad pathways for release of CO2 from carbonates: calcination and the acid-induced release of CO2. In Cambodia, we will find only emissions due to calcination. A typical calcination reaction would be the following:

$$CaCO_3 + Heat \rightarrow CaO + CO_2$$

CO_2 emissions from calcination of carbonates are mainly produced in three industrial activities: i) cement production, ii) lime production, and iii) glass production. Other industrial activities with lower significance are the production of ceramics, soda ash and magnesite production. According to this differentiation, IPCC 2006 Guidelines proposes the following categories for estimating CO2 emissions due to calcination of carbonates: 2A1 Cement production, 2A2 Lime production, 2A3 Glass production and 2A4 other uses of carbonates.

The methodologies for the estimation of the emissions in the four categories are based on the same methodological principle: the characterisation of the carbonates calcined with the objective of calculating stoichiometrically the CO_2 release to the atmosphere. The molecular weight of the reagents and products of the calcination will produce the emission factor for each case. In the case of the typical calcination reaction {1}, the stoichiometric emission factor for $CaCO_3$ will be ~ 44 tCO2/t Carbonate consumed:

$$CaCO_3 + Heat \rightarrow CaO + CO_2$$
$$\text{Molecular Weight: } [40 + 12 + 16x3] \rightarrow [40 + 16] + [12 + 16 x2]$$
$$100 \rightarrow 56 + 44$$

For the inventory, only the production of cement has been identified as occurring in the country. The completeness of the sector will need to be further assessed in the future.

Cement production

In cement manufacture, CO_2 is produced during the production of clinker, a nodular intermediate product that is then finely ground, along with a small proportion of calcium sulfate [gypsum ($CaSO_4 \cdot 2H_2O$) or anhydrite ($CaSO_4$)], into hydraulic (typically Portland) cement. During the production of clinker, limestone, which is mainly calcium carbonate ($CaCO_3$), is heated, or calcined, to produce lime (CaO) and CO_2 as a by-product (as in the expression above).

Additionally, cement kiln dust (CKD) may be generated during the manufacture of clinker. Emission estimates should account for emissions associated with the CKD.

Activity data

The data used for the estimation of the cement production emissions consist on:

i) national total cement production; and
ii) clinker and cement production from the biggest producer company in the country. The information of the production plant is not presented in this report for confidentiality reasons.

It is worth highlighting that 100% of national cement production is covered by the production plant which provided information for the period 2007-2015. In 2016, however, not all cement production is covered by the production of this plant. No information was available on cement production before 2007.

Table 39 - Activity data cement production. Data in tonnes

Year	National total cement production
2007	86 899
2008	772 029
2009	737 326
2010	814 105
2011	947 471
2012	1 071 899
2013	1 117 336
2014	1 161 633
2015	1 389 880
2016	3 034 231

Methodology and emission factors

The methodology followed is a combination of the tier 1 and tier 2 approaches of 2006 IPCC. First, the clinker production provided by the biggest production plant is used for calculating CO_2 emissions using the tier 2 approach. The following equation illustrates the method followed:

$$CO_2\ Emissions = M_{cl} * EF_{cl} * CF_{ckd}$$

Where:

M_{cl} = weight (mass) of clinker produced, tonnes

EF_{cl} = emission factor for clinker, tonnes CO_2/tonne clinker

CF_{ckd} = emissions correction factor for CKD, dimensionless

Then, as the information provided by the production plant included both cement and clinker production, the amount of cement not covered by the production plant was calculated by subtracting the production of the plant from the total national production. Using this quantity as activity data, the tier 1 method was applied, as follows:

$$CO_2\ Emissions = \left[\sum_i (M_{ci} * C_{cli}) - Im + E_x\right] * EF_{clc}$$

Where:

Mcl = weight (mass) of cement produced of type i, tonnes

Ccli = clinker fraction of cement of type i, tonnes

Im = imports for consumption of clinker, tonnes

Ex = esports of clinker, tonnes

EF_{clc} = emission factor for clinker in the particular cement, tonnes CO_2/tonne clinker. The default EF_{clc} is corrected for CKD

CF_{ckd} = emissions correction factor for CKD, dimensionless

The emission factor used was the default tier 1 emission factor, which is already corrected for CKD: 0.52 tonnes CO_2/tonne clinker.

The clinker fraction used for the cement production not covered by the production plan which provided information on clinker was the default provided by IPCC: 95%.

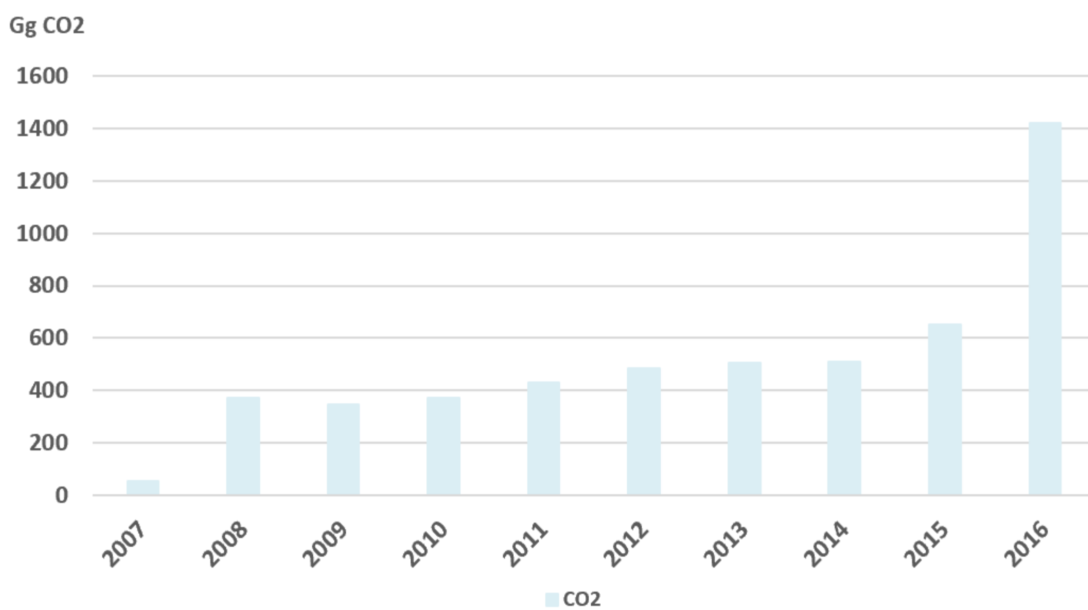
Results

Table 40 - Emissions in cement production. Data in Gg

Year	CO_2 (Gg)
1994	0
2005	0
2010	370.14
2011	430.89
2012	486.72
2013	507.13
2014	510.49
2015	652.89
2016	1 420.96

The high increase in CO_2 emissions in 2016 is explained by the commissioning of a new cement plant in 2015. In 2018 an additional plant has been inaugurated, so the increasing trend in CO_2 emissions from cement production is expected to continue in the future.

Figure 18 - Emissions of CO_2 in cement production. Data in Gg



2D1. Lubricants

Lubricants are mostly used in industrial and transportation applications. Lubricants are produced either at refineries through separation from crude oil or at petrochemical facilities. The use of lubricants in engines is primarily for their lubricating properties and associated emissions are therefore considered as non-combustion emissions to be reported in the IPPU Sector. However, in the case of 2-stroke engines, where the lubricant is mixed with another fuel and thus on purpose co-combusted in the engine, the emissions should be estimated and reported as part of the combustion emissions in the Energy Sector. In this edition of the inventory all the lubricants consumed in the country are considered as non-energy consumption and reported in the IPPU, consistently with the information provided in the energy balances of the country.

Activity data

The data used for the estimation of lubricant emissions consist on national total lubricant consumption from the energy balance developed by the ministry of Mines and Energy and ERIA (see the energy sector for additional information). Due to the unavailability of data, the information of year 1995 has been subrogated for obtaining the activity data and emissions of year 1994.

Table 40 - Activity data lubricant consumption. Data in tonnes

Year	Lubricant consumption (TJ)
1994	259.58
2005	437.10
2010	586.15
2011	795.49
2012	711.76
2013	795.49
2014	586.15
2015	1 925.93
2016	1 943.39

The increase of activity data of lubricants in the last years of the time series is due to a very significant increase in the lubricants used in the transport sector, which reflects the economic development (increased per capita income rates) of the country. The order of magnitude of this data and the time series consistency will need to be ascertained in future inventory editions.

Methodology and emission factors

The tier 1 approach of 2006 IPCC guidelines has been used, as follows:

$$CO_2\ Emissions = LC * CC_{Lubricant} * ODU_{Lubricant} * 44/12$$

Where:

LC = total lubricant consumption, TJ

CCLubricant = carbon content of lubricants (default), tonne C/TJ (=kg C/GJ)

ODULubricant = ODU factor (based on default composition of oil and grease), fraction 44/12 = mass ratio of CO_2/C

This equation has been applied using a Lubricant Carbon Content (tonne-C/TJ) of 20, and a Fraction Oxidized During Use (ODU factor) of 0.2.

Results

Table 41 - Emissions in lubricants category. Data in Gg

Year	CO_2 (Gg)
1994	3.81
2005	6.41
2010	8.60
2011	11.67
2012	10.44
2013	11.67
2014	8.60
2015	28.25
2016	28.50

The increasing trend of emissions of lubricants is driven by the increasing consumption, which is in turn due to the demographic and economic expansion of the country. The significant increase of lubricants in the last years of the series is due to a very significant increase in the lubricants used in the transport sector.

2F - Substitutes for Ozone Depleting Substances (F-gases)

Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and other fluorinated gases are serving as alternatives to ozone depleting substances (ODS) being phased out under the Montreal Protocol. The sectors in which HFC, PFC and other fluorinated gases are used are the following:

- refrigeration and air conditioning;
- fire suppression and explosion protection;
- aerosols;
- solvent cleaning;
- foam blowing; and
- other applications.

HFCs and PFCs have high global warming potentials and are acquiring importance at international level regarding their contribution to national totals of GHG emission inventories. In this edition of the inventory, HFC emissions of the categories refrigeration and air conditioning and fire protection have been estimated.

Activity data

The activity data of this category is obtained from a study carried out by The National Ozone Unit of the Ministry of Environment on Hydrofluorocarbons (HFC) consumed in the country. The information is limited to the imports of gases.

Table 42 - Activity data of refrigeration - Imports of gases (tonnes)

Year	HFC-125	HFC143a	HFC134a
2012	1.38	1.63	5.58
2013	1.19	1.41	7.00
2014	3.15	3.57	8.77
2015	2.35	2.72	10.79
2016	2.41	2.79	11.06

Table 43 - Activity data of air conditioning - Imports of gases (tonnes)

Year	HFC-125	HFC134a	HFC-32
2012	4.75	260.56	4.74
2013	6.20	269.64	6.16
2014	14.30	303.85	14.26
2015	15.98	317.38	15.94
2016	16.38	325.32	16.34

Table 44 - Activity data of fire protection- Imports of gases (tonnes)

Year	HFC-227ea
2012	0.000
2013	0.000
2014	0.080
2015	0.080
2016	0.082

Methodology and emission factors

The tier 1 approach provided by 2006 IPCC Guidelines has been followed by using the worksheets provided along with the guidelines available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol3.html

The main assumptions taken and default coefficients used for the estimation of the emissions are illustrated in the following table:

Table 45 - The main assumptions taken and coefficients used

Year of Introduction of the gases	2005
Growth Rate in New Equipment Sales	2.5%
Assumed Equipment Lifetime (years)	10
Emission Factor from installed base	15%
% of gas destroyed at End-of-Life	25%

The data which was made available to the inventory team consisted in imports of refrigerant products (blends). In order to obtain the activity data of each gas by category, the gas composition of blends provided by IPCC has been used to convert the data, as follows:

Table 46 - Gas composition of blends

Gas blend	HFC-125	HFC143a	HFC134a	HFC-32	Total
R-404A	44%	52%	4%		1
R-507A	50%	50%			1
R-410A	50%			50%	1
R-407C	25%		52%	23%	1

Source: table 7.8 chapter 7, volumen 2 IPPU, IPCC 2006

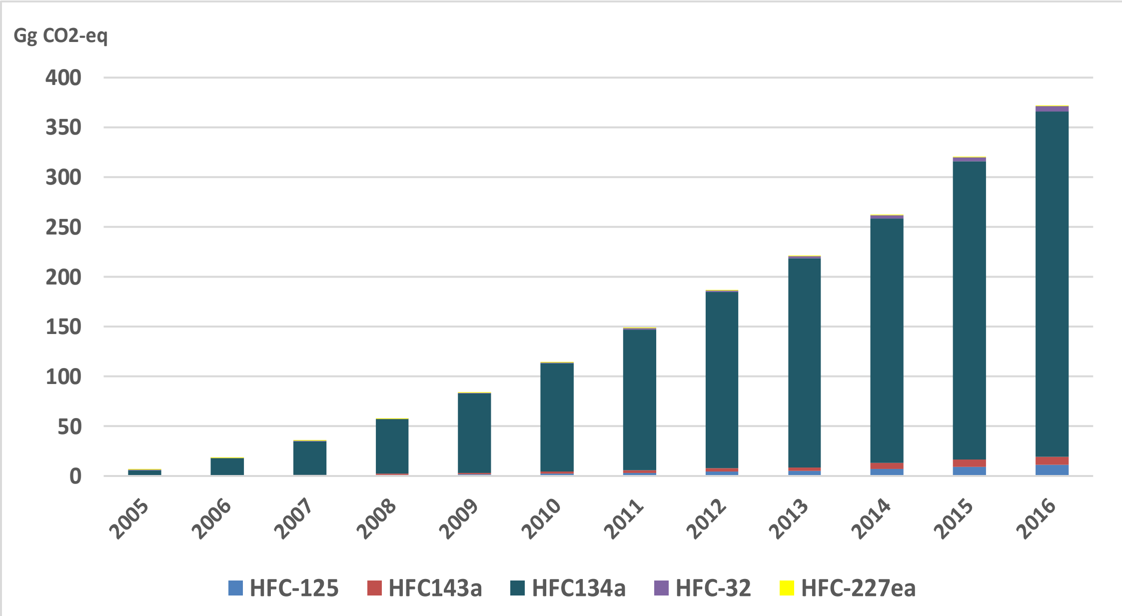
Results

Table 47 - HCF's Emissions. Data in Gg CO_2-eq

Year	HFC-125	HFC143a	HFC134a	HFC-32	HFC-227ea
1994	0	0.000	0.000	0	0
2005	0.15	0.12	6.00	0.050	0.003
2010	2.75	2.08	108.31	0.910	0.056
2011	3.58	2.70	140.79	1.183	0.073
2012	4.49	3.39	176.76	1.486	0.091
2013	5.07	3.83	209.58	1.887	0.111
2014	7.62	5.65	245.20	3.047	0.133
2015	9.46	7.02	299.23	4.376	0.162
2016	11.08	8.22	346.65	5.543	0.188

There has been a threefold increase in the consumption of HFCs gases. The most used gas is HFC134a, the HFC which is more used at international level in these applications. The increase in the consumption of gases has been driven by the expansion of the services sector (tourism).

Figure 19 - HFC emissions – data in Gg of CO_2-eq



3.4.4. IPPU emissions trends

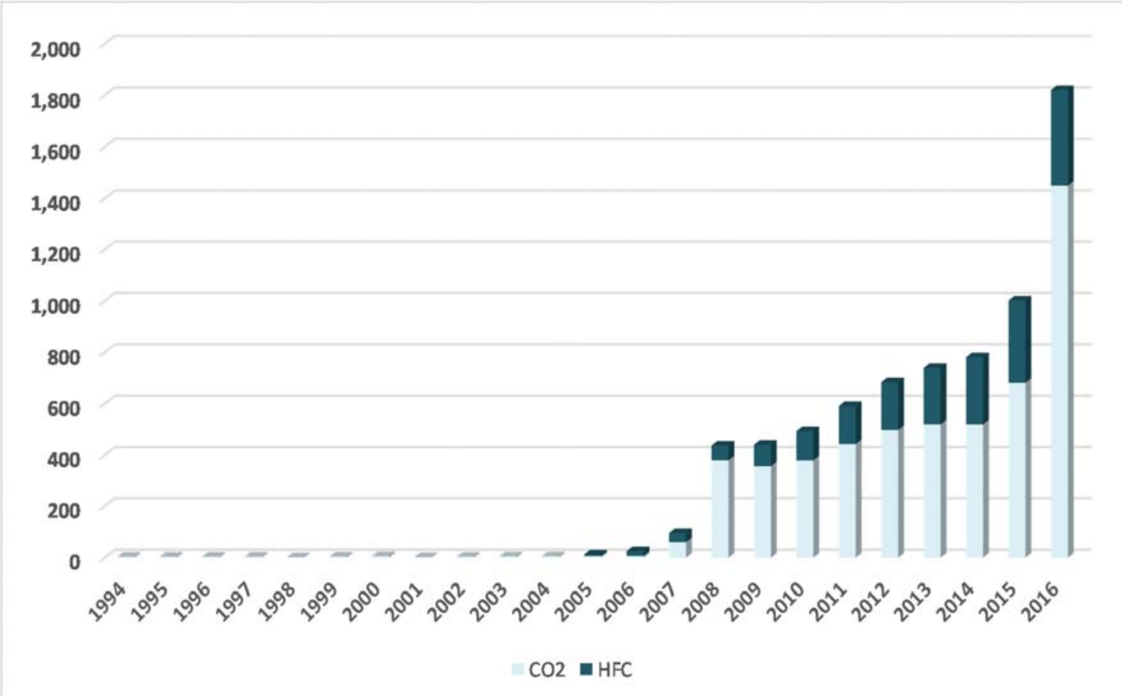
Table 48 - Trend of emissions (GHG, Gg CO_2-eq)

Inventory Sector	1994	2000	2005	2010	2015	2016
2A1. Cement production	NO	NO	NO	370	653	1,421
2D1. Lubricants	3.81	6.04	6.41	8.60	28.25	28.50
2F. Subst. for ODS (F-gases)	NO	NO	6.32	114.10	320.24	371.68
Total	3.81	6.04	12.73	492.84	1 001.38	1 821.15

Table 49 - Emissions by gas (Gg)

Inventory Sector	1994	2000	2005	2010	2015	2016
CO_2	3.81	6.04	6.41	378.74	681.14	1 449.46
CH_4	NA	NA	NA	NA	NA	NA
N_2O	NA	NA	NA	NA	NA	NA
HFC	NO	NO	6.32	114.10	320.24	371.68
NO_x	NA	NA	NA	NA	NA	NA
CO	NA	NA	NA	NA	NA	NA
NMVOC	NE	NE	NE	NE	NE	NE
SO_2	NA	NA	NA	NA	NA	NA
SF_6	NA	NA	NA	NA	NA	NA

Figure 20- GHG emissions in the IPPU sector– data in Gg of CO_2-eq



3.5. AFOLU sector

3.5.1. Characterization of the sector

AFOLU sector (Agriculture, forestry and other Land Uses), in Cambodia is very impacted by the land use part (category 3.B). For the period after 2010 especially, large emissions (131011 Gg CO2eq/yr) are estimated on the basis of changes measured between 2010 and 2014. Indeed, emissions largely exceeds removals for this category. In agriculture, rice cultivations and enteric fermentation are the main sources with respectively 9856 Gg CO2eq/yr and 3 554 Gg CO2eq/yr.

3.5.2. Data sources

The main data sources for agriculture are national statistics from the Ministry of Agriculture, Forestry and Fisheries (MAFF). It concerns animal populations, crop areas and productions.

Data on fertilizers is estimated thanks to statistics from the Ministry of Commerce (MoC). This data was completed by data estimated by the FAO and provided on FAOSTAT.

For the land use categories all the data used is coming from the report on forest reference level (FRL) provided by Cambodia to the UNFCCC within the REDD+ framework.

3.5.3. AFOLU emissions by category

3.A – Livestock

Activity data

All emissions from livestock are based on animal populations. The animal populations are estimated based on different references. Data from 1990-2007 is from Statics Yearbook 2008, data from 2009-2017 is from Annual Report of the General Directorate of Livestock and Livestock Production reports from the Ministry of Agriculture, Forestry and Fisheries (MAFF). Data for the year 2008 is estimated by linear interpolation between 2007 and 2009. Animal population of horses, sheep goats are extrapolated from 1990 to 2009 because of missing data. The category of poultry only includes chicken and ducks which are the main poultry production in Cambodia (pigeons, quails and geese are neglected).

Table 50 - Activity data - Animal populations (heads)

Year	Cattle	Buffaloes	Pigs	Poultry	Horses	Sheep	Goats
1990	2181000	736000	1515000	8163000	7682	689	23987
1991	2257100	755300	1550000	8816200	7682	689	23987
1992	2468000	804000	2043000	9901000	7682	689	23987
1993	2542010	823700	2122700	10692400	7682	689	23987
1994	2620905	809200	2024178	10017100	7682	689	23987
1995	2785725	764808	2043629	10062364	7682	689	23987
1996	2761823	743928	2151097	11411698	7682	689	23987
1997	2820783	693662	2438313	12098035	7682	689	23987
1998	2679928	693651	2339168	13116990	7682	689	23987
1999	2769420	653910	2189358	13417480	7682	689	23987
2000	2992670	693650	1933950	15249770	7682	689	23987
2001	2868830	626020	2114540	15248450	7682	689	23987
2002	2924480	625929	2105440	16678150	7682	689	23987
2003	2985300	660390	2304130	16013600	7682	689	23987
2004	3039939	710143	2428566	12990592	7682	689	23987
2005	3193146	676646	2688612	15085547	7682	689	23987
2006	3344742	724378	2740815	15135065	7682	689	23987
2007	3368449	772780	2389389	15825314	7682	689	23987
2008	3464691	750251	2257847	16176012	7682	689	23987
2009	3560932	727722	2126304	16514244	7682	689	23987
2010	3484481	702074	2057431	20543509	12468	613	10547
2011	3406967	689829	2099332	21307292	12573	346	11592
2012	3369790	656942	2208611	22834809	12312	215	11239
2013	3430895	619114	2454426	27316415	7119	100	12856
2014	3053537	541827	2360823	25461910	9078	238	16454
2015	2903421	506166	2357839	26506407	7486	378	21489
2016	2897126	523320	2371283	28230663	5610	400	22719

3.A.1 - Enteric Fermentation

Methodology and emission factors

Emissions from enteric fermentation are estimated with the tier 1 methodology from the 2006 IPCC guidelines according to these equations:

$$Emissions = EF_{(T)} * \left(\frac{N_{(T)}}{10^6}\right)$$

Where:

Emissions = methane emissions from Enteric Fermentation, Gg CH_4 yr^{-1}

$EF_{(T)}$ = emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}

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

T = species / category of livestock

$$Total\ CH_{4Enteric} = \sum_i E_i$$

Where:

Total $CH_{4Enteric}$ = total methane emissions from Enteric Fermentation, Gg CH_4 yr^{-1}

E_i = is the emissions for the i^{th} livestock categories and subcategories

Emission factors are default values proposed by the 2006 IPCC guidelines for Asia and developing countries in tables 10.10 and 10.11.

Table 51 - Emission factors for enteric fermentation – kg CH_4/head/year

Cattle	Buffaloes	Pigs	Poultry	Horses	Sheep	Goats
47	55	1	0	18	5	5

Results

Table 52 - Emission from enteric fermentation

Year	1994	2000	2005	2010	2015	2016
CH_4 (Gg/year)	170	181	190	205	167	168

3.A.2 - Manure Management

Methodology and emission factors for CH_4

CH_4 emissions from manure management are estimated with the tier 1 methodology from the 2006 IPCC guidelines according to this equation:

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

Where:

$CH_{4Manure}$ = CH_4 emissions from a manure management, for a defined population, Gg CH_4 yr^{-1}

$EF_{(T)}$ = emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}

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

T = species / category of livestock

CH_4 emission factors are default values proposed by the 2006 IPCC guidelines for Asia and developing countries with a warm climate in tables 10.14 and 10.15.

Table 53 - Emission factors for manure management – kg CH_4/head/year

Cattle	Buffaloes	Pigs	Poultry	Horses	Sheep	Goats	Elephants
1	2	7	0.02	2.19	0.2	0.22	0

The equations for tier 2 methodology proposed in the IPCC guidelines were also implemented with the default values proposed for manure management systems and logically, the emissions factors were like the ones proposed by the tier 1 methodology.

Results for CH_4

Table 54 - Emission from manure management

Year	1994	2000	2005	2010	2015	2016
CH_4 (Gg/year)	19	18	24	20	21	21

Methodology and emission factors for N_2O

N_2O emissions from manure management are estimated with the tier 1 methodology from the 2006 IPCC guidelines according to this equation:

$$N_2O_{D(mm)} = \left[\sum_{S}\left[\sum_{(T)}\left(N_{(T)} * Nex_{(T)} * MS_{(T,S)}\right)\right] * EF_{3(S)}\right] * \frac{44}{28}$$

Where:

$N_2O_{D(mm)}$ = direct N_2O emissions from a manure management in the country, Kg N_2O yr^{-1}

$N_{(T)}$ = number of head of livestock species/category *T* in the country Kg N animal yr^{-1}

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

$EF_{3(S)}$ = emission factor for the direct N_2O emissions from manure management system S in the country, Kg N_2O-N/kg N in manure management system *S*

S = manure management system

T = species / category of livestock

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

All parameters used in the calculations are default values proposed by IPCC guidelines for Asia: animal weights (TAM), nitrogen excretion rates (Nrate) and manure management systems.

Table 55 - Nitrogen excretion rates and animal weights

Variable\Animal	Cattle	Buffaloes	Pigs	Poultr y	Horses	Sheep	Goats
Nrate (kg N / 1000 kg animal/day)	0.34	0.32	0.5	0.82	0.46	1.17	1.37
TAM (kg/animal)	319	380	28	1.8	238	28	30
Nex (kg N/animal/year)	39.6	44.4	5.1	0.5	40.0	12.0	15.0

Table 56 - Manure management systems used for the entire time series

Variable\Animal	Cattle	Buffaloes	Pigs	Poultry	Horses	Sheep	Goats
Lagoon							
Liquid/Slurry			40%				
Solid storage							
Dry lot	46%	41%	54%				
Pasture range	50%	50%			100%	100%	100%
Daily spread	2%	4%					
Digester			6%				
Burned for fuel	2%	5%					
Pit <1 month							
Pit >1 month							
Poultry manure with litter				100%			
Other							

Emission factors are default values proposed by the 2006 IPCC guidelines in tables 10.21.

Table 57 - N_2O emission factors for manure management - kg N_2O-N/kg Nex

Lagoon	Liquid/Slurry	Solid storage	Dry lot	Daily spread	Digester	Pit <1 month	Pit >1 month	Poultry manure
0	0.005	0.005	0.02	0	0	0.002	0.002	0.001

Results for N_2O (direct emissions)

Table 58 - N_2O direct Emissions

Year	1994	2000	2005	2010	2015	2016
N_2O (Ggt/year)	2.18	2.32	2.50	2.62	2.22	2.23

3.B – Land

The calculations for the lands are based on a comprehensive monitoring of the land use and a country specific estimate for each type of land.

Activity data

The activity data is the set of land use matrixes implemented thanks to the comparison of different cartographies for 2006, 2010 and 2014. These matrixes are mostly focusing on forest areas because they were elaborated in the framework of the REDD+ program to define the forest reference level for Cambodia.

Table 59 - Activity data – Aggregated area land and land use changes (1 year matrixes) – ha or ha/Year

Year	Forest becoming other land	Other land becoming forest	Forest remaining forest	Other land remaining other land	Total forest	Total other land
2000	132733	37780	11363669	6626492	11401449	6759225
2001	132733	37780	11268715	6721446	11306495	6854179
2002	132733	37780	11173762	6816399	11211541	6949132
2003	132733	37780	11078808	6911353	11116587	7044086
2004	132733	37780	10983854	7006307	11021634	7139040
2005	132733	37780	10888901	7101260	10926680	7233994
2006	132733	37780	10793947	7196214	10831727	7328947
2007	132733	37780	10698993	7291168	10736773	7423901
2008	132733	37780	10604039	7386121	10641819	7518855
2009	132733	37780	10509086	7481075	10546865	7613808
2010	579280	95845	10356066	7129482	10451912	7708762
2011	579280	95845	9872632	7612917	9968477	8192197
2012	579280	95845	9389197	8096351	9485043	8675631
2013	579280	95845	8905763	8579786	9001608	9159066
2014	579280	95845	8422328	9063220	8518173	9642501
2015	579280	95845	7938894	9546655	8034739	10125935
2016	579280	95845	7455459	10030089	7551305	10609369

Methodology

For this inventory all the fluxes are calculated by stock variation by implanting the following equation 2.5 of the 2006 IPPC guidelines according to this:

$$\Delta C = \frac{(C_{t2} - C_{t1})}{(t_2 - t_1)}$$

Where:

ΔC = annual carbon stock change in the pool, tonnes C yr^{-1}

C_{t1} = carbon stock in the pool at time t_1, tonnes C

C_{t2} = carbon stock in the pool at time t_2, tonnes C

The different stocks are estimated based on different scientific references and national expertise. They are estimated for above ground and belowground biomass.

Table 60 - Parameter – Biomass content of forestlands

Land use/cover			Above ground biomass (t)*	Below ground biomass (t)**
Category		Sub-category		
Forest	Natural forest	Evergreen	163	31
		Semi-evergreen	243	44
		Deciduous	85	18
		Pine forest	100	20
		Bamboo	0	0
		Mangrove	150	29
		Rear mangrove	165	32
		Flooded forest	70	15
		Forest regrowth	75	16
	Planted forest	Pine plantation	100	20
		Other plantation	100	20

* Above ground biomass is estimated thanks to a various sources (UN-REDD, UNDP, IPCC, etc.) as presented in the Forest Reference Level (FRL)

** Below ground biomass is estimated on the basis of above ground biomass thanks to the equations proposed by Cairns et al (1997) in IPCC (2003)

Results

The emissions of this sub-sector have not been disaggregated into more detailed categories because all lands which are not forests were aggregated in the baseline data used by the inventory. In the current inventory, all GHG estimates are related to forest, they may concern afforestation, deforestation or changes in forests. Nevertheless deforestation, is not supposed to be reported under forest category but under the final use category, which is not known. For this reason, it was preferred to keep only one aggregated value for all land use estimates (category 3.B) in the nomenclature.

Table 61 - Land Emissions

AGB + BGB Fluxes (tC/yr)	2000	2005	2010	2015	2016
Forest becoming other land*	-9165575	-9165575	-40230160	-40230160	-40230160
Other land* becoming forest	1933497	1933497	5339125	5339125	5339125
Forest remaining forest	-136636	-136636	-839303	-839303	-839303
Other land* remaining other land*	0	0	0	0	0
Total forest	1796860	1796860	4499822	4499822	4499822
Total other land*	-9165575	-9165575	-40230160	-40230160	-40230160
Total (tC/yr)	-7368715	-7368715	-35730339	-35730339	-35730339

*Other lands encompass all lands which are not forests (croplands, grasslands, etc.)

Table 62 – CO_2 emissions for Land (Gg)

AGB + BGB Fluxes	1994	2000	2005	2010	2015	2016
Emissions (Gg CO_2/yr)	34 149	34 149	34 149	151 274	151 274	151 274
Removals (Gg CO_2/yr)	-7 130	-7 130	-7 130	-20 263	-20 263	-20 263
Emissions/Removals (Gg CO_2/yr)	27 019	27 019	27 019	131 011	131 011	131 011

3.C.1 - Emissions from biomass burning

Few information is known on biomass burning in Cambodia. For crop residue burning, relevant and accurate data has been found in a scientific publication (San et al, 2009[7]), this publication was used to estimate biomass burning from rice cultivation.

For grassland burning the estimates used in the first and second national communication that 50% (IPCC 1996 guidelines) of grassland was burnt has been kept for the entire time series.

Activity data

The activity data is the area concerned by biomass burning. For crop residues, biomass burning was considered for rice crops and sugar cane cultivation. For rice crops, it was estimated that straw is removed on 100% of rice fields but remaining stubble is burnt in some cases (stubble is supposed to be burnt on 30% in rainfed areas and 20% in irrigated areas). For sugar cane, burning before harvest is very common because harvest is difficult without burning when there is no mechanisation, it was estimated that 100% of the area of sugar cane is burnt. For other crops no information was found, it was supposed that residues are not burnt.

Table 63 - Activity data – Area and biomass burnt

Year	Area burnt (ha)			Biomass burnt (t)		
	rice	sugar cane	grassland	rice	sugar cane	grassland
1990	541 500	6 000	240 000	155 930	39 000	984 000
1991	500 700	6 000	240 000	145 822	39 000	984 000
1992	490 620	6 000	240 000	140 286	39 000	984 000
1993	532 088	6 473	240 000	151 752	42 075	984 000
1994	431 880	7 000	240 000	128 453	45 500	984 000
1995	555 700	7 420	241 417	176 718	48 230	989 808
1996	541 840	7 022	242 833	173 029	45 643	995 617
1997	556 387	8 035	244 250	176 131	52 228	1 001 425
1998	566 190	6 933	245 667	179 917	45 065	1 007 233
1999	600 893	8 374	247 083	197 238	54 431	1 013 042
2000	547 648	7 480	248 500	186 141	48 620	1 018 850
2001	569 278	7 727	248 500	191 737	50 226	1 018 850
2002	572 072	9 395	248 500	186 738	61 068	1 018 850
2003	644 778	8 482	248 500	218 531	55 133	1 018 850
2004	603 372	6 739	248 500	199 442	43 804	1 018 850
2005	692 247	5 992	248 500	252 324	38 948	1 018 850

[7] Estimation of methane and nitrous oxide emissions from rice field with rice straw management in Cambodia. Vibol San, Sirintornthep Towprayoon. Article in Environmental Monitoring and Assessment · April 2009

Year	Area burnt (ha)			Biomass burnt (t)		
	rice	sugar cane	grassland	rice	sugar cane	grassland
2006	722 156	8 296	248 500	263 714	53 924	1 018 850
2007	735 650	10 458	248 500	275 179	67 977	1 018 850
2008	747 946	13 297	248 500	286 103	86 431	1 018 850
2009	763 976	13 533	248 500	296 915	87 965	1 018 850
2010	798 126	17 072	248 500	317 423	110 968	1 018 850
2011	806 122	22 069	248 500	331 674	143 449	1 018 850
2012	787 528	27 859	248 500	321 047	181 084	1 018 850
2013	842 346	30 665	248 500	345 973	199 323	1 018 850
2014	859 565	25 503	248 500	187 061	165 770	1 018 850
2015	858 744	27 316	248 500	348 218	177 554	1 018 850
2016	878 079	28 972	248 500	191 052	188 318	1 018 850

Methodology

Estimation of greenhouse gas emissions from fire were calculated according to the following equation:

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

Where:

Lf_{ire} = amount of greenhouse gas emissions from fire, tonnes of each GHG e.g., CH_4, N_2O, etc.

A = area burnt, ha

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

C_f = combustion factor, dimensionless

G_{ef} = emissions factor, g kg-1 dry matter burnt

Note: Where data for M_B and C_f are not available, a default value for the amount of fuel actually burnt (the product of M_B and C_f) can be used from IPCC guidelines.

Emission factors are default values proposed by the IPCC 2006 guidelines in table 2.5.

Table 64 - CH_4 and N_2O emission factors for biomass burning

Variable	CH_4	N_2O
Agricultural residues (g/kg)	2.7	0.07
Grassland (g/kg)	2.3	0.21

Results

Table 65 - CH_4 emissions for biomass burning (Gg)

CH_4 (Gg/yr)	1994	2000	2005	2010	2015	2016
Crop residue burning	0.47	0.63	0.79	1.16	1.42	1.02
Grassland burning	2.26	2.34	2.34	2.34	2.34	2.34

Table 66 - NO_2 emissions for biomass burning (Gg)

N_2O (Gg/yr)	1994	2000	2005	2010	2015	2016
Crop residue burning	0.01	0.02	0.02	0.03	0.04	0.03
Grassland burning	0.21	0.21	0.21	0.21	0.21	0.21

3.C.2 – Liming

No data on liming were collected, CO_2 emissions from liming are thus neglected. This activity is supposed to be weak in Cambodia.

3.C.3 - Urea application

Activity data

The activity data is the amount of urea spread in the fields. Data on fertilizers are not easy to use and data treatment was necessary to estimate a relevant estimate of fertilizer use in Cambodia. For this source only urea must be considered among fertilizer (mostly included in urea and urea ammonium nitrate). The form of nitrogen fertilizer is provided by FAOSTAT (even if this data is very fluctuating on the period). Gaps in the data sets are fulfilled by extrapolation.

Table 67 - Activity data – Urea application (Gg)

Year	Urea (t)	Urea ammonium nitrate (t)	Source
1990	600	0	FAOSTAT
1991	1 500	0	FAOSTAT
1992	1 200	0	FAOSTAT
1993	3 600	0	FAOSTAT
1994	2 200	0	FAOSTAT
1995	2 200	0	FAOSTAT
1996	1 600	0	FAOSTAT
1997	2 000	0	FAOSTAT
1998	3 220	0	FAOSTAT
1999	2 244	0	estimate
2000	2 244	0	estimate
2001	2 244	0	estimate
2002	2 244	0	estimate
2003	2 244	0	estimate
2004	2 244	0	estimate
2005	2 244	0	estimate
2006	2 244	0	estimate
2007	2 559	0	FAOSTAT
2008	13 377	483	FAOSTAT
2009	16 129	1 476	FAOSTAT
2010	40 629	294	FAOSTAT
2011	23 378	751	estimate
2012	23 378	751	estimate
2013	23 378	751	estimate

2014	23 378	751	estimate
2015	23 378	751	estimate
2016	23 378	751	estimate

Methodology and emission factors

CO_2 emissions from urea application are estimated with the tier 1 methodology from the 2006 IPCC guidelines. The emission factor is 0.2 tC/t urea. The fertilizer named “Urea ammonium nitrate” (UAN) contains approximatively 50% of urea, the emission factor is thus 0.1 tC/t UAN.

$$CO_2 - C\ Emission = M * EF$$

Where:

CO_2-C Emission = annual C emissions from urea application, tonnes C yr^{-1}

M = annual amount of urea fertilization, tonnes urea yr^{-1}

EF = emission factor, tonne of C (tonne of urea)$^{-1}$

Results

Table 68 - CO_2 emissions for Urea application

Gas	1994	2000	2005	2010	2015	2016
CO_2 (Gg)	1.61	1.65	1.65	29.90	17.42	17.42

3.C.4 - Direct N_2O emissions from managed soils

Activity data

Direct N_2O emissions are based on different nitrogen inputs. Mineral fertilizers, organic fertilisers, pasture and crop residues are taken into account for this calculation.

- Mineral fertilisation is not easy to estimate in Cambodia. Data by nutrients and products are provided by FAOSTAT for some years and the Ministry of Commerce (MoC) provides statistics on total fertilisers (tons of product) since 2002. FAOSTAT data by nutrient and data from MoC are rather consistent considering average nutrient contents of fertilizers (20% of N in nitrogenous fertilizers, 30% of P2O5 in phosphate fertilizers and 20% of K_2O in potash fertilizers). The trend of fertiliser consumption is similar in both FAOSTAT data and MoC. For the inventory it was chosen to use MoC data to estimate the fertilizer consumption associated with nitrogen content of fertilizer indicated by FAOSTAT data. This mineral fertilisation, which remains rather low, is supposed applied on rice cultivation (assumption due to missing additional elements on the type of crop fertilised with mineral fertiliser).
- Organic fertilisation is directly estimated from the livestock calculation. All organic calculation is also considered in rice cultivation.
- Nitrogen inputs due to pasture are directly estimated from livestock calculations. All nitrogen inputs from pasture are put on other fields than rice areas.
- Nitrogen inputs due to crop residues are calculated on the basis of crop areas and crop productions. Crop residues were estimated for rice, maize, castor oil,

cotton, sesame, beans, peanuts soybeans, cassava, sweet potatoes and other roots and tubers.

Table 69 - Activity data – Inorganic fertilizers

Year	Inorganic fertilizer (tons of product)	Nitrogen Content (%)	Nitrogen in fertilizers (tN)
1990			7 044
1991			7 044
1992			7 044
1993			7 044
1994			7 044
1995			7 044
1996			7 044
1997			7 044
1998			7 044
1999			7 044
2000			7 044
2001			7 044
2002	78 393	9%	7 044
2003	78 920	9%	7 117
2004	79 511	9%	7 438
2005	114 278	9%	10 441
2006	112 404	9%	10 175
2007	111 525	7%	7 572
2008	127 450	11%	13 608
2009	186 931	11%	20 485
2010	196 123	11%	21 672
2011	259 051	13%	32 668
2012	335 863	14%	47 056
2013	364 317	16%	57 347
2014	399 764	17%	67 319
2015	446 344	18%	78 849
2016	393 005	17%	68 505

Table 70 - Activity data – Nitrogen inputs (tN)

Year	Urine and dung deposited by cattle, poultry and pigs (t N)	Urine and dung deposited by sheep and others (t N)	Inorganic fertilizers (t N)	Organic fertilizer applied to soils (t N)	Rice residues (t N)	Other Crop residues (t N)
1990	43171	17 008	7 044	40 952	16 401	2 828
1991	44677	17 437	7 044	42 349	15 447	2 876
1992	48851	18 517	7 044	47 146	14 756	3 164
1993	50316	18 955	7 044	48 694	15 905	2 650
1994	51878	18 633	7 044	48 950	13 842	2 727
1995	55141	17 648	7 044	50 377	19 549	2 917
1996	54667	17 184	7 044	50 528	19 202	3 158
1997	55834	16 069	7 044	51 632	19 476	3 339
1998	53046	16 069	7 044	49 985	19 921	2 783
1999	54818	15 187	7 044	50 163	22 057	4 071
2000	59237	16 069	7 044	52 960	21 161	4 265
2001	56785	14 568	7 044	51 237	21 753	4 546
2002	57887	14 566	7 044	52 236	21 009	4 776
2003	59091	15 330	7 117	53 776	24 835	7 755
2004	60172	16 435	7 438	54 576	22 597	8 606
2005	63205	15 691	10 441	57 273	29 447	10 206
2006	66206	16 750	10 175	59 780	30 764	13 637
2007	66675	17 825	7 572	59 786	32 381	15 810
2008	68580	17 325	13 608	60 320	33 934	18 970
2009	70485	16 825	20 485	60 854	35 449	21 763
2010	68972	16 244	21 672	60 536	37 898	23 336
2011	67437	15 989	32 668	59 821	39 380	29 709
2012	66701	15 242	47 056	59 725	42 160	30 894
2013	67911	14 218	57 347	61 906	42 232	30 607
2014	60442	12 637	67 319	55 820	17 518	28 481
2015	57470	11 859	78 849	53 920	42 346	28 724
2016	57346	12 183	68 505	54 563	17 924	32 371

Methodology and emission factors

N_2O emissions from nitrogen inputs are estimated with the tier 1 methodology from the 2006 IPCC guidelines.

$$N_2O_{Direct} - N = N_2O - N_{Nimputs} + N_2O - N_{OS} + N_2O - N_{PRP}$$

Where

$$N_2O - N_{Nimputs} = [[(F_{SN} + F_{ON} + F_{CR} + F_{SOM}) * EF_1] + [(F_{SN} + F_{ON} + F_{CR} + F_{SOM})_{FR} * EF_{1FR}]]$$

$$N_2O - N_{OS} = [(F_{OS,CG,Temp} * EF_{2CG,Temp}) + (F_{OS,CG,Trop} * EF_{2CG,Trop}) + (F_{OS,F,Temp,NR} * EF_{2F,Temp,NR}) + (F_{OS,F,Temp,NP} * EF_{2F,Temp,NP}) + (F_{OS,F,Trop} * EF_{2F,Trop})]$$

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

Where:

N_2ODirect –N = annual direct N_2O–N emissions produced from managed soils, kg N_2O–N yr^{-1}

N_2O–NN inputs = annual direct N_2O–N emissions from N inputs to managed soils, kg N_2O–N yr^{-1}

N_2O–NOS = annual direct N_2O–N emissions from managed organic soils, kg N_2O–N yr^{-1}

N_2O–NPRP = annual direct N_2O–N emissions from urine and dung inputs to grazed soils, kg N_2O–N yr^{-1}

F_{SN} = annual amount of synthetic fertiliser N applied to soils, kg N yr^{-1}

F_{ON} = annual amount of animal manure, compost, sewage sludge and other organic N additions applied to

soils (Note: If including sewage sludge, cross-check with Waste Sector to ensure there is no double counting of N_2O emissions from the N in sewage sludge), kg N yr^{-1}

F_{CR} = annual amount of N in crop residues (above-ground and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils, kg N yr^{-1}

F_{SOM} = annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes to land use or management, kg N yr^{-1}

F_{OS} = annual area of managed/drained organic soils, ha (Note: the subscripts CG, F, Temp, Trop, NR and NP refer to Cropland and Grassland, Forest Land, Temperate, Tropical, Nutrient Rich, and Nutrient Poor, respectively)

F_{PRP} = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N yr^{-1} (Note: the subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep and Other animals, respectively)

EF_1 = emission factor for N_2O emissions from N inputs, kg N_2O–N (kg N input)$^{-1}$(Table 11.1)

EF_{1FR} is the emission factor for N_2O emissions from N inputs to flooded rice, kg N_2O–N (kg N input)$^{-1}$ (Table 11.1) 5

EF_2 = emission factor for N_2O emissions from drained/managed organic soils, kg N_2O–N ha^{-1} yr^{-1}; (Table 11.1) (Note: the subscripts CG, F, Temp, Trop, NR and NP refer to Cropland and Grassland, Forest Land, Temperate, Tropical, Nutrient Rich, and Nutrient Poor, respectively)

EF_{3PRP} = emission factor for N_2O emissions from urine and dung N deposited on pasture, range and paddock by grazing animals, kg N_2O–N (kg N input)$^{-1}$; (Table 11.1) (Note: the subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep and Other animals, respectively)

Emission factors are default values proposed by the IPCC 2006 guidelines in tables 11.1.

Table 71 - N_2O emission factors for managed soils

	Inorganic fertilizers	Organic fertilzer applied to soils	Urine and dung deposited by cattle, poultry and pigs	Urine and dung deposited by sheep and others	Crop residu es	EF for flooded rice fields
Emission Factor (Kg N_2O-N /(kg N)	0.01	0.01	0.02	0.01	0.01	0.003

Results

Table 72 - N_2O emissions for managed soils

	1994	2000	2005	2010	2015	2016
N_2O (kt)	2.30	2.56	2.85	3.36	3.27	3.17

3.C.5 - Indirect N2O emissions from managed soils

Activity data

Indirect N_2O emissions are due to volatilization and to leaching of nitrogen. These activities are calculated on the basis of the data available in the estimation direct N_2O emissions and specific parameters provide by the IPCC 2006 guidelines.

Table 73 - Activity data – Volatilized and leached nitrogen on managed soils

Year	Volatilized N from agricultural inputs of N (tN)	N that is lost through leaching and run-off (tN)
1990	20 931	38 222
1991	21 597	38 949
1992	23 607	41 844
1993	24 297	43 069
1994	24 597	42 922
1995	25 337	45 802
1996	25 180	45 535
1997	25 412	46 018
1998	24 524	44 654
1999	24 738	46 002
2000	26 358	48 221
2001	25 222	46 780
2002	25 642	47 256
2003	26 351	50 371
2004	26 980	50 947
2005	28 278	55 879
2006	29 565	59 193
2007	29 614	60 014
2008	30 606	63 821
2009	31 681	67 758
2010	31 317	68 597

2011	31 916	73 501
2012	33 039	78 533
2013	34 542	82 266
2014	32 512	72 665
2015	32 535	81 950
2016	31 669	72 868

Methodology and emission factors

The N_2O emissions from atmospheric deposition of N volatilised from managed soil are estimated using the equation 11.9 from IPCC guidelines:

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

Where

$N_2O_{(ATD)}$–N = annual amount of N_2O–N produced from atmospheric deposition of N volatilised from managed soils, kg N_2O–N yr^{-1}

F_{SN} = annual amount of synthetic fertiliser N applied to soils, kg N yr^{-1}

$Frac_{GASF}$ = fraction of synthetic fertiliser N that volatilises as NH_3 and NO_x, kg N volatilised (kg of N applied)-1 (Table 11.3)

F_{ON} = annual amount of managed animal manure, compost, sewage sludge and other organic N additions applied to soils, kg N yr^{-1}

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

$Frac_{GASM}$ = fraction of applied organic N fertiliser materials (F_{ON}) and of urine and dung N deposited by grazing animals (F_{PRP}) that volatilises as NH_3 and NO_x, kg N volatilised (kg of N applied or deposited)$^{-1}$ (Table 11.3)

EF_4 = emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces, [kg N–N_2O (kg NH_3–N + NO_x–N volatilised)-1] (Table 11.3)

Conversion of N_2O(ATD)-N emissions to N_2O emissions for reporting purposes is performed by using the following equation:

$$N_2O_{(ATD)} = N_2O_{(ATD)} - N * 44/28$$

The N_2O emissions from leaching and runoff in regions where leaching and runoff occurs are estimated using Equation 11.10 from IPCC guidelines:

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

Where

$N_2O_{(L)}$–N = annual amount of N_2O–N produced from leaching and runoff of N additions to managed soils in regions where leaching/runoff occurs, kg N_2O–N yr^{-1}

F_{SN} = annual amount of synthetic fertiliser N applied to soils in regions where leaching/runoff occurs, kg N yr^{-1}

F_{ON} = annual amount of managed animal manure, compost, sewage sludge and other organic N additions applied to soils in regions where leaching/runoff occurs, kg N yr^{-1}

F_{PRP} = annual amount of urine and dung N deposited by grazing animals in regions where leaching/runoff occurs, kg N yr^{-1}

F_{CR} = amount of N in crop residues (above- and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils annually in regions where leaching/runoff occurs, kg N yr^{-1}

F_{SOM} = annual amount of N mineralised in mineral soils associated with loss of soil C from soil organic matter as a result of changes to land use or management in regions where leaching/runoff occurs, kg N yr^{-1} (from Equation 11.8)

$Frac_{LEACH-(H)}$ = fraction of all N added to/mineralised in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff, kg N (kg of N additions)$^{-1}$ (Table 11.3)

EF_5 = emission factor for N_2O emissions from N leaching and runoff, kg N–N_2O (kg N leached and runoff)$^{-1}$] (Table 11.3)

Conversion of N_2O(ATD)-N emissions to N_2O emissions for reporting purposes is performed by using the following equation:

$$N_2O_{(L)} = N_2O_{(L)} - N * 44/28$$

Parameters and emission factors are default values proposed by the IPCC 2006 guidelines in tables 11.3.

Table 74 - Parameters and emission factors for indirect emissions for managed soils

Parameters and emission factors	Value
Frac leach (kg N/kg of N additions)	0.3
Frac gasm (kg N volatilized/kg of N applied or deposited) for organic fertilizer	0.2
Frac gasf (kg N volatilized/kg of N applied) for synthetic fertilizer	0.1
Atmospheric deposition (kg N2O-N/kg NH3-N+NOx-N volatilized)	0.01
Nitrogen Leaching and runoff (kg N2O-N/kg N leaching/runoff)	0.0075

Results

Table 75 - N2O indirect emission for managed soils

N_2O (kt/yr)	1994	2000	2005	2010	2015	2016
Atmospheric deposition (kt/yr)	0.390	0.427	0.464	0.492	0.453	0.460
Nitrogen Leaching and runoff (kt/yr)	0.094	0.102	0.109	0.118	0.104	0.106
Totals (kt/yr)	0.483	0.529	0.573	0.609	0.557	0.566

3.C.6 - Indirect N2O emissions from manure management

Activity data

On the same basis as nitrogen in managed soils, indirect N2O emissions may occur during storage of manure management. The methodologies are similar and based on IPCC 2006 guidance. The percentages of losses due to volatilization are based on default values provide in Table 10.22 of the IPCC 2006 guidelines and the rates of leaching are obtained by difference between the total losses presented in Table 10. 23 and the losses by volatilization.

Table 76 - Activity data – Volatilized and leached nitrogen from manure management

Year	N volatilized (tN/year)	N leached (tN/year)
1990	20 645	6 686
1991	21 377	6 920
1992	23 938	7 645
1993	24 771	7 898
1994	24 802	7 953
1995	25 509	8 189
1996	25 745	8 206
1997	26 458	8 343
1998	25 720	8 093
1999	25 786	8 153
2000	27 173	8 686
2001	26 438	8 362
2002	27 036	8 544
2003	27 781	8 761
2004	27 934	8 848
2005	29 514	9 270
2006	30 722	9 683
2007	30 636	9 756
2008	30 878	9 872
2009	31 120	9 989
2010	31 298	9 982
2011	31 042	9 861
2012	31 180	9 837
2013	32 717	10 196
2014	29 634	9 173
2015	28 826	8 863
2016	29 283	8 984

Methodology and emission factors

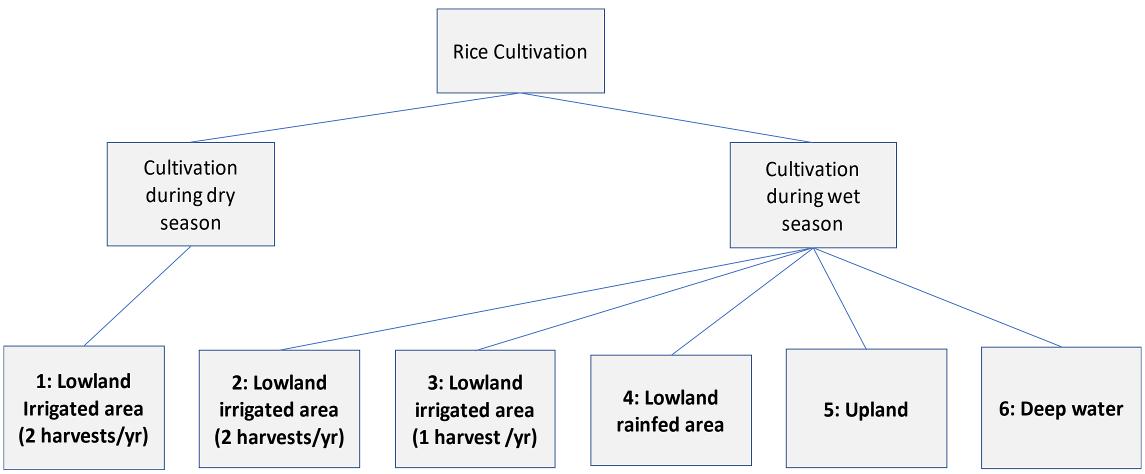
The methodology and emission factors are similar to those used on managed soils.

Results

Table 77 - N_2O indirect emission for manure management

N_2O (Gg/yr)	1994	2000	2005	2010	2015	2016
Atmospheric deposition	0.390	0.427	0.464	0.492	0.453	0.460
Nitrogen Leaching and runoff	0.094	0.102	0.109	0.118	0.104	0.106
Totals	0.483	0.529	0.573	0.609	0.557	0.566

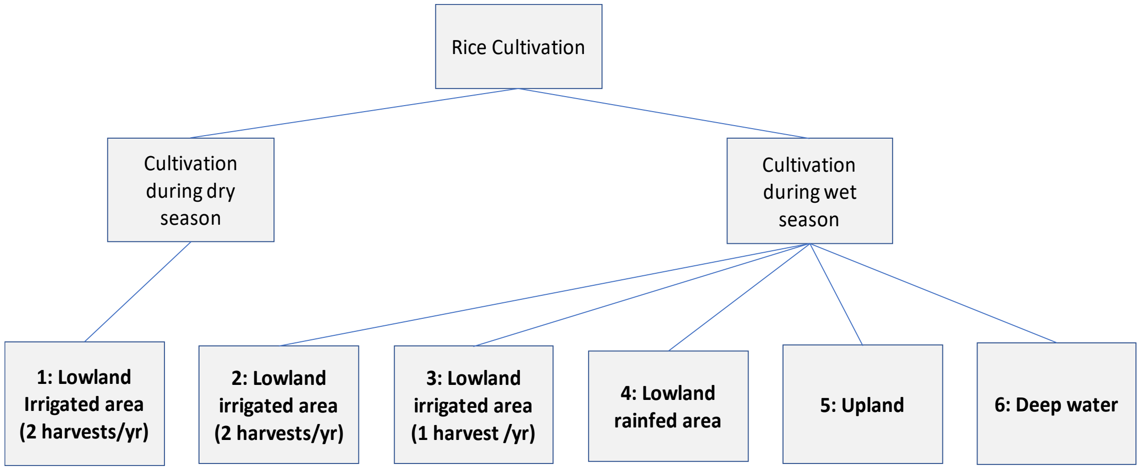
3.C.7 - Rice cultivation



Activity data

The areas of rice cultivation are estimated on the basis of different datasets. MAFF publications were used for the period since 2004, with the detail for both wet and dry seasons (MAFF Annual Report 2016-2017 and direction for 2017-2018, and MAFF annual report 2013-2014). For the years before 2004, total harvested area was based on FAOSTAT and the split between wet and dry season was estimated thanks to different sources (national communications, etc.). Production is also available but is only indirectly used to estimate CH_4 from rice cultivation in the tier 1 methodology (production is used to estimate the amount of residues).

For this inventory, the 2006 IPCC guidelines were implemented, and 6 types of rice cultivation were defined in relation with IPCC requirements.



Type 1 (dry season - lowland irrigated area - 2 harvests/yr): The area is estimated on the basis of the area harvested in dry season (MAFF statistics since 2004 and for the following years 1993, 1994, 1995, 2000)

Type 2 (wet season - lowland irrigated area - 2 harvests/yr): the area is the same as type 1. It is estimated on the basis of rice area harvested during dry season because it is considered that these areas are also irrigated (when necessary) during the wet season.

Type 3 (wet season - lowland irrigated area - 1 harvest/yr): Cambodia made developed a lot its irrigation during the covered period. It is estimated by the International Rice Research Institute (IRRI) that irrigated area was around 15% in 2005 and 25% in 2010[8] in Cambodia. 25% of rice area represents more than the area harvested in dry season which means that some areas are irrigated to produce rice only in wet season. The area of type 3 is estimated by difference between total irrigated area and the irrigated areas which allows 2 harvests/yr (types 1 and 2).

Type 4 (wet season - lowland rainfed area): this area is obtained by difference between total harvested area and all other types of rice cultivation.

Type 5 (wet season - upland area): this area (35 000 ha) is estimated on the basis of the area estimated in 1993 (MAFF) and maintained for the entire times series.

Type 6 (wet season - deep water): this area (108 500 ha) is estimated on the basis of the area estimated in 1993 (Bulletin of agriculture statistics, 1993) and maintained for the entire times series.

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[8] GRiSP (Global Rice Science Partnership). 2013. Rice almanac, 4th edition. Los Baños Philippines): International Rice Research Institute. 283 p.

Table 78 - Activity data – Area of rice crops split into 6 types (1000 ha/yr)

Year	Type 1 (dry season - lowland irrigated area - 2 harvests/yr)	Type 2 (wet season - lowland irrigated area - 2 harvests/yr)	Type 3 (wet season - lowland irrigated area - 1 harvest/yr)	Type 4 (wet season - lowland rainfed area)	Type 5 (wet season - upland area)	Type 6 (wet season - deep water)	Total harvested area
1990	150	150	0	1 412	35	109	1 855
1991	150	150	0	1 276	35	109	1 719
1992	150	150	0	1 242	35	109	1 685
1993	150	150	0	1 380	35	109	1 824
1994	165	165	0	1 021	35	109	1 495
1995	215	215	0	1 351	35	109	1 924
1996	219	219	0	1 298	35	109	1 879
1997	222	222	0	1 341	35	109	1 929
1998	226	226	0	1 367	35	109	1 963
1999	229	229	0	1 477	35	109	2 079
2000	233	233	0	1 294	35	109	1 903
2001	248	248	0	1 341	35	109	1 980
2002	263	263	0	1 325	35	109	1 995
2003	278	278	0	1 542	35	109	2 242
2004	293	293	0	1 379	35	109	2 109
2005	321	321	0	1 629	35	109	2 414
2006	328	328	44	1 673	35	109	2 516
2007	344	344	78	1 657	35	109	2 567
2008	361	361	112	1 636	35	109	2 613
2009	384	384	143	1 620	35	109	2 675
2010	405	405	193	1 631	35	109	2 777
2011	472	472	121	1 558	35	109	2 767
2012	495	495	78	1 768	35	109	2 980
2013	483	483	138	1 721	35	109	2 969
2014	491	491	144	1 760	35	109	3 029
2015	489	489	145	1 759	35	109	3 026
2016	519	519	127	1 792	35	109	3 100

Methodology and emission factors

CH_4 emissions from rice cultivation are estimated with the tier 1 methodology from the 2006 IPCC guidelines. Equations for rice cultivation is equation 5.1:

$$CH4Rice = \sum_{i,j,k} \left(EF_{i,j,k} * t_{i,j,k} * A_{i,j,k} * 10^{-6} \right)$$

Where:

CH_4 Rice = annual methane emissions from rice cultivation, Gg CH_4 yr^{-1}

EF_{ijk} = a daily emission factor for i, j, and k conditions, kg CH_4 ha-1 day^{-1}

t_{ijk} = cultivation period of rice for i, j, and k conditions, day

A_{ijk} = annual harvested area of rice for i, j, and k conditions, ha yr-1

i, j, and k = represent different ecosystems, water regimes, type and amount of organic amendments, and other conditions under which CH_4 emissions from rice may vary

Emissions factors are based on the equations 5.2 and 5.3 and different assumptions relative to rice management. The 6 types of rice cultivation defined previously were subdivided into 4 subcategories dependent on residue management and manure application. This subdivision was made on the basis of a scientific publication (San et al, 2009[9]).

- Subcategory A: Manure application and stubble incorporation
- Subcategory B: Manure application and stubble burning
- Subcategory C: No manure application and stubble incorporation
- Subcategory D: No manure application and stubble burning

Table 79 - Rice cultivation subdivision

Variable	Wet season	Dry season
A: Manure + Stubble incorporation	53%	48%
B: Manure + Stubble burning	23%	12%
C: No manure + Stubble incorporation	18%	32%
D: No manure + Stubble burning	8%	8%

These values are estimated for the years 2005-2006 but applied for the entire time series.

The amount of manure and stubble incorporated are calculated consistently with the rest of the GHG inventory for livestock and crop residues.

[9] Estimation of methane and nitrous oxide emissions from rice field with rice straw management in Cambodia. Vibol San, Sirintornthep Towprayoon. Article in Environmental Monitoring and Assessment · April 2009

Parameters and emission factor - kg CH_4/ha/day

$$EF_i = EF_c * SF_w * SF_p * SF_o * SF_{s,y}$$

Where:

EF_i = adjusted daily emission factor for a particular harvested area

EF_c = baseline emission factor for continuously flooded fields without organic amendments

SF_w = scaling factor to account for the differences in water regime during the cultivation period (from Table 5.12)

SF_p = scaling factor to account for the differences in water regime in the pre-season before the cultivation period (from Table 5.13)

SF_o = scaling factor should vary for both type and amount of organic amendment applied (from Equation 5.3 and Table 5.14)

$SF_{s,r}$ = scaling factor for soil type, rice cultivar, etc., if available

$$SF_o = \left(1 + \sum_i ROA_i * CFOA_i\right)^{0.59}$$

Where:

SF_o = scaling factor for both type and amount of organic amendment applied

ROA_i = application rate of organic amendment i, in dry weight for straw and fresh weight for others, tonne ha^{-1}

$CFOA_i$ = conversion factor for organic amendment i (in terms of its relative effect with respect to straw applied shortly before cultivation) as shown in Table 5.14.

Considering the types (1 to 6) and the subdivision (A, B, C, D), 24 categories were defined with specific emission factors. Emission factors are changing on the time series because of changes in crop residues and manure availability.

Considering the expert judgements used for the first national communication cultivation length is fixed at 115 days for the dry season and 165 days for the wet season. This value could be improved by taking into account the changes in rice varieties which lead to shorter cultivation periods.

Table 80 - Rice cultivation emission factors

kg CH_4/ha/yr	1994	2000	2005	2010	2015	2016
Type 1A	307	297	288	284	275	275
Type 1B	256	245	235	230	220	220
Type 1C	233	233	233	233	233	233
Type 1D	214	214	214	214	214	214
Type 2A	440	425	413	407	395	394
Type 2B	368	351	337	330	316	316
Type 2C	335	335	335	335	335	335
Type 2D	307	307	307	307	307	307
Type 3A	255	244	235	230	221	220
Type 3B	250	239	229	224	215	215
Type 3C	172	172	172	172	172	172
Type 3D	166	166	166	166	166	166
Type 4A	71	68	66	64	62	62
Type 4B	70	67	64	63	60	60

kg CH_4/ha/yr	1994	2000	2005	2010	2015	2016
Type 4C	48	48	48	48	48	48
Type 4D	46	46	46	46	46	46
Type 5A	0	0	0	0	0	0
Type 5B	0	0	0	0	0	0
Type 5C	0	0	0	0	0	0
Type 5D	0	0	0	0	0	0
Type 6A	79	76	73	71	68	68
Type 6B	78	74	71	70	67	67
Type 6C	53	53	53	53	53	53
Type 6D	51	51	51	51	51	51

Results

Table 81 - CH_4 emissions from rice cultivation

	1994	2000	2005	2010	2015	2016
CH_4 (kt/yr)	184	240	309	399	438	453

3.D.1 - Harvested wood products

This category is currently included in the GHG estimate due to limited data and time constrain.

3.5.4. AFOLU emissions trends

Table 82 - Trend of emissions (GHG, Gg CO_2-eq)

Inventory Sector	1994	2000	2005	2010	2015	2016
3A. Livestock	5 370.57	5 678.87	6 100.43	6 399.75	5 362.78	5 384.54
3B. Land	27 019	27 019	27 019	131 011	131 011	131 011
3C. Crop cultivation	5 832.01	7 353.45	9 235.95	11 736.33	12 705.57	13 013.13
Total	38 221.2	40 050.9	42 355.0	149 147.3	149 079.6	149 408.9

Table 83 - Emissions by gas (Gg)

Inventory Sector	1994	2000	2005	2010	2015	2016
CO_2	27 020.23	27 020.26	27 020.26	131 041.14	131 028.66	131 028.66
CH_4	375.69	442.23	526.79	627.28	629.41	645.15
N_2O	6.07	6.63	7.27	8.13	7.77	7.56

3.6. Waste sector

3.6.1. Characterization of the sector

The waste sector includes the emissions that occur in the generation and management of waste. Based on the 2006 IPCC Guidelines, the emissions of the waste sector are split in the following categories:

- 4A. Solid Waste Disposal
- 4B. Biological treatment of solid waste
- 4C. Incineration and open burning of waste
- 4D. Wastewater treatment and discharge

Typically, the most important sources of emissions in this sector are the CH_4 emissions from solid waste disposal, CH_4 emissions from wastewater treatment and discharge and CO_2 emissions which occur in Incineration and open burning of waste.

This edition of the inventory includes estimates for all the categories defined by 2006 IPCC Guidelines.

The following table provides a summary of the emissions reported in the waste sector. Complete reporting tables are provided in section *Reporting tables*.

Table 84 - Sectoral reporting table – Waste sector – Emissions of year 2016

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 (1)	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
	(Gg)						
Total waste	994.26	129.1	0.82	NE	NE	NE	NE
A. Solid waste disposal	NA	57.09		NA	NA	NA	
1. Managed waste disposal sites	NA	IE					
2. Unmanaged waste disposal sites	NA	IE					
3. Uncategorized waste disposal sites	NA	IE					
B. Biological treatment of solid waste		0.33	0.02	NA	NA	NA	
1. Composting		0.32	0.02				
2. Anaerobic digestion at biogas facilities		0.01	NA				
C. Incineration and open burning of waste	994.26	9.46	0.14	NA	NA	NA	NA
1. Waste incineration	NE	NA	NE				
2. Open burning of waste	994.26	9.46	0.14				
D. Wastewater treatment and discharge		61.54	0.66	NA	NA	NA	
1. Domestic wastewater		61.54	0.66				
2. Industrial wastewater		NA	NA				
3. Other *(as specified in table 5.D)*		NO	NO	NO	NO	NO	
E. Other *(please specify)*	NO	NO	NO	NO	NO	NO	NO
Memo item: (2)							
Long-term storage of C in waste disposal sites	2,978						
Annual change in total long-term C storage	106.01						
Annual change in total long-term C storage in HWP waste(3)	29.58						

3.6.2. Data sources

The following is the list of data sources used for calculating the GHG emissions of the waste sector:

- The study "State of Waste Management in Phnom Penh, Cambodia" carried out by UNEP in 2018. This study is available at https://www.researchgate.net/publication/326293569_State_of_Waste_Management_in_Phnom_Penh_Cambodia
- Population data from National Committee for Sub-National Democratic Development (NCDD) complemented with the world bank data base
- Gross Domestic Product (GDP) from the Ministry of Planning (MOP) complemented with the world bank database
- Waste generation from the Ministry of Environment (Based on 2006 IPCC default value)3d
- Amount of dung used for producing biogas: energy balance and "Assessment of the Cambodian National Biodigester Program"[10]
- Protein consumption from FAO
- Percentage of people open burning waste from Yut S. and Seng B., 2018. KAP on waste management (data of 2012)

3.6.3. Waste emissions by category

The data available at national level on waste generation and management has been used to derive a complete characterization of the overall management of waste in the country and its temporal evolution. Analogously, the data available was used to characterize the typology of wastewater discharges needed for estimating the GHG emissions of the wastewater sector.

The following tables show the evolution of the country profile regarding waste generation and management as well as wastewater discharges typology.

[10] https://www.sciencedirect.com/science/article/pii/S0973082618302588#bb0185

Table 85 – Waste management practices in Cambodia – 1990 - 2016

Year	Total MSW generated (Gg)	% of waste burned	% of waste composted	% of waste used as animal food	% of waste recycled	% wastes going to landfills	Columns in grey are not summed. These figures are the breakdown of the % of wastes going to landfill					Total
							% of waste going to managed landfills	% of waste going to un-managed landfills	% of waste to unmanaged landfills - shallow	% of waste to unmanaged landfills - deep	% of waste going to Unspecified landfills	
Before 1990	…	66%	2%	0.302%	0.000%	32%	0%	11%	11%	0%	21%	100%
1990	2 508	66%	2%	0.302%	0.000%	32%	2%	11%	11%	0%	19%	100%
1991	2 596	65%	2%	0.300%	0.000%	33%	2%	11%	11%	0%	19%	100%
1992	2 689	65%	2%	0.299%	0.000%	33%	2%	11%	11%	0%	20%	100%
1993	2 786	65%	2%	0.298%	0.000%	33%	2%	11%	11%	0%	20%	100%
1994	2 883	64%	2%	0.297%	0.000%	34%	2%	11%	11%	0%	20%	100%
1995	2 977	64%	2%	0.295%	0.000%	34%	2%	11%	11%	0%	21%	100%
1996	3 069	64%	2%	0.294%	0.000%	34%	2%	11%	11%	0%	21%	100%
1997	3 157	63%	2%	0.293%	0.000%	35%	2%	11%	11%	0%	21%	100%
1998	3 241	63%	2%	0.292%	0.000%	35%	2%	11%	11%	0%	22%	100%
1999	3 321	62%	2%	0.291%	0.000%	35%	2%	11%	11%	0%	22%	100%
2000	3 396	62%	2%	0.291%	0.000%	36%	2%	11%	11%	0%	22%	100%
2001	3 550	62%	2%	0.290%	0.000%	36%	2%	11%	11%	0%	23%	100%
2002	3 638	61%	2%	0.290%	0.000%	37%	3%	11%	11%	0%	22%	100%
2003	3 726	61%	2%	0.290%	0.000%	37%	5%	11%	11%	0%	20%	100%
2004	3 661	61%	2%	0.289%	0.000%	37%	9%	11%	11%	0%	17%	100%
2005	3 745	60%	2%	0.289%	0.000%	38%	9%	11%	11%	0%	18%	100%
2006	3 532	60%	2%	0.288%	0.000%	38%	11%	11%	11%	0%	15%	100%
2007	3 601	59%	2%	0.288%	0.000%	38%	13%	12%	12%	0%	13%	100%
2008	3 738	59%	2%	0.287%	0.000%	39%	14%	12%	12%	0%	13%	100%
2009	3 780	59%	2%	0.287%	0.000%	39%	15%	12%	12%	0%	13%	100%
2010	3 847	58%	2%	0.286%	3.197%	36%	15%	12%	12%	0%	10%	100%
2011	3 906	58%	2%	0.286%	3.512%	36%	16%	12%	12%	0%	9%	100%
2012	3 991	58%	2%	0.285%	1.949%	38%	23%	12%	12%	0%	3%	100%
2013	4 086	57%	2%	0.285%	1.824%	39%	24%	12%	12%	0%	3%	100%
2014	4 156	57%	2%	0.284%	2.379%	38%	26%	12%	12%	0%	0.3%	100%
2015	4 179	57%	2%	0.283%	2.379%	38%	28%	10%	10%	0%	0.3%	100%
2016	4 239	57%	2%	0.282%	2.379%	38%	30%	7.90%	7.90%	0%	0.3%	100%
Source	2006 IPCC defaults*population	Estimate based on Yut S. and Seng B., 2018. KAP on waste management			MoE	MoE + Yut S. and Seng B., 2018. KAP on waste management	MoE	Estimate based on Yut S. and Seng B., 2018. KAP on waste management				

Table 86 – Wastewater discharges typology – Assumption on the temporal evolution

	Degree of utilization of treatment or discharge pathway or method for each income group									
	U=rural					U=urban low income				
	Septic Tank	Latrine	Other	Sewer	None	Septic Tank	Latrine	Other	Sewer	None
Default IPCC for the region	0%	47%	0%	10%	43%	14%	10%	3%	53%	20%
1990	0%	9%	0%	2%	89%	14%	10%	3%	53%	20%
1991	0%	10%	0%	2%	87%	14%	10%	3%	53%	20%
1992	0%	12%	0%	2%	86%	14%	10%	3%	53%	20%
1993	0%	13%	0%	3%	84%	14%	10%	3%	53%	20%
1994	0%	14%	0%	3%	83%	14%	10%	3%	53%	20%
1995	0%	16%	0%	3%	81%	14%	10%	3%	53%	20%
1996	0%	17%	0%	4%	79%	14%	10%	3%	53%	20%
1997	0%	18%	0%	4%	78%	14%	10%	3%	53%	20%
1998	0%	20%	0%	4%	76%	14%	10%	3%	53%	20%
1999	0%	21%	0%	4%	74%	14%	10%	3%	53%	20%
2000	0%	22%	0%	5%	73%	14%	10%	3%	53%	20%
2001	0%	24%	0%	5%	71%	14%	10%	3%	53%	20%
2002	0%	25%	0%	5%	70%	14%	10%	3%	53%	20%
2003	0%	26%	0%	6%	68%	14%	10%	3%	53%	20%
2004	0%	28%	0%	6%	66%	14%	10%	3%	53%	20%
2005	0%	29%	0%	6%	65%	14%	10%	3%	53%	20%
2006	0%	30%	0%	6%	63%	14%	10%	3%	53%	20%
2007	0%	32%	0%	7%	62%	14%	10%	3%	53%	20%
2008	0%	33%	0%	7%	60%	14%	10%	3%	53%	20%
2009	0%	34%	0%	7%	58%	14%	10%	3%	53%	20%
2010	0%	36%	0%	8%	57%	14%	10%	3%	53%	20%
2011	0%	37%	0%	8%	55%	14%	10%	3%	53%	20%
2012	0%	38%	0%	8%	53%	14%	10%	3%	53%	20%
2013	0%	40%	0%	8%	52%	14%	10%	3%	53%	20%
2014	0%	41%	0%	9%	50%	14%	10%	3%	53%	20%
2015	0%	44%	0%	9%	49%	14%	10%	3%	53%	20%
2016	0%	44%	0%	9%	47%	14%	10%	3%	53%	20%

4A. Solid waste disposal

Category 4A Solid waste disposal includes the emissions that occur in the treatment and disposal of municipal, industrial and other solid waste.

Activity data

Table 87 - Activity data MSW production. Data in tonnes

Year	Population (M)	Total MSW (Gg)	GDP (M USD; current prices)	Total Industrial waste (Gg)
1994	11	2 883	2 770	21.03
2000	13	3 396	3 649	27.71
2005	14	3 745	6 293	47.79
2010	14	3 847	11 634	88.35
2011	14	3 906	12 965	98.46
2012	15	3 991	14 054	106.73
2013	15	4 086	15 229	115.65
2014	15	4 156	16 796	127.55
2015	15	4 179	18 078	137.29
2016	16	4 239	19 843	150.70

Waste per capita/year: 270. Source: default IPCC 2006
Waste generation rate: 0.007594366 Gg/M GDP. Source: calculated using data from the MoE
MSW: Municipal solid waste
GDP: gross domestic product

Methodology and emission factors

The GHG emissions have been calculated using the tier 1 methodology provided by IPCC 2006 using the default values provided by the guidelines complementing it with national specific information. The IPCC methodology for estimating CH_4 emissions from Solid Waste Disposal Sites (SWDP) is based on the First Order Decay (FOD) method. This method assumes that the degradable organic component (degradable organic carbon, DOC) in waste decays slowly throughout a few decades, during which CH_4 and CO_2 are formed.

Table 88 - Waste composition used

Food	Garden	Paper	Wood	Textile	Nappies	Plastics, other inert
55%	0%	10%	2%	2%	0%	30%

Source: •The study "State of Waste Management in Phnom Penh, Cambodia" carried out by UNEP in 2018. This study is available at https://www.researchgate.net/publication/326293569_State_of_Waste_Management_in_Phnom_Penh_Cambodia

The parameters used in the estimation are those provided by 2006 IPCC guidelines for Asia-southeast, "Moist and wet tropical" weather. The starting year for the estimation is 1950.

The following tables show the key parameters used in the estimation of emissions:

Table 89 - Key parameters used

Parameters	Value used
Methane generation rate constant (k)	
Food waste	0.4
Garden	0.17
Paper	0.07
Wood and Straw	0.035
Textiles	0.07
Disposable nappies	0.17
Sewage sludge	0.4
Industrial waste	0.17
Delay time (months)	6
Fraction of methane (F) in developed gas	0.5
Conversion factor c to CH4	1.33

Regarding the Methane correction factor (MCF), for municipal solid waste the MCF value is calculated using the distribution of waste disposal sites types shown in table *Waste management practices in Cambodia* above. For industrial wastes, the MCF used in the one that corresponds to a 100% of wastes going to uncategorized landfill sites.

Table 90 – Weighted average methane correction factor

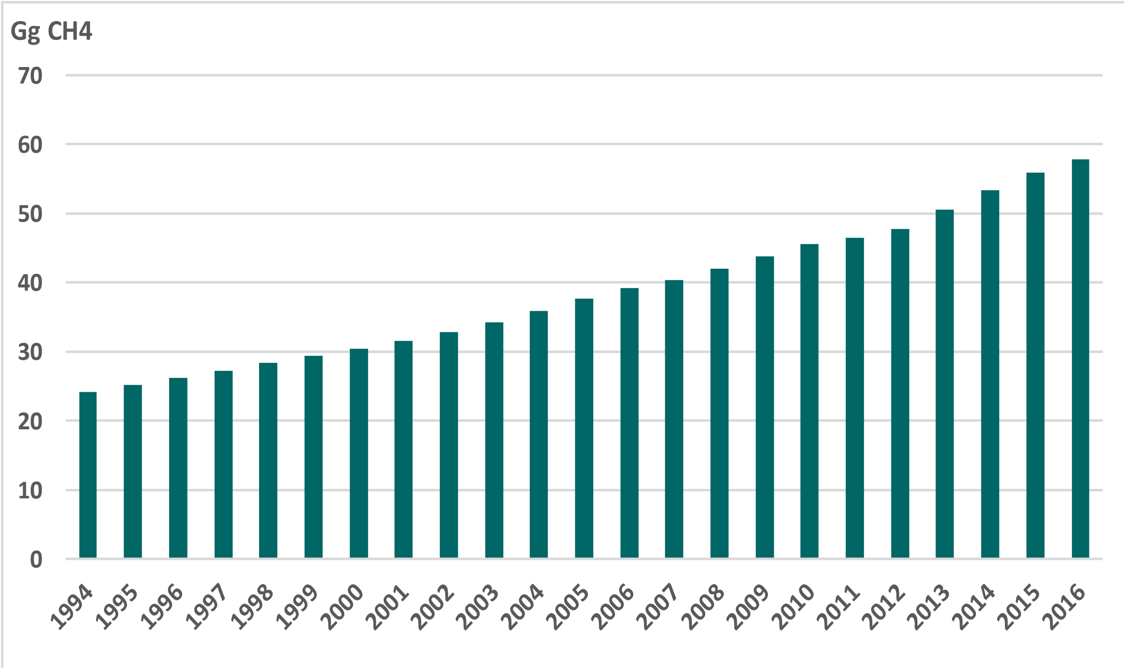
Year	MSW	Industrial
	Weighted average MCF for MSW	Weighted average MCF for Industrial Waste
1994	0.66	0.60
2000	0.66	0.60
2010	0.80	0.60
2015	0.93	0.60
2016	0.96	0.60

Results

Table 91 - CH_4 emissions from solid waste disposal

Year	CH_4 (Gg)
1994	24.21
2005	37.62
2010	45.52
2011	46.45
2012	47.68
2013	50.60
2014	53.31
2015	55.86
2016	57.79

Figure 21 - CH_4 emissions from solid waste disposal (Gg CH_4)



4B. Biological treatment of waste

Category 4B *Biological treatment of waste* includes the emissions from composting and anaerobic digestion in biogas facilities. Both activities occurred in the country in the inventoried period.

Activity data

Table 92 - Activity data used

Year	Total Annual amount composted (Gg)	Total Annual amount treated by biological treatment facilities (Gg)
1994	51.34	0
2005	68.43	0
2010	70.80	42.16
2011	72.00	54.34
2012	73.71	47.30
2013	75.62	12.56
2014	77.08	18.37
2015	77.69	18.37
2016	79.00	18.37

The total amount of waste composted has been calculated by applying to national total waste generated the percentage of waste composted (see table on Waste management practices in Cambodia above). The total amount of waste treated by biological treatment facilities has been calculated using data from the energy balance on amount of biogas produced and a conversion rate (m^3/kg) calculated using data from the "Assessment of the Cambodian National Biodigester Programme".

The following tables show the data used for the calculation and the results obtained.

Table 93 - Activity data – Calculation of conversion rate

Variable	Type 1	Type 2	Type 3	Type 4	Type 5
Dung requirements (kg/day)	30	50	70	90	125
Estimated gas production (m^3/day)	1.2	2	2.8	3.6	5
Conversion rate (m^3/kg)	0.04	0.04	0.04	0.04	0.04

Extracted from: https://www.sciencedirect.com/science/article/pii/S0973082618302588#bb0185

Table 94 - Activity data – Calculation of the amount of waste (animal dung) treated

Variable	2010	2011	2012	2013	2014	2015	2016
Amount of biogas produced and consumed from the Energy Balance (tonnes)	2024	2608	2271	603	882	882	882
Density (kg/m^3)	1.2	1.2	1.2	1.2	1.2	1.2	1.2
m^3	1686333	2173675	1892175	502208	734617	734617	734617
Dung (Gg)	42.16	54.34	47.30	12.56	18.37	18.37	18.37

Methodology

The tier 1 methodology proposed by 2006 IPCC has been applied using an emission factor of 4 g CH_4/kg waste treated and 0.24 g N_2O/kg waste treated for calculating the emissions from compost and an emission factor 0.8 g/kg waste treated for calculating the emissions from anaerobic digestion. There is no recovery of methane.

Results

Table 95 – Emissions from biological treatment of wastes (Gg)

Year	CH_4 emissions from Composting (Gg)	N_2O emissions from Composting (Gg)	CH_4 emissions from Anaerobic digestion (Gg)
1994	0.21	0.012	NO
2005	0.27	0.016	NO
2010	0.28	0.017	0.03
2011	0.29	0.017	0.04
2012	0.29	0.018	0.04
2013	0.30	0.018	0.01
2014	0.31	0.018	0.01
2015	0.31	0.019	0.01
2016	0.32	0.019	0.01

Figure 22 - CH_4 emissions from solid waste disposal (Gg CH_4)

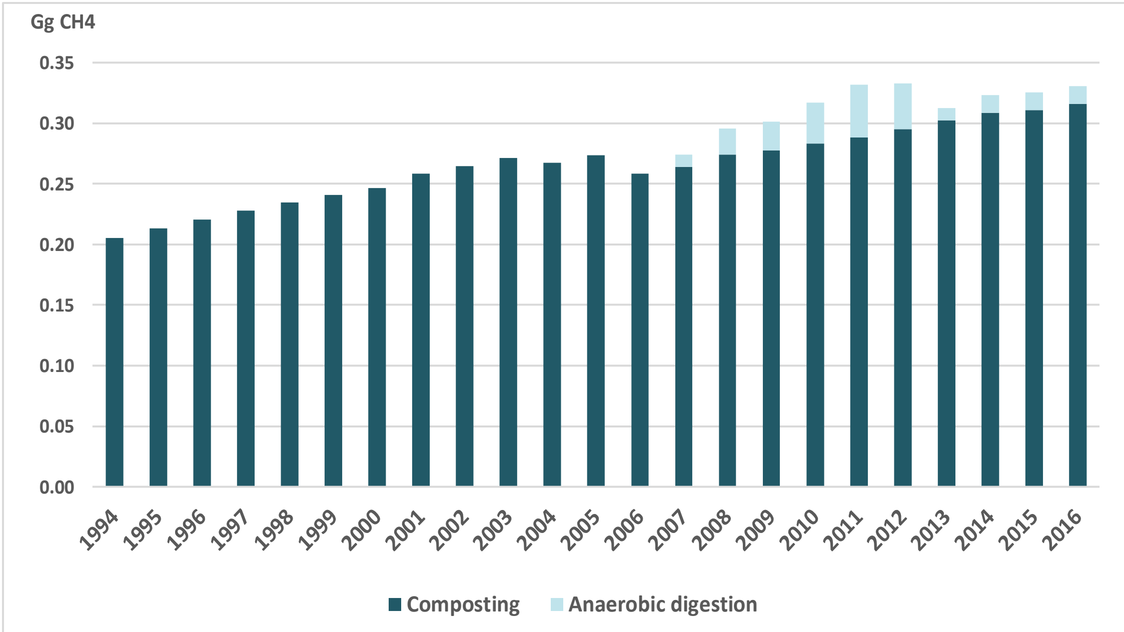
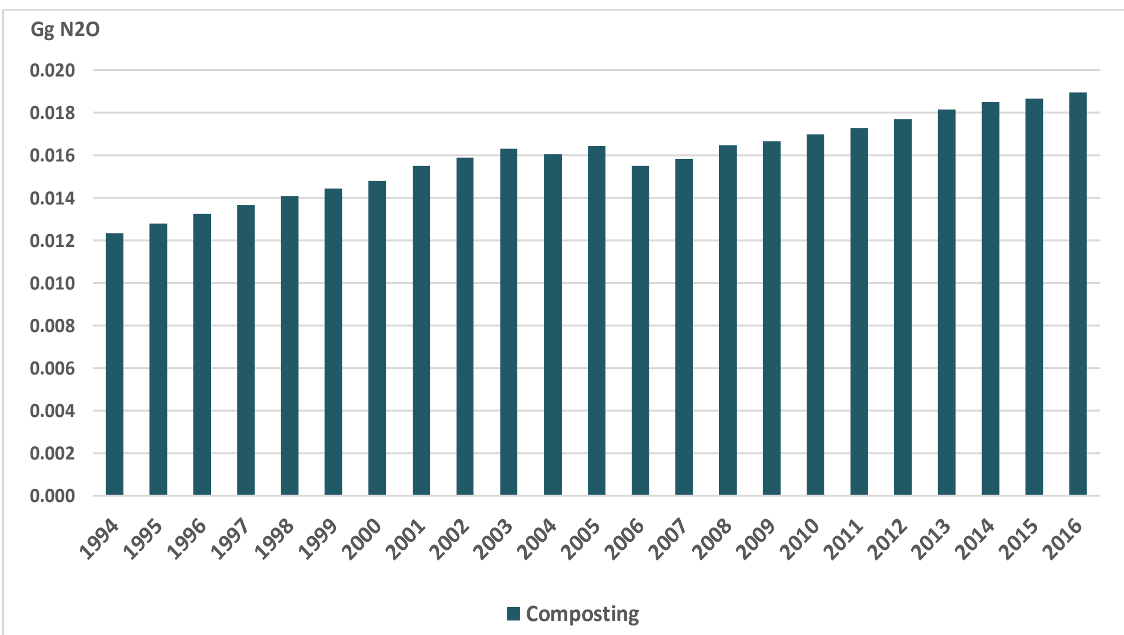


Figure 23 - N_2O emissions from solid waste disposal (Gg N_2O)



4C. Incineration and open burning

Category 4C2 *Incineration and open burning of waste* includes the emissions from the combustion of waste in controlled facilities or in open dumps. Incineration of waste does not occur in Cambodia and therefore it is not included in the inventory.

Activity data

Table 96 - Activity data on open burning

Year	Population Burning Waste (%)	Total Amount of MSW Open-burned – wet basis (Gg)
1994	64%	1,113
2005	60%	1,353
2010	58%	1,346
2011	58%	1,357
2012	58%	1,378
2013	57%	1,409
2014	57%	1,431
2015	57%	1,437
2016	57%	1,455

The percentage of population burning waste has been estimated based on the information available in Yut S. and Seng B., 2018. KAP on waste management.

The Activity data has been calculated using the following equation:

$$MSW_B = P * P_{frac} * MSW_p * B_{frac} * 365 * 10^{-6}$$

Where:

MSW_B = Total amount of municipal solid waste open-burned, Gg/yr

P = population (capita)

P_{frac} = fraction of population burning waste, (fraction)

MSW_p = per capita waste generation, Kg waste/capita/day

B_{frac} = fraction of the waste amount that is burned relative to the total amount of waste treated, (fraction)

365 = number of days by year

10^{-6} = conversion factor from kilogram to gigagram

The per cápita waste generation used is the same value used in category 4A solid waste disposal. The default value for Bfrac used is 0.6 as provided in the corresponding chapter of 2006 IPCC Guidelines.

Methodology and emission factors

Once the amount of total waste open burned is calculated, the emissions are calculated by applying an emission factor to the amount of waste burned in wet basis, for the case of CH4 and N2O, and by estimating the waste amount burned in dry basis for CO_2 emissions as follows:

$$CO_2\ Emissions = \sum_i (SW_i * dm_i * CF_i * FCF_i * OF_i) * 44/12$$

Where:

SW_i = total amount of solid waste of type *i* (wet weight) incinerated or open-burned, Gg/yr

dm_i = dry matter content in the waste (wet weight) incinerated or open-burned, (fraction)

CF_i = fraction of carbon in the dry matter (total carbon content), (fraction)

FCF_i = fraction of fossil carbon in the total carbon, (fraction)

OF_i = oxidation factor, (fraction)

44/12 = conversion factor from C to CO_2

i = type of waste incinerated/open-burned specified as follows:

MSW: municipal solid waste; ISW: industrial solid waste,

The parameters used in the calculation are the following:

- Oxidation factor: 0.58
- Th coefficients provided by 2006 IPCC of Dry Matter Content, Fraction of Carbon in Dry Matter and Fraction of Fossil Carbon in Total Carbon, which are specific to each component of the waste.

The emissions factors used for calculating the emissions are those proposed by 2006 IPCC guidelines for the tier 1 method: 6.5 g CH4/kg and 0.15 g N2O/kg.

Results

Table 97- Emission results – Open burning (data in Gg)

Year	CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)
1994	761.18	7.24	0.108
2005	924.79	8.79	0.131
2010	920.15	8.75	0.131
2011	927.26	8.82	0.132
2012	941.53	8.95	0.134
2013	962.68	9.16	0.137
2014	977.75	9.30	0.139
2015	981.77	9.34	0.139
2016	994.26	9.46	0.141

4D. Wastewater treatment and discharge

Category 4D *Wastewater treatment and discharge* includes the emissions of CH_4 and NO_2 that occur when the wastewater is treated or disposed anaerobically. 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.

Activity data

Table 98 - Activity data domestic wastewater

Year	Organically degradable material in wastewater (TOW) (kg BOD/yr)	Average annual per capita protein generation (kg/person/yr)
1994	194864907.9	15.57
2005	253164000	20.81
2010	260040819	22.05
2011	263985520	22.42
2012	269740000	22.79
2013	276167760	23.17
2014	280886808.5	23.54
2015	282462951.5	23.92
2016	286515162.6	24.29

The Organically degradable material in wastewater (TOW), has been calculated as follows, using the value "collected" for the adjustment of industrial wastewater and the BOD value provided for "Asia, Middle East, Latin America":

$$TOW = P * BOD * 0.001 * I * 365$$

Where:

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

P = country population in inventory year, (person)

BOD = country-specific per capita BOD in inventory year, g/person/day

0.001 = conversion from grams BOD to kg BOD

I = correction factor for additional industrial BOD discharged into sewers (for collected the default is 1.25, for uncollected the default is 1.00)

The default factor for BOD used is 40 kg BOD/cap/day extracted from Table 6.4 IPCC 2006. Value for Asia, Middle East, Latin America.

The data on Average annual per capita protein generation is provided by FAO for years 1990-92, 1995-97, 2000-02 and 2005-07. Intermediate years have been interpolated. The years 2007-2016 have been extrapolated using the expression of trend of the time series:

$$Y_t = 0.3745X - 730.7$$

Methodology and emission factors

The Tier 1 methodology provided by IPCC 2006 has been followed for estimating the emissions of both CH_4 and N_2O. For the emissions of CH_4, the following equation has been used:

$$CH_4\ Emissions = \left[\sum_{i,j}(U_i * T_{i,j} * EF_j)\right](TOW - S) - R$$

Where:

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

S = organic component removed as sludge in inventory year, kg BOD/yr

U_i = fraction of population in income group *i* in inventory year

$T_{i,j}$ = degree of utilisation of treatment/discharge pathway or system, *j*, for each income group fraction *i* in inventory year

i = income group: rural, urban high income and urban low income

j = each treatment/discharge pathway or system

$EF_{i,j}$ = emission factor, kg CH_4/kg BOD

R = amount of CH_4 recovered in inventory year, kg CH_4/yr

The previous equation is complemented with the following expression for estimating the emission factor:

$$EF_j = B_o * MCF_j$$

Where:

j = each treatment/discharge pathway or system

Bo = maximum CH_4 producing capacity, Kg CH_4/kg BOD

MCF_j = methane correction factor

For the calculation of the CH_4 emissions, the assumptions made regarding the split of type of discharges for rural and urban population are contained in table *Wastewater discharges typology* above, so the corresponding coefficients of 2006 IPCC Guidelines have been used for calculating the emission factor by treatment.

The final emission factors used for estimating CH_4 emissions are the following:

Table 99 - Emission factors used – CH_4 emissions in domestic wastewater

Type of treatment	Methane correction factor for each treatment system (MCF)	Maximum methane producing capacity (Bo) (kg CH4/kg BOD)	Emission factor (EF) (kg CH4/kg BOD)
Untreated-sea,river,lake	0.1	0.6	0.060
Untreated-flowing sewer	0	0.6	0
Treated-septic system	0.5	0.6	0.3
Treated-Latrine with sediments removal	0.1	0.6	0.060

For the case of N_2O, the following expression has been used:

$$N_{EFFLUENT} = (P * Protein * F_{NPR} * F_{NON-CON} * F_{IND-COM}) - N_{SLUDGE}$$

Where:

NEFFLUENT = total annual amount of nitrogen in the wastewater effluent, kg N/yr

P = human population

Protein = annual per capita protein consumption, kg/person/yr

F_{NPR} = fraction of nitrogen in protein, default = 0.16, kg N/kg protein

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

$F_{IND-COM}$ = factor for industrial and commercial co-discharged protein into the sewer system

N_{SLUDGE} = nitrogen removed with sludge (default = zero), kg N/yr

Results

Table 100 - Emissions in domestic wastewater (Gg)

Year	CH_4 (Gg)	N_2O (Gg)
1994	23	0.29
2005	43	0.50
2010	49	0.54
2011	51	0.56
2012	53	0.58
2013	56	0.61
2014	58	0.63
2015	61	0.64
2016	62	0.66

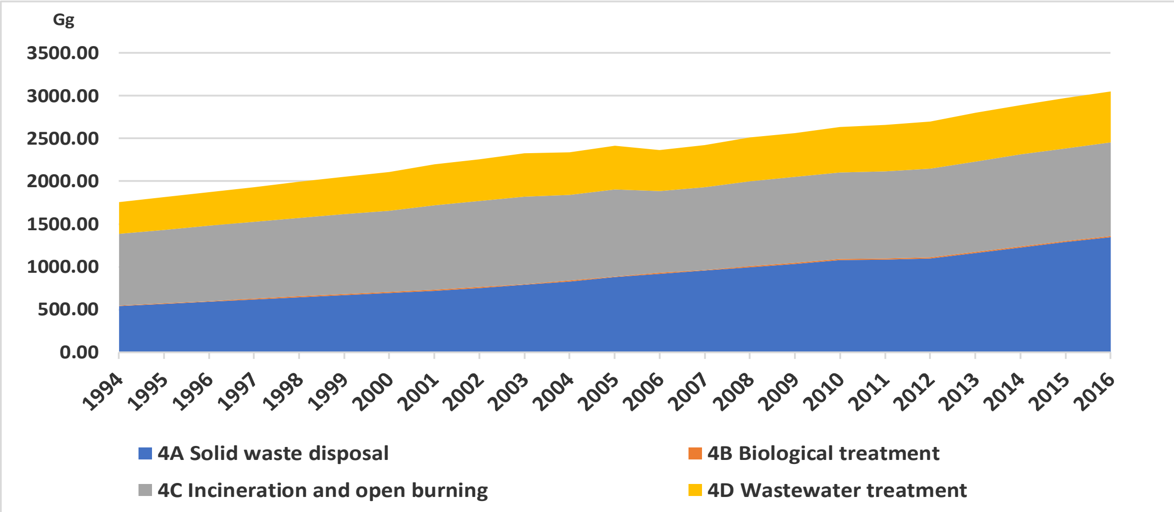
3.6.4. Waste emissions trends

The GHG emissions of the waste sector are driven by the increase of urban population, along the improvements in sanitation and waste management.

Table 101 - Trend of emissions (GHG, Gg CO_2-eq)

Inventory Sector	1994	2000	2005	2010	2015	2016
4A1 Solid waste disposal	605.14	760.99	940.47	1 138.11	1 396.46	1 444.85
4B2 Biological treatment	8.81	10.57	11.74	12.99	13.69	13.92
4C2 Open Burning	974.26	1 106.75	1 183.79	1 177.84	1 256.76	1 272.76
4D1 Domestic wastewater	660.26	960.46	1 215.79	1 393.58	1 710.77	1 734.93
Total	2 248.46	2 838.77	3 351.78	3 722.53	4 377.68	4 466.45

Figure 24 – GHG emissions in the waste sector - 1994-2016 (Gg CO_2-eq)



As illustrated in the previous figure, waste GHG emissions show an increasing trend in all categories. The main contributor to the emissions of the sector is category 4D1 Domestic wastewate, with a contribution that ranges from a 29.4% in 1994 to a 38.8% in 2016. The increasing emissions of this category are explained by the expansion of the use of latrines in rural areas. The use of sanitary latrines involve higher methane emissions compared to other practices such as the discharges in lakes and rivers. The second contributor the waste GHG emissions is solid waste disposal, with a contribution that ranges from a 26.9% in 1994 to a 32.3% in 2016. The increasing emissions of this category are driven by the improvements in the waste management systems, particularly the shift from un-managed to managed landfills. Even this is a significant improvement for the country, the GHG emissions associated have growth, as the methane emissions associated to aerobic managed sites are significantly higher than the emissions for un-managed landfills[11]. The third contributor to waste emissions is open burning of waste, which a contribution than ranges from a 43.3% in 1994 to a 28.5 in 2016. The contribution has been reduced maninly driven by the migration of population from rural to urban areas, where open burning is a practice less extended among population. Finally, biological treatment of waste has a very low contribution to waste emissions, with a contribution that ranges from a 0.4% in 1994 to a 0.3% in 2016.

Regarding the contribution of each gas to total GHG emissions, the following table show the detailed evolution of the split of greenhous gases for the entire time period.

[11] The methane correction factors provided by 2006 IPCC Guidelines for unmanaged sites are significantly lower than those for managed sites, affecting the final GHG emissions estimated.

Table 102 - Percentage of emissions by gas (%)

Inventory Sector	1994	2000	2005	2010	2015	2016
CH_4	60.7%	63.7%	66.7%	69.8%	72.1%	72.3%
CO_2	33.9%	30.5%	27.6%	24.7%	22.4%	22.3%
N_2O	5.4%	5.9%	5.7%	5.5%	5.4%	5.5%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note – This contribution is calculated converting first the emissions of each gas to CO2-eq using global warming potentials

The gas which is predominant in the sector is CH_4 followed by CO_2.

The following table shows the emissions of each gas for the entire time series, in terms of mass of emissions of each gas:

Table 103 - Emissions by gas (Gg)

Gas	1994	2000	2005	2010	2015	2016
CO_2	761.18	864.63	924.79	920.15	981.77	994.26
CH_4	54.6	72.3	89.4	103.9	126.3	129.1
N_2O	0.41	0.56	0.65	0.69	0.80	0.82
HFC	NA	NA	NA	NA	NA	NA
NO_x	NA	NA	NA	NA	NA	NA
CO	NA	NA	NA	NA	NA	NA
NMVOC	NA	NA	NA	NA	NA	NA
SO_2	NA	NA	NA	NA	NA	NA
SF_6	NA	NA	NA	NA	NA	NA

3.7. Key category assessment and uncertainty analysis

3.7.1. Key category assessment

The 2006 IPCC Guidelines define key category (KC) as "(…) one that is prioritised within the national inventory system because its estimate has a significant influence on a country's total inventory of greenhouse gases in terms of the absolute level, the trend, or the uncertainty in emissions and removals. Whenever the term key category is used, it includes both source and sink categories. (…)"

As far as possible, key categories should receive special consideration in terms of three important inventory aspects.

- Firstly, identification of key categories in national inventories enables limited resources available for preparing inventories to be prioritised.
- Secondly, in general, more detailed higher tier methods should be selected for key categories.
- Thirdly, it is good practice to give additional attention to key categories with respect to quality assurance and quality control (QA/QC)

The general approach for identifying key categories is to identify KC in terms of their contribution to the absolute level of national emissions and removals. For the inventories considering time series, the quantitative determination of key categories should include **an evaluation of both the absolute level and the trend of emissions and removals.**

The 2006 IPCC approach 1 have been used to identify key categories, for both the level and the trend. The following is a description of the methodology followed:

Level assessment

The contribution of each source or sink category to the total national inventory level is calculated according to the following equation:

$$L_{x,t} = \frac{|E_{x,t}|}{\sum_y |E_{y,t}|}$$

$Where:$

$L_{x,t} = level\ assessment\ for\ source\ or\ sink\ x\ in\ latest\ inventory\ year$
$|E_{x,t}| = absolute\ value\ of\ emission\ or\ removal\ estimate\ of\ source\ or\ sink\ cateogy\ x\ in\ year\ t$
$\sum_y |E_{y,t}| = total\ contribution, which\ is\ the\ sum\ of\ the\ absolute\ values\ of\ emissions\ and\ removals\ in\ year\ t$

Trend assessment

The Trend Assessment is calculated according to the following equation:

$$T_{x,t} = \frac{|E_{x,0}|}{\sum_y |E_{y,0}|} \cdot \left| \frac{|E_{x,t} - E_{x,0}|}{|E_{x,0}|} - \frac{\left(\sum_y |E_{y,t}| - \sum_y |E_{y,0}|\right)}{\sum_y |E_{y,0}|} \right|$$

$Where:$

$T_{x,t} = trend\ assessment\ for\ source\ or\ sink\ x\ in\ year\ t\ as\ compared\ to\ the\ base\ year\ (year\ 0)$
$|E_{x,0}| = absolute\ value\ of\ emission\ or\ removal\ estimate\ of\ source\ or\ sink\ cateogy\ x\ in\ year\ 0$
$E_{x,t}\ and\ E_{x,0} = real\ values\ of\ estimate\ of\ source\ or\ sink\ category\ X\ in\ years\ t\ and\ 0, respectively.$
$\sum_y |E_{y,t}|\ and\ \sum_y |E_{y,0}| = Total\ incventoy\ estimates\ in\ years\ t\ and\ 0, respectively.$

Disaggregation level

The results of the key category identification will be most useful if the analysis is done at the appropriate disaggregation level of categories. The assessment performed has followed, as far as possible, the suggested aggregation level of analysis for approach 1 provided by 2006 IPCC Guidelines. The exception is the Forestry and Other Land Uses subsector. In this sector, the break down in more disaggregated categories has not been possible because of the data available.

Results

Table 104 - Summary of key categories identified by method

IPCC category	Name	Gas	With FOLU			Without FOLU		
			L2016	L1994	Trend	L2016	L1994	Trend
3B	Land	CO2	X	X	X			
3A1	Enteric Fermentation	CH4	X	X	X	X	X	X
1A1- Solid	Energy industries - solid fuels	CO2	X		X	X		X
3C7	Rice cultivations	CH4	X	X	X	X	X	X
2A1	Cement production	CO2	X		X	X		X
1A3b - liquid	Road transport - liquid fuels	CO2	X	X	X	X	X	X
3A2	Manure Management	N2O		X	X	X	X	X
4C2	Open burning	CO2		X	X	X	X	X
3C4	Direct N2O Emissions from managed soils	N2O		X	X	X	X	X
3A2	Manure Management	CH4		X	X	X	X	X
2F1	Refrigeration and air conditioning	HFC				X		X
1A2 - Liquid	Manufacturing industries and construction - Liquid fuels	CO2				X		X
1A1- biomass	Energy industries - biomass	CH4			X		X	X
1A1 - liquid	Energy industries - liquid fuels	CO2				X		X
4A1	Solid waste disposal	CH4	X	X	X	X	X	X
4D1	Domestic wastewater	CH4			X	X		X
3C5	Indirect N2O Emissions from managed soils	N2O			X	X	X	X
1A4 - biomass	Other sectors - biomass	CH4			X	X	X	X
4C2	Open burning	CH4					X	

Table 105 - Key category analysis with FOLU – Level (2016)

IPCC category	Name	Gas	Emissions year 2016	Assessment for year 2016	Cummulative total 2016	KCA order 2016
3B	Land	CO2	131011.24	0.79	0.79	1
3C7	Rice cultivations	CH4	11323.14	0.07	0.86	2
1A3b – liquid	Road transport - liquid fuels	CO2	4933.16	0.03	0.89	3
3A1	Enteric Fermentation	CH4	4188.38	0.03	0.92	4
1A1- Solid	Energy industries - solid fuels	CO2	2663.57	0.02	0.93	5
2A1	Cement production	CO2	1420.96	0.01	0.95	6
4A1	Solid waste disposal	CH4	1345.77	0.01	0.957	7

Table 106 - Key category analysis with FOLU– Level (1994)

IPCC category	Name	Gas	Emissions year 1994	Assessment for year 1994	Cummulative total 2016	KCA order 1994
3B	Land	CO2	27018.62	0.63	0.626	1
3C7	Rice cultivations	CH4	4602.85	0.11	0.733	2
3A1	Enteric Fermentation	CH4	4249.36	0.10	0.831	3
1A3b – liquid	Road transport - liquid fuels	CO2	1849.58	0.04	0.874	4
3C4	Direct N2O Emissions from managed soils	N2O	684.01	0.02	0.900	5
3A2	Manure Management	N2O	649.45	0.02	0.915	6
4C2	Open burning	CO2	623.20	0.01	0.930	7
4A1	Solid waste disposal	CH4	539.20	0.01	0.942	8
3A2	Manure Management	CH4	471.76	0.01	0.954	9

Table 107 - Key category analysis with FOLU– Trend (1994-2016)

IPCC category	Name	Gas	Trend assessment	% Contribution to the trend	Total cumulative trend	Order trend
3B	Land	CO2	0.64	0.42	0.424	1
3A1	Enteric Fermentation	CH4	0.28	0.19	0.610	2
3C7	Rice cultivations	CH4	0.15	0.10	0.707	3
1A1- Solid	Energy industries - solid fuels	CO2	0.06	0.04	0.748	4
1A3b – liquid	Road transport - liquid fuels	CO2	0.05	0.03	0.786	5
3A2	Manure Management	N2O	0.04	0.03	0.814	6
3C4	Direct N2O Emissions from managed soils	N2O	0.04	0.03	0.841	7
4C2	Open Burning	CO2	0.04	0.02	0.865	8
2A1	Cement production	CO2	0.03	0.02	0.887	9
3A2	Manure Management	CH4	0.03	0.02	0.907	10
4A1	Solid waste disposal	CH4	0.02	0.01	0.918	11
1A1	Energy industries – biomass	CH4	0.02	0.01	0.929	12
4D1	Domestic wastewater	CH4	0.02	0.01	0.940	13
3C5	Indirect N2O Emissions from managed soils	N2O	0.01	0.01	0.950	14
1A4 - biomass	Other sectors - biomass	CH4	0.01	0.01	0.957	15

Table 108 - Key category analysis without FOLU – Level (2016)

IPCC category	Name	Gas	Emissions year 2016	Assessment for year 2016	Cummulative total 2016	KCA order 2016
3C7 - Rice cultivations	Rice cultivations	CH4	11323.14	0.34	0.34	1
1A3b - liquid	Road transport - liquid fuels	CO2	4933.16	0.15	0.49	2
3A1 - Enteric Fermentation	Enteric Fermentation	CH4	4188.38	0.13	0.62	3
1A1- Solid	Energy industries - solid fuels	CO2	2663.57	0.08	0.70	4
2A1	Cement production	CO2	1420.96	0.04	0.75	5
4A1 - Solid waste disposal	Solid waste disposal	CH4	1345.77	0.04	0.79	6
3C4 - Direct N2O Emissions from managed soils	Direct N2O Emissions from managed soils	N2O	943.80	0.03	0.82	7
4C2 - Open burning	Open burning	CO2	814.55	0.02	0.84	8
3A2 - Manure Management	Manure Management	N2O	663.06	0.02	0.86	9
1A2 - Liquid	Manufacturing industries and construction - Liquid fuels	CO2	603.88	0.02	0.88	10
3A2 - Manure Management	Manure Management	CH4	533.10	0.02	0.90	11
3C5 - Indirect N2O Emissions from managed soils	Indirect N2O Emissions from managed soils	N2O	404.22	0.01	0.91	12
4D1 - Domestic wastewater	Domestic wastewater	CH4	401.48	0.01	0.92	13
2F1	Refrigeration and air conditioning	HFC	371.95	0.01	0.93	14
1A1 - liquid	Energy industries - liquid fuels	CO2	326.84	0.01	0.94	15
1A4 - biomass	Other sectors - biomass	CH4	265.56	0.01	0.95	16

Table 109 - Key category analysis without FOLU– Level (1994)

IPCC category	Name	Gas	Emissions year 1994	Assessment for year 1994	Cummulative total 1994	KCA order 1994
3C7 - Rice cultivations	Rice cultivations	CH4	11323.14	0.34	0.34	1
3A1 - Enteric Fermentation	Enteric Fermentation	CH4	4,249.36	0.27	0.566	2
1A3b - liquid	Road transport - liquid fuels	CO2	1,849.58	0.12	0.684	3
3C4 - Direct N2O Emissions from managed soils	Direct N2O Emissions from managed soils	N2O	684.01	0.04	0.727	4
3A2 - Manure Management	Manure Management	N2O	649.45	0.04	0.769	5
4C2 - Open burning	Open burning	CO2	623.20	0.04	0.809	6
4A1 - Solid waste disposal	Solid waste disposal	CH4	539.20	0.03	0.843	7
3A2 - Manure Management	Manure Management	CH4	471.76	0.03	0.873	8

IPCC category	Name	Gas	Emissions year 1994	Assessment for year 1994	Cummulative total 1994	KCA order 1994
4D1 - Domestic wastewater	Domestic wastewater	CH4	286.25	0.02	0.8915	9
3C5 - Indirect N2O Emissions from managed soils	Indirect N2O Emissions from managed soils	N2O	265.93	0.02	0.909	10
1A1- biomass	Energy industries - biomass	CH4	250.28	0.02	0.925	11
1A4 - biomass	Other sectors - biomass	CH4	195.49	0.01	0.937	12
4C2 - Open burning	Open burning	CH4	180.88	0.01	0.949	13
3C6 - Indirect N2O Emissions from manure management	Indirect N2O Emissions from manure management	N2O	144.08	0.01	0.958	14

Table 110 - Key category analysis without FOLU– Trend (1994-2016)

IPCC category	Name	Gas	Trend assessment	% Contribution to the trend	Total cumulative trend	Order trend
3A1 - Enteric Fermentation	Enteric Fermentation	CH4	0.30	0.29	0.290	1
1A1- Solid	Energy industries - solid fuels	CO2	0.17	0.16	0.453	2
3C7 - Rice cultivations	Rice cultivations	CH4	0.11	0.10	0.554	3
2A1	Cement production	CO2	0.09	0.09	0.641	4
1A3b - liquid	Road transport - liquid fuels	CO2	0.07	0.06	0.705	5
3A2 - Manure Management	Manure Management	N2O	0.04	0.04	0.748	6
4C2 - Open burning	Open burning	CO2	0.03	0.03	0.778	7
3C4 - Direct N2O Emissions from managed soils	Direct N2O Emissions from managed soils	N2O	0.03	0.03	0.808	8
3A2 - Manure Management	Manure Management	CH4	0.03	0.03	0.836	9
2F1	Refrigeration and air conditioning	HFC	0.02	0.02	0.859	10
1A2 - Liquid	Manufacturing industries and construction - Liquid fuels	CO2	0.02	0.02	0.881	11
1A1- biomass	Energy industries - biomass	CH4	0.02	0.02	0.898	12
1A1 - liquid	Energy industries - liquid fuels	CO2	0.01	0.01	0.912	13
4A1 - Solid waste disposal	Solid waste disposal	CH4	0.01	0.01	0.925	14
4D1 - Domestic wastewater	Domestic wastewater	CH4	0.01	0.01	0.937	15
3C5 - Indirect N2O Emissions from managed soils	Indirect N2O Emissions from managed soils	N2O	0.01	0.01	0.947	16
1A4 - biomass	Other sectors - biomass	CH4	0.01	0.01	0.956	17

3.7.2. Uncertainty analysis

The following table shows the uncertainty values estimated by CRF category of the inventory. Specifically, the following table shows:

- The uncertainty of the activity data and emission factor by emission source. The source of all the uncertainty values for the energy sector is IPCC 2006. For the selection of the uncertainty among those provided by IPCC 2006, the criteria have been based on the conservative principle, using the upper values of the ranges by default.
- The combined uncertainty calculated with the uncertainty of the activity data and emission factor and the emission level and trend, where appropriate,
- The calculation for the sensitivity type A and B, based on the equations provided in 2016 IPCC guidelines.
- The uncertainty in the total level and trend of the emissions of the inventory.

The methodology followed is the tier 1 provided by 2006 IPCC Guidelines. The following table and the associated calculations are extracted from the table 3.2, volume 1, chapter 3 of 2006 IPCC Guidelines. A complete description of each of the terms of the table is available in this chapter of the 2006 IPCC Guidelines.

Table 111 – Uncertainty of the inventory

IPCC category	Gas	Base year emissions	2016 emissions	Activity data uncertainty	Emission factor Uncertainty	Combined uncertainty	Contribution to variance by category in year 2016	Type A sensitivity	Type B sensitivity	Uncertainty in trend by EF	Uncertainty in trend by AD	Uncertainty introduced into the trend in total national emissions
		Gg of CO2-eq		%	%	%		%	%	%	%	
1A1 -Energy industries– Solid	CO2	0.00	2 663.57	5	7	9	0.020	0.062	0.062	0.437	0.312	0.288
1A1 -Energy industries – Solid	CH4	0.00	0.69	5	100	100	0.000	0.000	0.000	0.002	0.000	0.000
1A1 -Energy industries – Solid	N2O	0.00	12.39	5	75	75	0.000	0.000	0.000	0.022	0.001	0.000
1A1 -Energy industries – Liquid	CO2	48.28	326.84	5	7	9	0.000	0.003	0.008	0.023	0.038	0.002
1A1 -Energy industries – Liquid	CH4	0.05	0.32	5	100	100	0.000	0.000	0.000	0.000	0.000	0.000
1A1 -Energy industries – Liquid	N2O	0.11	0.76	5	75	75	0.000	0.000	0.000	0.001	0.000	0.000
1A1 -Energy industries – Biomass	CH4	250.28	250.32	60	100	117	0.032	-0.017	0.006	-1.666	0.352	2.899
1A1 -Energy industries – Biomass	N2O	0.15	0.70	60	75	96	0.000	0.000	0.000	0.000	0.001	0.000
1A2 -Manufacturing Industries– Solid	CO2	0.00	68.40	3	7	8	0.000	0.002	0.002	0.011	0.005	0.000
1A2 -Manufacturing Industries – Solid	CH4	0.00	0.02	3	100	100	0.000	0.000	0.000	0.000	0.000	0.000
1A2 -Manufacturing Industries – Solid	N2O	0.00	0.32	3	75	75	0.000	0.000	0.000	0.001	0.000	0.000
1A2 -Manufacturing Industries – Liquid	CO2	114.84	603.88	3	7	8	0.001	0.004	0.014	0.027	0.042	0.003
1A2 -Manufacturing Industries – Liquid	CH4	0.12	0.60	3	100	100	0.000	0.000	0.000	0.000	0.000	0.000
1A2 -Manufacturing Industries – Liquid	N2O	0.28	1.42	3	75	75	0.000	0.000	0.000	0.001	0.000	0.000
1A2 -Manufacturing Industries – Biomass	CH4	27.48	27.63	60	100	117	0.000	-0.002	0.001	-0.183	0.039	0.035
1A2 -Manufacturing Industries – Biomass	N2O	43.67	43.92	60	75	96	0.001	-0.003	0.001	-0.218	0.062	0.051
1A3a - Domestic aviation– liquid	CO2	2.48	59.87	5	7	9	0.000	0.001	0.001	0.008	0.007	0.000

IPCC category	Gas	Base year emissions	2016 emissions	Activity data uncertainty	Emission factor Uncertainty	Combined uncertainty	Contribution to variance by category in year 2016	Type A sensitivity	Type B sensitivity	Uncertainty in trend by EF	Uncertainty in trend by AD	Uncertainty introduced into the trend in total national emissions
		Gg of CO2-eq		%	%	%		%	%	%	%	
1A3a - Domestic aviation – liquid	CH4	0.00	0.01	5	100	100	0.000	0.000	0.000	0.000	0.000	0.000
1A3a - Domestic aviation – liquid	N2O	0.02	0.50	5	75	75	0.000	0.000	0.000	0.001	0.000	0.000
1A3b -Road transport– liquid	CO2	1 849.58	4 933.16	5	7	9	0.067	-0.051	0.116	-0.356	0.578	0.461
1A3b -Road transport – liquid	CH4	12.85	30.25	5	100	100	0.000	0.000	0.001	-0.045	0.004	0.002
1A3b -Road transport – liquid	N2O	27.11	70.42	5	75	75	0.001	-0.001	0.002	-0.059	0.008	0.004
1A4 -Others– liquid	CO2	91.55	189.57	15	7	17	0.000	-0.004	0.004	-0.027	0.067	0.005
1A4 -Others – liquid	CH4	0.30	0.56	15	100	101	0.000	0.000	0.000	-0.001	0.000	0.000
1A4 -Others – liquid	N2O	0.21	0.35	15	75	76	0.000	0.000	0.000	-0.001	0.000	0.000
1A4 -Others – biomass	CH4	195.49	265.56	60	100	117	0.036	-0.011	0.006	-1.137	0.373	1.432
1A4 -Others – biomass	N2O	26.10	49.60	60	75	96	0.001	-0.001	0.001	-0.089	0.070	0.013
2A1 – Cement	CO2	0.00	1 420.96	10	10	14	0.015	0.033	0.033	0.333	0.333	0.222
2D1 – Lubricants	CO2	3.81	28.50	3	50	50	0.000	0.000	0.001	0.016	0.002	0.000
2F - F-gases	HFC	0.00	371.95	100	100	141	0.103	0.009	0.009	0.872	0.872	1.520
3A1 - Enteric Fermentation	CH4	4 249.36	4 188.38	20	30	36	0.849	-0.284	0.098	-8.520	1.963	76.448
3A2 - Manure Management	CH4	471.76	533.10	20	30	36	0.014	-0.030	0.012	-0.899	0.250	0.870
3A2 - Manure Management	N2O	649.45	663.06	20	50	54	0.047	-0.043	0.016	-2.145	0.311	4.699
3B – Land	CO2	27 018.62	131 011.24	20	100	102	6,646	0.634	3.070	63.448	61.404	7 796
3C1 - Emissions from biomass burning	CH4	68.32	84.19	100	50	112	0.003	-0.004	0.002	-0.209	0.197	0.083
3C1 - Emissions from biomass burning	N2O	65.21	71.67	100	50	112	0.002	-0.004	0.002	-0.209	0.168	0.072
3C3 - Urea application	CO2	1.61	17.42	50	5	50	0.000	0.000	0.000	0.001	0.020	0.000

IPCC category	Gas	Base year emissions	2016 emissions	Activity data uncertainty	Emission factor Uncertainty	Combined uncertainty	Contribution to variance by category in year 2016	Type A sensitivity	Type B sensitivity	Uncertainty in trend by EF	Uncertainty in trend by AD	Uncertainty introduced into the trend in total national emissions
		Gg of CO2-eq		%	%	%		%	%	%	%	
3C4 - Direct N2O Emissions from managed soils	N2O	684.01	943.80	50	100	112	0.415	-0.039	0.022	-3.944	1.106	16.776
3C5 - Indirect N2O Emissions from managed soils	N2O	265.93	404.22	50	100	112	0.076	-0.014	0.009	-1.446	0.474	2.315
3C6 - Indirect N2O Emissions from manure management	N2O	144.08	168.68	50	100	112	0.013	-0.009	0.004	-0.901	0.198	0.852
3C7 - Rice cultivations	CH4	4 602.85	11 323.14	10	75	76	27.330	-0.149	0.265	-11.156	2.654	131
4A1 - Solid waste disposal	CH4	539.20	1 345.77	100	102	143	1.376	-0.017	0.032	-1.733	3.154	12.949
4B2 – Composting	CH4	5.13	7.90	100	5	100	0.000	0.000	0.000	-0.001	0.019	0.000
4B2 – Composting	N2O	3.67	5.65	100	5	100	0.000	0.000	0.000	-0.001	0.013	0.000
4B2 - Anaerobic digestion	CH4	0.00	0.37	100	100	141	0.000	0.000	0.000	0.001	0.001	0.000
4C2 - Open burning	CO2	623.20	814.55	100	100	141	0.494	-0.037	0.019	-3.699	1.909	17.329
4C2 - Open burning	N2O	32.19	42.08	100	100	141	0.001	-0.002	0.001	-0.191	0.099	0.046
4C2 - Open burning	CH4	180.88	236.42	100	100	141	0.042	-0.011	0.006	-1.074	0.554	1.460
4D1 – Domestic wastewater	CH4	286.25	401.48	59	117	131	0.103	-0.016	0.009	-1.913	0.555	3.969
4D1 – Domestic wastewater	N2O	85.66	196.45	20	8	22	0.001	-0.003	0.005	-0.025	0.092	0.009

National total emissions	42 672	163 883	
Year uncertainty	81.72		
Trend uncertainty	89.84		

Energy sector

The following table shows a summary of the uncertainty values at category level*fuel*gas level for the energy sector:

Table 112 - Uncertainty in the energy sector

CRF category	Gas	AD uncertainty (%)	EF uncertainty (%)	Combined uncertainty (%)
1A1 -Energy industries– Solid	CO2	5	7	9
1A1 -Energy industries – Solid	CH4	5	100	100
1A1 -Energy industries – Solid	N2O	5	75	75
1A1 -Energy industries – Liquid	CO2	5	7	9
1A1 -Energy industries – Liquid	CH4	5	100	100
1A1 -Energy industries – Liquid	N2O	5	75	75
1A1 -Energy industries – Biomass	CO2	60	7	60
1A1 -Energy industries – Biomass	CH4	60	100	117
1A1 -Energy industries – Biomass	N2O	60	75	96
1A2 -Manufacturing Industries– Solid	CO2	3	7	8
1A2 -Manufacturing Industries – Solid	CH4	3	100	100
1A2 -Manufacturing Industries – Solid	N2O	3	75	75
1A2 -Manufacturing Industries – Liquid	CO2	3	7	8
1A2 -Manufacturing Industries – Liquid	CH4	3	100	100
1A2 -Manufacturing Industries – Liquid	N2O	3	75	75
1A2 -Manufacturing Industries – Biomass	CO2	60	7	60
1A2 -Manufacturing Industries – Biomass	CH4	60	100	117
1A2 -Manufacturing Industries – Biomass	N2O	60	75	96
1A3a - Domestic aviation– liquid	CO2	5	7	9
1A3a - Domestic aviation – liquid	CH4	5	100	100
1A3a - Domestic aviation – liquid	N2O	5	75	75
1A3b -Road transport– liquid	CO2	5	7	9
1A3b -Road transport – liquid	CH4	5	100	100
1A3b -Road transport – liquid	N2O	5	75	75
1A4 -Others– liquid	CO2	15	7	17
1A4 -Others – liquid	CH4	15	100	101
1A4 -Others – liquid	N2O	15	75	76
1A4 -Others – biomass	CO2	60	7	60
1A4 -Others – biomass	CH4	60	100	117
1A4 -Others – biomass	N2O	60	75	96

The source of all the uncertainty values for the energy sector is IPCC 2006. For the selection of the uncertainty among those provided by IPCC 2006, the criteria have been based on the conservative principle, using the upper values of the ranges by default.

IPPU sector

The following table shows a summary of the uncertainty values at category *gas level for the IPPU sector:

Table 113 - Uncertainty in the IPPU sector

Category	Gas	AD uncertainty (%)	EF uncertainty (%)	Combined uncertainty (%)
2A1 – Cement production	CO_2	10	10	14
2D1 – Lubricants	CO_2	3	50	50
2F - Subst. for ODS (F-gases)	HFC-125	100	100	141
2F - Subst. for ODS (F-gases)	HFC143a	100	100	141
2F - Subst. for ODS (F-gases)	HFC134a	100	100	141
2F - Subst. for ODS (F-gases)	HFC-32	100	100	141
2F - Subst. for ODS (F-gases)	HFC-227ea	100	100	141

The uncertainty values allocated in this sector are mainly based on expert judgment (based on 2006 IPCC guidance) rather than default values. The reason for that is the limited guidance provided by 2006 IPCC Guidelines. More information on uncertainties can be found on the IPPU work file, sheet "Uncertainty".

Waste sector

The following table shows a summary of the uncertainty values at category*gas level for the waste sector:

Table 114 - Uncertainty in the waste sector

CRF category	Gas	AD uncertainty (%)	EF uncertainty (%)	Combined uncertainty (%)
4A1 - Solid waste disposal	CH4	100	102	143
4B2 – Composting	CH4	100	5	100
4B2 – Composting	N2O	100	5	100
4B2 - Anaerobic digestion	CH4	100	100	141
4C2 - Open burning	CO2	100	100	141
4C2 - Open burning	N2O	100	100	141
4C2 - Open burning	CH4	100	100	141
4D1 – Domestic wastewater	CH4	59	117	130
4D1 – Domestic wastewater	N2O	20	8	22

The uncertainty values allocated in this sector are mainly based on expert judgment (based on 2006 IPCC guidance) rather than default values. The reason for that is the limited guidance provided by 2006 IPCC Guidelines.

AFOLU sector

The following table shows a summary of the uncertainty values at category*gas level for the AFOLU sector:

Table 115 - Uncertainty in the waste sector

CRF category	AD uncertainty (%)	EF uncertainty (%)	Combined uncertainty (%)
Enteric fermentation			
3.A.1.a.i - Dairy Cows	20	30	36
3.A.1.a.ii - Other Cattle	20	30	36
3.A.1.b - Buffalo	20	30	36
3.A.1.c - Sheep	20	30	36
3.A.1.d - Goats	20	30	36
3.A.1.e - Camels	20	30	36
3.A.1.f - Horses	20	30	36
3.A.1.g - Mules and Asses	20	30	36
3.A.1.h - Swine	20	30	36
3.A.1.j – Other	20	30	36
Manure management – CH4			
3.A.2.a.i - Dairy cows	20	30	36
3.A.2.a.ii - Other cattle	20	30	36
3.A.2.b - Buffalo	20	30	36
3.A.2.c - Sheep	20	30	36
3.A.2.d - Goats	20	30	36
3.A.2.e - Camels	20	30	36
3.A.2.f - Horses	20	30	36
3.A.2.g - Mules and Asses	20	30	36
3.A.2.h - Swine	20	30	36
3.A.2.i - Poultry	20	30	36
Manure management – N2O			
3.A.2.a.i - Dairy cows	20	50	54
3.A.2.a.ii - Other cattle	20	50	54
3.A.2.b - Buffalo	20	50	54
3.A.2.c - Sheep	20	50	54
3.A.2.d - Goats	20	50	54
3.A.2.e - Camels	20	50	54
3.A.2.f - Horses	20	50	54
3.A.2.g - Mules and Asses	20	50	54
3.A.2.h - Swine	20	50	54
3.A.2.i - Poultry	20	50	54
3-B Land	**20**	**100**	
3.C - Aggregate sources and non-CO2 emissions sources on land – CH4			
3.C.1.b - Biomass burning in croplands	50	50	71
3.C.1.c - Biomass burning in grasslands	100	50	112

CRF category	AD uncertainty (%)	EF uncertainty (%)	Combined uncertainty (%)
3.C - Aggregate sources and non-CO2 emissions sources on land – N2O			
3.C.1.b - Biomass burning in croplands	50	50	71
3.C.1.c - Biomass burning in grasslands	100	50	112
3.C.3 - Urea application	50	5	50
3.C.4 - Direct N2O Emissions from managed soils	50	100	112
3.C.5 - Indirect N2O Emissions from managed soils	50	100	112
3.C.6 - Indirect N2O Emissions from manure management	50	100	112
3.C.7 - Rice cultivations	10	75	76

The source of all the uncertainty values for categories included within 3A Livestock is IPCC 2006. For the selection of the uncertainty among those provided by IPCC 2006, the criteria have been based on the conservative principle, using the upper values of the ranges by default.

Conversely, the uncertainty values allocated in 3B Land and 3C Aggregate sources and non-CO2 emissions sources on land are mainly based on expert judgment (based on 2006 IPCC guidance) rather than default values. The reason for that is the limited guidance provided by 2006 IPCC Guidelines. More information on uncertainties can be found on the results in the AFOLU work files, sheet "Uncertainty".

3.8. Results of the QA/QC

Quality Control

Quality Control (QC) is a system of routine technical activities aimed at assessing and ensuring the quality of the inventory as it is compiled. The quality of control needs to be developed in all steps of the inventory compilation, from the data gathering to the submission of reports. QC is developed in line with the specificities defined in the QA/QC plan (see section on the QA/QC plan within the National System above).

In its 2019 edition of the GHG emission inventory, Cambodia has developed two types of quality control procedures: general QC procedures and category specific QC procedures, as proposed by 2016 IPCC Guidelines.

General QC procedures include generic quality checks related to calculations, data processing, completeness, and documentation that are applicable to all inventory source and sink categories.

For the general QC procedures, a QC template was used by national compilers for reviewing the GHG emission compilation of all sectors. The following table shows the QC procedures checked by national compilers.

Table 116 – General QC Procedures

QC activity	Procedures
Documentation	
Base information	Detailed description of the references of the base information used
Methodological coefficients	Detailed description of the references of the methodological coefficients used
Conversion coefficients	Detailed reference of all the conversion coefficients used
Units	Documentation of the units of the series
Data Transcription	
Base information	Errors in the transcription of the base information
Methodological coefficients	The methodological coefficients must coincide with the reference sources
Conversion coefficients	The conversion coefficients coincide with the reference sources (if possible)
Units	The units of the original data are correct
Emissions calculations	
Last inventory year	Check current year estimates against previous years (if available) and investigate unexplained departures from trend
Emission factor	Assess representativeness of emission factors, given national circumstances and analogous emissions data
Conversion factors	Check that conversion factors are correct
Time series	Review of the accuracy and temporal coherence of the time series. Check that there are no errors in the calculation, and examine the temporal coherence of the series, looking for anomalous data in the time series and comparing with indicators (if possible)
Uncertainty	
Assignment of uncertainties	The assigned uncertainties (tab "Uncertainty") are consistent with IPCC 2006

The QC procedures of the template were checked in all inventory categories, specifying the errors found, proposing corrective actions and making observations, if appropriate.

The following issues were identified and corrected as a result of the general QC procedures:

i) The emission factors for category 1A4 were linked to those of category 1A1.
ii) There was an error in the conversion performed in the calculation of the biogas consumption
iii) There was an error in the formulae for the calculation of domestic wastewater.

iv) There was an error in the amount of gases used as a raw data for the calculation of emissions within category 2F.

An additional general QC procedure was carried out in the 2019 edition of the inventory. The GHG emission calculations were performed in the 2006 IPCC software and the results were compared against the results obtained in the Excel worksheets. The differences between both approached in terms of GHG emissions were below 2% in all cases.

Category specific QC procedures complements general inventory QC procedures and are directed at specific types of data used in the methods for individual source or sink categories. These procedures require knowledge of the specific category, the types of data available and the parameters associated with emissions or removals and are performed in addition to the general QC checks. The category specific procedures were carried out by International inventory compilers during the inventory development. The main category specific procedures developed were the following:

Energy sector: reference vs sectoral approach; comparison of the data provided by the different sources of information; In the comparison of the reference approach, the differences for some years were above 5%. See methodological section for the energy sector for more detailed information.

IPPU sector: comparison of tier 1 and tier 2 estimates in cement production. As there are data on clinker production from one cement plant as well as data on cement production, it was verified that the differences between estimations are due just to the different coefficients used (95% clinker content vs national specific clinker quantities).

Waste sector: Comparison of the default rate provided by 2006 IPCC for industrial waste generation against a national rate estimated using real data on industrial waste generated. Two conclusions were raised from this QC: i) the default value provided by IPCC is not adequate for the conditions of Cambodia as the results on emissions were higher than those of municipal solid waste; ii) The scope of the data on industrial waste generated is not 100% of the activity data. As a result of the QC, the rate estimated using national data was used, but this issue needs to be improved in future editions of the inventory.

Quality Assurance

In the international team a peer reviewer expert was assigned by sector to undertake checks, propose improvements and ensure the quality of the inventory. These checks have been designed to verify the transparency, accuracy, consistency, comparability and completeness of the information submitted and include:

a) an assessment whether all emission source categories and gases are reported;
b) an assessment whether emissions data time series are consistent;
c) an assessment whether implied emission factors are comparable to the emissions factors of other countries with similar national circumstances such as Vietnam and also taking the IPCC default emission factors into account;
d) an assessment of the use of 'Not Estimated' notation keys where IPCC tier 1 methodologies exist;
e) an analysis of recalculations performed for the inventory submission, compared to the inventories presented in previous national communications;
f) a comparison of the national data using both different national data sources and international data sources when available;
g) a comparison of the results of the reference approach with the sectoral approach for the energy sector;
h) an assessment whether there were potential overestimations or underestimations relating to a key category in the inventory.

In particular, the peer reviewers checked if the international team in charge of the inventory compilation had implemented the following activities:

- Source data received are traceable back to their source in the compilation system. The mechanisms for this are spreadsheet notes, and a common system of data referencing of activity data and emission factors in each sector.
- Checks are undertaken at each stage of the inventory compilation – on receipt of the data, after each calculation step and at the end of the process before dissemination.
- Calculations are also checked and the checks applied are described in the QA/QC Plan.
- Checks are made on the inventory comparing the emissions of the whole time series and looking for explanations of the trend to ensure that large inter-annual variations have been investigated.
- Compare the reference and the sectoral approach in the energy sector and look for explanations in case of large discrepancies (the total emissions by fuel, must be consistent with the total emissions by source).
- All spreadsheets are subject to second-person checking prior to data uploading to the IPCC software.
- As an additional quality check, the national emission estimates were also prepared via the IPCC software by introducing the activity data and emission factors.
- The national report provides full details of inventory estimation methodologies by source category. The report includes summaries of key data sources and significant revisions to methods and historic data, where appropriate. It also describes the assumptions used in the compilation.
- The uncertainty analysis and the key category analysis for the greenhouse gas inventory is detailed within the National Inventory Report.

- The national report includes a programme of continuous improvement.
- At the end of each reporting cycle it is planned that all the database files, spreadsheets, on-line manual, electronic source data, paper source data, output files, etc, are in effect frozen and archived. An annual report outlining the methodology of the inventory and data sources is produced. Electronic information is stored on hard disks that are regularly backed up.

Final quality assurance checks: Official consideration and approval of the inventory

The official approval procedure of the inventory consisted in one-month period of interactions between the technical international consultants and the national team who held meetings by sector with the most relevant national stakeholders. During this period, the international team revised the inventory according to the observations and recommendations of the competent authority. On the basis of this interaction process, the final version of the inventory was compiled and presented in a validation workshop.

3.9. Improvement plan

Energy sector

The following are the main areas of improvement of the inventory in the energy sector:

1) Consistency of the time series for future inventories. The data used regarding fuel consumption comes from different data sources (The Ministry of Mines and energy, the ERIA report and ASEAN database). The most complete, robust and consistent data is available in the ERIA report, which was developed by a group of experts completing the raw data provided by the Ministry of Mines and Energy. Nevertheless, the Ministry of mines and energy has not followed the work made for the ERIA report for year 2016, issue that affects the consistency of the dataset, but it is highlighted in the following sectors*fuels:

    - Evolution of biomass consumption in its distinct types, at least firewood, charcoal and biogas. The different aggregation levels provided by ASEAN, ERIA and the Ministry of Mines affects the consistency of the time series of biomass consumption of categories 1A1, 1A2 and 1A4.
    - The value of 2016 for transport jet fuel consumption is very high compared to 2015 of ERIA. The same issue happens in category 1A4, regarding the consumption of oil products in the commerce and public services sector.
    - The figures for fuel consumption of oil products in the residential sector are not comparable between the Ministry of Mines and ERIA.

2) Sectoral disaggregation of the energy sector. Related to the previous point, the data of fuel consumption included in the ERIA report contained certain sectoral break down which is useful for the inventory. In the future, it is recommended to try obtaining more data detailed at sectoral level. As a result of the point 1) and 2) above, it is therefore recommended to the Ministry of mines and energy of Cambodia to implement changes in the collection of energy data to provide more accurate and consistent data to the inventory.

3) Develop road transport estimates based on data of vehicles*km. This approach will enable to compare the estimates performed using fuel consumption and improve the quality of the inventory.

4) Develop estimates for railway (starting in May 2016), marine navigation and international marine bunkers.

IPPU sector

The following are the main areas of improvement of the inventory in the IPPU sector:

1) **Improvement of national statistics on production and consumption of products**. The Ministry of Industry have provided some (limited) data on production for years 2012-2016. It would be relevant for the country to address the need of having systematic and robust statistics.

2) **Improvement of the estimates of cement production**. In this edition of the inventory, there is data available regarding cement and clinker production from the biggest production plant in the country. This has enabled the inventory to apply a tier 2 methodology for this production. Nevertheless, this production plant accounts for 2/3 of the national production, so cement production is not apply a tier 2 entirely (for the whole category). The obtainment of information from the remaining production plants will enable Cambodia to have a full tier 2 methodology or the next inventory edition.

3) **Continuation of the methodology of F-gases.** Cambodia has made a significant effort for obtaining data on HFC imports. The continuation of this approach will be key for the quality of the inventory of future editions.

4) **Improving the completeness of the IPPU sector**. The lack of reliable statistics in the country has hampered an appropriate assessment of the completeness of the inventory. Cambodia should address the identification of activities and launch processes for raising new raw data for the inventory.

AFOLU sector

3.A.1 - Enteric Fermentation

Emissions from enteric fermentation is estimated thanks to a tier 1 methodology, the main expected improvement for future inventories is to shift towards a tier 2 methodology. For this source, **IPCC tier 2 is very detailed and leads to a significative improvement** in the inventory. Of course, this methodology is based on additional requirements in terms of data collection. The main data needs concern the characterization of animal populations:

- Typical body weight,
- Meat yields,
- Milk yields,
- Type of feeding, etc.

This effort could be led for cattle, buffaloes and swine which are the main productions for Cambodia.

3.A.2 - Manure Management

For manure management tier 1 and tier 2 are based on the same equations. Currently the inventory corresponds to a tier 1 because only default IPCC parameters are used. But It would be possible to implement a tier 2 by using **country-specific data for the distribution between the different manure management systems**. In particular, data exist on the development of biogas production in small farms, this type of data could be used to modify the current estimate based on default value proposed by IPCC for Asia. Another key element is the time spent by cattle and buffaloes for grazing. Emissions from grazing are significantly different from those in housing and manure storage, it would be a real improvement to use a country specific estimate for the percentage of manure disposed by grazing. For manure management it would be useful to make additional cross checking between the amount of straw produced by rice crops which are mostly used for livestock feeding and bedding and the estimated of solid manure. In the short-term, it is unrealistic to propose country-specific emission factors for manure management because this emission factors are rather difficult to elaborate and present a very high uncertainty. Moreover, this source remains quite low compared to major key categories of agriculture (enteric fermentation, rice cultivation).

3.B - Land

The methodology used for this inventory is completely copied from the work made for the forest reference level (FRL) in the framework of REDD+ program. Indeed, it is better to keep consistent methodologies and results for the different publications of Cambodia. Nevertheless, it is possible to improve both publications in the future. Different elements could be improved in the future.

Completeness could be improved by adding estimates for the following categories:

- Carbon stock changes for **mineral soils**. This category was not estimated and may represent a very significative work for inventory teams but, it would complete the reporting for this sector.

- Carbon stock change for **dead organic matter** (litter and dead wood). Lower impacts are expected from these pools compared to soil, but it is very dependent on forest types.

- Carbon stock changes for **harvested wood products**.

- Emissions from biomass burning in relation with land use conversions

- Emissions from forest wildfires

- Emissions from mineralization of organic matter in soils

- Emissions from organic soils

Accuracy, could be improved by collecting additional country specific data:

- **On areas**. Currently two periods (2006-2010 and 2010-2014) are monitored thanks to 3 different maps (2006, 2010, 2014). It is a very good basis for calculating carbon stock changes, but the period remains a bit short to have a complete view on land use changes. Indeed, in the IPCC it is common to use default period of 20 years to use the default parameters for example for soils. Because the covered period is shorter than 20 years, conversion rates are extrapolated for most recent years and for the period before 2006.
- Many references were collected to estimate **carbon stocks** on the different categories of lands that are monitored by remote sensing. It is very good but cannot be compared to real data coming from a national forest inventory for example. The collection of specific references on forest areas from Cambodia would represent a strong improvement.

Accuracy, could also be improved by **applying IPCC tier 1 methodology for biomass** in forest areas:

- Currently a tier 2 is applied with the use of a stock change method for biomass in forest. But it would be possible to implement a tier 1 with the use of growth factors and harvested wood, at least for comparison.

- Currently data were collected and offer the **possibility to make a complete approach 2 or even approach 3**. Currently, the calculation made corresponds to an approach one which means that carbon stocks changes are fully symmetric in the calculations. For example, the losses observed on deforested area are equivalent to the gains on afforested area. Specific calculations could be developed according to the type of changes in the future.

3.C.1 - Biomass burning

Burning of residues is a real concern for rice cultivation. Currently country-specific data was used to estimate the share of the **areas where burning of stubble occurs** (on the basis of data for 2005-2006). It is already very good, but it only provides a steady estimate although is likely that this type of practice may change overtime. A major improvement would be to monitor this practice with **a new survey** to estimate the changes since 2005-2006.

For grassland the current estimate is based on very scarce information. A specific monitoring would be necessary to improve the estimate of activity data for this source.

3.C.2 - Liming

Liming is not covered currently. It would be necessary to collect such information with a survey to estimate the associated emissions.

3.C.3 - Urea application

Urea consumption is not monitored. Data on fertilizers are provided by the Ministry of Commerce since 2002 but this data only concerns the total amount of fertilizers and not the amounts by type of fertilizer. Currently urea consumption was estimated thanks to FAOSTAT data to estimate a proportion of urea in fertilizers. The monitoring of urea and other nitrogenous fertilizers is part of the improvement plan. The related emissions are currently rather low but fertilizer consumption could increase a lot in the future.

3.C.4 - Direct N2O Emissions from managed soils

As mentioned for urea consumption, nitrogen consumption from mineral fertilizer is not known with a lot of accuracy and this estimate could be improved. Nevertheless, the contribution of mineral fertilizers remains quite low compared to the contribution of organic amendments, pasture, and crop residues. It is certainly more important to focus on organic fertilizers and on the management of crop residues to improve the estimate of this source.

3.C.5 - Indirect N2O Emissions from managed soils

This source may represent big amounts of N_2O, but it is linked with the other parameters used to estimated direct N_2O emission. The main improvement which could be expected concerns the estimate of NH3 volatilisation.

3.C.6 - Indirect N2O Emissions from manure management

This source represents a very small amount of emissions and is based on very uncertain parameters. It does not appear as a priority in the improvement plan.

3.C.7 - Rice cultivations

This category is a major category for Cambodia. Currently the calculation is based on tier 1 methodology from the IPCC but the calculation is made for 24 different types of rice cultivation. It represents a very detailed calculation and could nearly be considered as a tier 2 (some country-specific parameters are used, and the categorization is high). The main improvements that could be led concern the **amounts of residues** which are incorporated after harvest and the **amounts of organic manure** which brought to soils. It could be very interesting to collect additional data on the area really irrigated because the current estimates are based on different sources but not on dedicated statistics. Currently, the cultivation period is defined by type but not changing on the period. In practices varieties of rice are improved and the periods of cultivations are becoming shorter. It could be included in the calculations.

Waste sector

The following are the main areas of improvement of the inventory in the waste sector:

- Developing estimates for the **rate of waste generation per capita** for the entire time series. Currently, the rate used is constant for the entire time series. The rate is likely to be lower in the historical period, but it has not been estimated in this edition.
- Improving the information on **waste composition**. In this inventory edition, different studies have been considered for the choice of activity data. The differences between studies were found to be significative.
- Improving the data gathered on **waste disposal**, including industrial waste disposal. The information used has been gathered by the MoE and includes municipal and industrial waste disposal. Nevertheless, this information is only partial and do not cover the 100% of the scope of the activity. This issue could be improved by obtaining additional data from the remaining landfills and improving the characterization of the waste management sector in the country.
- Raise information about **incineration of wastes**. This activity occurs in the country, but it has not been estimated due to unavailability of data.
- Estimate the amount of waste burned in landfills. This has not been estimated in the current edition of the inventory and could raise significantly the emissions of category 4C3 open burning.
- Obtain direct information about **composting**. This activity occurs in the country, but it has been estimated using assumptions.
- Improve the **data available from the national biodigesters programme**. In the current edition of the inventory, the estimation of emissions due to the production of biogas in the residential sector (which is happening thanks to the national biodigester program), has been estimated deriving the activity data (amount of wastes treated), from information on biogas produced. This information could be improved for future inventory editions.
- **Improve the statistics on population** for improving the estimates **of open burning and domestic wastewater**. The split between urban and rural population is needed for different areas of the inventory. National statistics has changed the definition of rural used, hampering the estimation of a consistent time series. This issue has been solved using the estimates provided by the World bank. In the future, the improvement of this statistics will enhance the quality of the inventory.
- **Improve the data on discharge types by population fraction, to improve the calculation of domestic wastewater.**
- Improving **national statistic on industrial production**. The quality of the IPPU and waste sectors are very affected for the lack of available information on industrial production. In the future, the improvement of this statistics will enhance the quality of the inventory.

3.10. Reporting tables

This section includes information in tabular format regarding all the emissions calculated in the 2019 edition of the GHG National Inventory.

Table 116 – Table A - Summary Table

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO2	CH4	N2O	HFC	PFC	SF6	Other halogenated gases with CO2 equivalent conversion factors (3)	Other halogenated gases without CO2 equivalent conversion factors (4	NOx	CO	NMVOCs	SO2
	Gg			CO2 equivalents (Gg)					Gg			
Total national emissions and removals	142137.97	747.87	8.98	371.68	NA, NE, NO	NA, NE, NO	NA, NE, NO	NA, NE, NO	43.43	160.46	45.03	32.61
1. Energy	8845.29	23.04	0.61						43.43	160.46	45.03	32.61
1A. Fuel combustion (sectoral approach)	8845.29	23.04	0.61						43.43	160.46	45.03	32.61
1A1. Energy industries	2990.41	10.05	0.05						9.23	3.47	0.29	25.14
1A2. Manufacturing industries and construction	672.28	1.13	0.15						6.95	23.32	11.39	3.12
1A3. Transport	4993.03	1.21	0.24						19.61	86.54	8.61	3.25
1A4. Other sectors	189.57	10.64	0.17						7.64	47.14	24.73	1.09
1A5. Non specified	NO	NO	NO						NO	NO	NO	NO
1B. Fugitive emissions from fuels	NO	NO	NO						NO	NO	NO	NO
1B1. Solid fuels	NO	NO	NO						NO	NO	NO	NO
1B2. Oil and natural gas	NO	NO	NO						NO	NO	NO	NO
1B3. Other emissions from energy production	NO	NO	NO						NO	NO	NO	NO
1C Carbon Dioxide Transport and Storage	NO								NO	NO	NO	NO
1C1. Transport of CO2	NO								NO	NO	NO	NO
1C2. Injection and Storage	NO								NO	NO	NO	NO
2. Industrial processes	1449.46	NA, NE, NO	NA, NE, NO	371.68	NA, NE, NO	NA, NE, NO	NA, NE, NO	NA, NE, NO	NA, NE, NO	NA, NE, NO	NA, NE, NO	NA, NE, NO
2A. Mineral products	1420.96	NA	NA						NE	NE	NE	NE
2A1 Cement Production	1420.96	NA	NA						NE	NE	NE	NE
2A2 Lime Production	NE	NA	NA						NE	NE	NE	NE
2A3 Glass Production	NE	NA	NA						NE	NE	NE	NE
2A4 Other Process Uses of Carbonates	NE	NA	NA						NE	NE	NE	NE

	Net CO2	CH4	N2O	HFC	PFC	SF6	Other halogenated gases with CO2 equivalent conversion factors (3)	Other halogenated gases without CO2 equivalent conversion factors (4	NOx	CO	NMVOCs	SO2
2A5 Other (please specify)	NO	NA	NA						NE	NE	NE	NE
2B. Chemical industry	NO	NO	NO						NO	NO	NO	NO
2B1. Ammonia production	NO	NO	NO						NO	NO	NO	NO
2B2. Nitric acid production	NO	NO	NO						NO	NO	NO	NO
2B3. Adipic acid production	NO	NO	NO						NO	NO	NO	NO
2B4. Caprolactam, glyoxal and glyoxylic acid production	NO	NO	NO						NO	NO	NO	NO
2B5. Carbide production	NO	NO	NO						NO	NO	NO	NO
2B6. Titanium dioxide production	NO	NO	NO						NO	NO	NO	NO
2B7. Soda ash production	NO	NO	NO						NO	NO	NO	NO
2B8. Petrochemical and carbon black production	NO	NO	NO						NO	NO	NO	NO
2B9. Fluorochemical production				NO	NO	NO	NO	NO	NO	NO	NO	NO
2B10. Other (as specified in table 2(I).A-H)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2C. Metal industry	NE, NO	NE, NO	NE, NO						NE, NO	NE, NO	NE, NO	NE, NO
2C1. Iron and steel production	NE	NE	NE						NE	NE	NE	NE
2C2. Ferroalloys production	NO	NO	NO						NO	NO	NO	NO
2C3. Aluminium production	NO	NO	NO		NO				NO	NO	NO	NO
2C4. Magnesium production	NO			NO	NO	NO	NO	NO	NO	NO	NO	NO
2C5. Lead production	NO								NO	NO	NO	NO
2C6. Zinc production	NO								NO	NO	NO	NO
2C7. Other (as specified in table 2(I).A-H)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2D. Non-energy products from fuels and solvent use	28.50	NE	NE						NE, NO	NE, NO	NE, NO	NE, NO
2D1. Lubricant use	28.50								NE	NE	NE	NE
2D2. Paraffin wax use	NE	NE	NE						NE	NE	NE	NE
2D3. Other									NO	NO	NO	NO

	Net CO2	CH4	N2O	HFC	PFC	SF6	Other halogenated gases with CO2 equivalent conversion factors (3)	Other halogenated gases without CO2 equivalent conversion factors (4	NOx	CO	NMVOCs	SO2
2E. Electronics industry	NE		NE	NE, NO	NE, NO	NE, NO	NE, NO	NE, NO	NE, NO	NE, NO	NE, NO	NE, NO
2E1. Integrated circuit or semiconductor	NE		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2E2. TFT flat panel display				NO	NO	NO	NO	NO	NO	NO	NO	NO
2E3. Photovoltaics				NO	NO	NO	NO	NO	NO	NO	NO	NO
2E4. Heat transfer fluid												
2E5. Other (as specified in table 2(II))	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2F. Product uses as substitutes for ODS(2)	NA, NO	NA, NO	NA, NO	371.68	NE, NO		NE, NO	NE, NO	NE, NO	NE, NO	NE, NO	NE, NO
2F1. Refrigeration and air conditioning	NA	NA	NA	371.50	NE		NE	NE	NE	NE	NE	NE
2F2. Foam blowing agents	NA			NE	NE		NE	NE	NE	NE	NE	NE
2F3. Fire protection	NA			0.19	NE		NE	NE	NE	NE	NE	NE
2F4. Aerosols				NE	NE		NE	NE	NE	NE	NE	NE
2F5. Solvents				NE	NE		NE	NE	NE	NE	NE	NE
2F6. Other applications	NO	NO	NO	NO	NO		NO	NO	NO	NO	NO	NO
2G. Other product manufacture and use	NO	NO	NE	NO	NA, NO	NE, NO	NE, NO	NE, NO	NA	NA	NA	NA
2G1. Electrical equipment					NA	NE	NE	NE	NA	NA	NA	NA
2G2. SF6 and PFCs from other product use					NO	NO	NO	NO	NA	NA	NA	NA
2G3. N2O from product uses			NE						NA	NA	NA	NA
2G4. Other	NO	NO		NO			NO	NO	NA	NA	NA	NA
2H. Other (as specified in tables 2(I).A-H and 2(II))(3)	NA, NO	NA, NO							NE	NE	NE	NE
2H1 Pulp and Paper Industry	NA	NA							NE	NE	NE	NE
2H2 Food and Beverages Industry	NA	NA							NE	NE	NE	NE
2H3 Other (please specify)	NO	NO	NO						NE	NE	NE	NE
3 AGRICULTURE, FORESTRY AND OTHER LAND USE	131028.66	645.15	7.56						NE, NA,NO	NE, NA,NO	NE, NA,NO	NE, NA,NO
3A Livestock		188.86	2.23						NE	NA	NE	NA

	Net CO2	CH4	N2O	HFC	PFC	SF6	Other halogenated gases with CO2 equivalent conversion factors (3)	Other halogenated gases without CO2 equivalent conversion factors (4	NOx	CO	NMVOCs	SO2
3A1 Enteric Fermentation		167.54							NE	NA	NE	NA
3A2 Manure Management		21.32	2.23						NE	NA	NE	NA
3B Land	131011.24	NE	NE						NA	NA	NA	NA
3B1 Forest Land	IE	NE	NE						NA	NA	NA	NA
3B2 Cropland	IE	NE	NE						NA	NA	NA	NA
3B3 Grassland	IE	NE	NE						NA	NA	NA	NA
3B4 Wetlands	IE	NE	NE						NA	NA	NA	NA
3B5 Settlements	IE	NE	NE						NA	NA	NA	NA
3B6 Other Land	IE	NE	NE						NA	NA	NA	NA
3C Aggregate Sources and Non-CO2 Emissions Sources on Land	17.42	456.29	5.33						NA	NA	NA	NA
3C1 Biomass Burning	NA	3.37	0.24						NE	NE	NE	NE
3C2 Liming	NE								NA	NA	NA	NA
3C3 Urea Application	17.42								NA	NA	NA	NA
3C4 Direct N2O Emissions from Managed Soils			3.17						NA	NA	NA	NA
3C5 Indirect N2O Emissions from Managed Soils			1.36						NA	NA	NA	NA
3C6 Indirect N2O Emissions from Manure Management			0.57						NA	NA	NA	NA
3C7 Rice Cultivations		452.93	IE						NA	NA	NA	NA
3C8 Other (please specify)	NO	NO	NO						NO	NO	NO	NO
3D Other	NE,NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3D1 Harvested Wood Products	NE								NO	NO	NO	NO
3D2 Other (please specify)	NO	NO	NO						NO	NO	NO	NO
4 WASTE	814.553	79.678	0.82						NE	NE	NE	NE
4A Solid Waste Disposal		53.83	NA						NE	NE	NE	NE
4B Biological Treatment of Solid Waste		0.33	0.02						NE	NE	NE	NE

	Net CO2	CH4	N2O	HFC	PFC	SF6	Other halogenated gases with CO2 equivalent conversion factors (3)	Other halogenated gases without CO2 equivalent conversion factors (4	NOx	CO	NMVOCs	SO2
4C Incineration and Open Burning of Waste	814.55	9.46	0.14						NE	NE	NE	NE
4D Wastewater Treatment and Discharge		16.06	0.66						NE	NE	NE	NE
4E Other (please specify)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5 OTHER	NE, NO	NO	NE, NO	NO	NO	NO	NO	NO	NE, NO	NE, NO	NE, NO	NE, NO
5A Indirect N2O Emissions from the Atmospheric Deposition of Nitrogen in NOx and NH3			NE						NE	NE	NE	NE
5B Other (please specify)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Memo items (5)												
International Bunkers												
International Aviation (International Bunkers)	236.49	0.00	0.01						0.83	94.44	1.50	0.08
International Water-borne Transport (International Bunkers)	NE	NE	NE						NE	NE	NE	NE
Multilateral Operations	NE	NE	NE						NE	NE	NE	NE

Table 117 – Table B - Short Summary table

	Net CO2	CH4	N2O	HFC	PFC	SF6	Other halogenated gases with CO2 equivalent conversion factors (3)	Other halogenated gases without CO2 equivalent conversion factors (4	NOx	CO	NMVOCs	SO2
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Gg			CO2 equivalents (Gg)					Gg			
Total national emissions and removals	142137.97	747.87	8.98	371.68	NA, NE, NO	NA, NE, NO	NA, NE, NO	NA, NE, NO	43.43	160.46	45.03	32.61
1. Energy	8845.29	23.04	0.61						43.43	160.46	45.03	32.61
1A. Fuel combustion (sectoral approach)	8845.29	23.04	0.61						43.43	160.46	45.03	32.61
1B. Fugitive emissions from fuels	NO	NO	NO						NO	NO	NO	NO
1C Carbon Dioxide Transport and Storage	NO								NO	NO	NO	NO
2. Industrial processes	1449.46	NA, NE, NO	NA, NE, NO	371.68	NA, NE, NO	NA, NE, NO	NA, NE, NO	NA, NE, NO	NA, NE, NO	NA, NE, NO	NA, NE, NO	NA, NE, NO
2A. Mineral products	1420.96	NA	NA						NE	NE	NE	NE
2B. Chemical industry	NO	NO	NO						NO	NO	NO	NO
2C. Metal industry	NE ,NO	NE, NO	NE, NO						NE, NO	NE, NO	NE, NO	NE, NO
2D. Non-energy products from fuels and solvent use	28.50	NE	NE						NE, NO	NE, NO	NE, NO	NE, NO
2E. Electronics industry	NE		NE	NE, NO	NE, NO	NE, NO	NE, NO	NE, NO	NE, NO	NE, NO	NE, NO	NE, NO
2F. Product uses as substitutes for ODS(2)	NA , NO	NA, NO	NA, NO	371.68	NE, NO		NE, NO	NE, NO	NE, NO	NE, NO	NE, NO	NE, NO
2G. Other product manufacture and use	NO	NO	NE	NO	NA, NO	NE, NO	NE, NO	NE, NO	NA	NA	NA	NA
2H. Other (as specified in tables 2(I).A-H and 2(II))(3)	NA ,NO	NA, NO	NA, NO						NE	NE	NE	NE
3 AGRICULTURE, FORESTRY AND OTHER LAND USE	131028.66	645.15	7.56						NE, NA,NO	NE, NA,NO	NE, NA,NO	NE, NA,NO
3A Livestock		188.86	2.23						NE	NA	NE	NA
3B Land	131011.24	NE	NE						NA	NA	NA	NA
3C Aggregate Sources and Non-CO2 Emissions Sources on Land	17.42	456.29	5.33						NA	NA	NA	NA
3D Other	NE,NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4 WASTE	814.553	79.678	0.82						NE	NE	NE	NE

	Net CO2	CH4	N2O	HFC	PFC	SF6	Other halogenated gases with CO2 equivalent conversion factors (3)	Other halogenated gases without CO2 equivalent conversion factors (4	NOx	CO	NMVOCs	SO2
4A Solid Waste Disposal		53.83	NA						NE	NE	NE	NE
4B Biological Treatment of Solid Waste		0.33	0.02						NE	NE	NE	NE
4C Incineration and Open Burning of Waste	814.55	9.46	0.14						NE	NE	NE	NE
4D Wastewater Treatment and Discharge		16.06	0.66						NE	NE	NE	NE
4E Other (please specify)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5 OTHER	NE, NO	NO	NE, NO	NO	NO	NO	NO	NO	NE, NO	NE, NO	NE, NO	NE, NO
5A Indirect N2O Emissions from the Atmospheric Deposition of Nitrogen in NOx and NH3			NE						NE	NE	NE	NE
5B Other (please specify)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Memo items (5)												
International Bunkers												
International Aviation (International Bunkers)	236.49	0.00	0.01						0.83	94.44	1.50	0.08
International Water-borne Transport (International Bunkers)	NE	NE	NE						NE	NE	NE	NE
Multilateral Operations	NE	NE	NE						NE	NE	NE	NE

Table 118 – CO2 emissions

Emission source		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1A1	Energy Industries	48.28	48.28	50.64	52.10	57.27	76.05	86.02	85.58	108.35	112.74	145.40	160.39
1A2	Manufacturing Industry	114.84	114.84	114.71	118.20	152.98	148.84	161.50	190.09	173.10	181.93	193.41	220.26
1A3	Transport	1852.05	1852.05	1888.66	1956.78	2131.31	2150.83	1963.09	2164.41	1965.50	1973.21	1986.68	2161.75
1A4	Other	91.55	91.55	93.00	96.25	121.14	127.39	157.36	156.76	173.68	213.15	199.91	217.63
2A1	Cement production	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2D1	Lubricants	3.81	3.81	4.11	4.23	2.21	4.44	6.04	2.47	3.82	5.29	5.84	6.41
2F	Subst. for ODS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3A	Livestock												
3B	Land	27018.62	27018.62	27018.62	27018.62	27018.62	27018.62	27018.62	27018.62	27018.62	27018.62	27018.62	27018.62
3C	Aggregate sources and non-CO2 emissions sources on land	1.61	1.61	1.17	1.47	2.36	1.65	1.65	1.65	1.65	1.65	1.65	1.65
3D	Other												
4A	Solid waste disposal												
4B	Biological treatment of solid waste												
4C	Incineration and Open burning of waste	623.20	639.91	655.58	670.23	683.86	696.60	708.13	735.76	749.41	762.83	745.01	757.52
4D	Wastewater treatment and discharge												
Total (Gg)		29753.96	29770.67	29826.48	29917.88	30169.75	30224.43	30102.41	30355.34	30194.14	30269.42	30296.52	30544.23
Total with FOLU (Gg CO2-eq)		29753.96	29770.67	29826.48	29917.88	30169.75	30224.43	30102.41	30355.34	30194.14	30269.42	30296.52	30544.23
Total without FOLU (Gg CO2-eq)		2735	2752	2808	2899	3151	3206	3084	3337	3176	3251	3278	3526

Table 119 – cont CO2 emissions

Emission source		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1A1	Energy Industries	160.39	271.13	392.78	575.93	714.72	852.97	895.48	850.04	678.49	1405.28	2503.66	2990.41
1A2	Manufacturing Industry	220.26	235.75	267.84	279.78	543.55	626.92	655.82	640.77	576.59	508.68	384.87	672.28
1A3	Transport	2161.75	2317.23	2502.67	2644.18	2721.59	2838.89	3251.22	3736.99	3755.94	4057.82	4533.51	4993.03
1A4	Other	217.63	234.02	253.79	270.45	296.31	303.95	336.70	278.93	243.42	223.32	189.57	189.57
2A1	Cement production	NO	NO	52.63	371.26	347.46	370.14	430.89	486.72	507.13	510.49	652.89	1,420.96
2D1	Lubricants	6.41	6.84	7.39	8.07	8.62	8.60	11.67	10.44	11.67	8.60	28.25	28.50
2F	Subst. for ODS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3A	Livestock												
3B	Land	27018.62	27018.62	27018.62	27018.62	27018.62	131011.24	131011.24	131011.24	131011.24	131011.24	131011.24	131011.24
3C	Aggregate sources and non-CO2 emissions sources on land	1.65	1.65	1.88	9.99	12.37	29.90	17.42	17.42	17.42	17.42	17.42	17.42
3D	Other												
4A	Solid waste disposal												
4B	Biological treatment of solid waste												
4C	Incineration and Open burning of waste	757.52	709.84	719.22	741.89	745.45	753.71	759.55	771.27	788.63	801.00	804.30	814.55
4D	Wastewater treatment and discharge												
Total (Gg)		30,544.23	30795.08	31216.81	31920.17	32408.69	136796.33	137370.00	137803.82	137590.52	138543.85	140125.72	142137.97
Total with FOLU (Gg CO2-eq)		30,544.23	30795.08	31216.81	31920.17	32408.69	136796.33	137370.00	137803.82	137590.52	138543.85	140125.72	142137.97
Total without FOLU (Gg CO2-eq)		3,526	3776	4198	4902	5390	5785	6359	6793	6579	7533	9114	11126.73

Table 120 – CH4 emissions

Emission source		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1A1	Energy Industries	10.01	10.01	10.74	11.24	14.54	14.55	14.57	14.59	17.04	17.77	14.24	14.06
1A2	Manufacturing Industry	1.10	1.10	1.14	1.14	1.21	1.19	1.16	1.14	1.07	1.03	1.06	1.03
1A3	Transport	0.51	0.51	0.53	0.55	0.52	0.57	0.45	0.44	0.45	0.43	0.42	0.46
1A4	Other	7.83	7.83	8.19	8.26	9.32	9.19	9.03	8.92	9.06	9.00	8.46	8.23
2A1	Cement production	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2D1	Lubricants	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2F	Subst. for ODS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3A	Livestock	188.84	194.38	192.93	195.21	187.67	188.51	199.49	191.13	193.75	200.21	206.61	214.17
3B	Land	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3C	Aggregate sources and non-CO2 emissions sources on land	186.85	232.00	232.16	236.98	238.93	245.83	242.74	252.35	261.65	280.73	283.88	312.61
3D	Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4A	Solid waste disposal	21.57	22.52	23.58	24.65	25.70	26.69	27.74	28.79	30.04	31.46	33.16	35.02
4B	Biological treatment of solid waste	0.21	0.21	0.22	0.23	0.23	0.24	0.25	0.26	0.26	0.27	0.27	0.27
4C	Incineration and Open burning of waste	7.24	7.43	7.61	7.78	7.94	8.09	8.22	8.54	8.70	8.86	8.65	8.79
4D	Wastewater treatment and discharge	11.45	11.83	12.09	12.44	12.78	12.98	13.28	13.89	14.23	14.45	14.20	14.53
Total (Gg)		435.61	487.84	489.21	498.48	498.84	507.86	516.92	520.04	536.25	564.23	570.95	609.19
Total with FOLU (Gg CO2-eq)		10890.33	12195.93	12230.24	12461.89	12471.08	12696.53	12923.06	13001.00	13406.16	14105.65	14273.75	15229.81
Total without FOLU (Gg CO2-eq)		10890.33	12195.93	12230.24	12461.89	12471.08	12696.53	12923.06	13001.00	13406.16	14105.65	14273.75	15229.81

Table 121 – Cont. CH4 emissions

Emission source		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1A1	Energy Industries	14.06	13.63	12.87	12.11	11.35	10.59	9.83	9.06	9.43	9.88	10.04	10.05
1A2	Manufacturing Industry	1.03	0.99	0.97	0.95	0.98	0.85	0.87	0.93	0.99	1.06	1.13	1.13
1A3	Transport	0.46	0.49	0.53	0.57	0.61	0.64	0.68	0.80	0.81	0.91	1.11	1.21
1A4	Other	8.23	7.95	9.18	9.47	9.54	9.64	9.94	10.00	9.97	10.50	10.64	10.64
2A1	Cement production	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2D1	Lubricants	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2F	Subst. for ODS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3A	Livestock	214.17	224.59	225.69	227.98	230.27	224.70	220.65	217.88	220.54	197.34	188.10	188.86
3B	Land	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3C	Aggregate sources and non-CO2 emissions sources on land	312.61	329.36	345.23	361.34	380.95	402.58	423.41	442.80	443.46	443.51	441.31	456.29
3D	Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4A	Solid waste disposal	35.02	36.76	38.12	39.74	41.43	43.09	43.36	43.94	46.44	48.99	51.53	53.83
4B	Biological treatment of solid waste	0.27	0.26	0.27	0.30	0.30	0.32	0.33	0.33	0.31	0.32	0.33	0.33
4C	Incineration and Open burning of waste	8.79	8.24	8.35	8.61	8.65	8.75	8.82	8.95	9.16	9.30	9.34	9.46
4D	Wastewater treatment and discharge	14.53	13.59	13.98	14.39	14.43	14.81	14.91	15.11	15.60	15.74	16.10	16.06
Total (Gg)		609.19	635.86	655.18	675.45	698.51	715.96	732.79	749.80	756.73	737.55	729.63	747.87
Total with FOLU (Gg CO2-eq)		15229.81	15896.43	16379.49	16886.24	17462.81	17899.08	18319.70	18744.92	18918.17	18438.66	18240.74	18696.71
Total without FOLU (Gg CO2-eq)		15229.81	15896.43	16379.49	16886.24	17462.81	17899.08	18319.70	18744.92	18918.17	18438.66	18240.74	18696.71

Table 122 – N2O Emissions

Emission sources		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1A1	**Energy Industries**	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002
1A2	**Manufacturing Industry**	0.147	0.147	0.153	0.152	0.162	0.159	0.155	0.152	0.143	0.138	0.142	0.138
1A3	**Transport**	0.091	0.091	0.093	0.096	0.106	0.106	0.098	0.109	0.098	0.099	0.099	0.108
1A4	**Other**	0.088	0.088	0.092	0.092	0.101	0.099	0.097	0.095	0.093	0.091	0.090	0.087
2A1	**Cement production**	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2D1	**Lubricants**	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2F	**Subst. for ODS**	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3A	**Livestock**	2.18	2.25	2.24	2.27	2.18	2.20	2.32	2.23	2.26	2.34	2.41	2.50
3B	**Land**	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3C	**Aggregate sources and non-CO2 emissions sources on land**	3.89	4.08	4.06	4.11	3.96	4.06	4.31	4.15	4.22	4.40	4.48	4.76
3D	**Other**	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4A	**Solid waste disposal**	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4B	**Biological treatment of solid waste**	0.012	0.013	0.013	0.014	0.014	0.014	0.015	0.015	0.016	0.016	0.016	0.016
4C	**Incineration and Open burning of waste**	0.108	0.111	0.114	0.116	0.119	0.121	0.123	0.128	0.130	0.132	0.129	0.131
4D	**Wastewater treatment and discharge**	0.287	0.292	0.301	0.310	0.346	0.383	0.421	0.440	0.451	0.473	0.476	0.499
Total (Gg)		6.80	7.07	7.06	7.16	7.00	7.14	7.54	7.33	7.41	7.69	7.84	8.25
Total with FOLU (Gg CO2-eq)		2027.85	2107.43	2104.22	2134.56	2084.56	2127.90	2245.84	2182.98	2209.12	2292.50	2337.39	2457.67
Total without FOLU (Gg CO2-eq)		2027.85	2107.43	2104.22	2134.56	2084.56	2127.90	2245.84	2182.98	2209.12	2292.50	2337.39	2457.67

Table 123 – Cont N2O Emissions

Emission sources		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1A1	Energy Industries	0.002	0.003	0.004	0.006	0.007	0.008	0.009	0.009	0.007	0.021	0.040	0.046
1A2	Manufacturing Industry	0.138	0.133	0.129	0.127	0.132	0.115	0.118	0.126	0.134	0.143	0.152	0.153
1A3	Transport	0.108	0.116	0.125	0.132	0.136	0.141	0.162	0.184	0.184	0.197	0.217	0.238
1A4	Other	0.087	0.084	0.131	0.167	0.176	0.207	0.240	0.226	0.147	0.166	0.168	0.168
2A1	Cement production	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2D1	Lubricants	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2F	Subst. for ODS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3A	Livestock	2.50	2.62	2.63	2.66	2.69	2.62	2.58	2.55	2.59	2.32	2.22	2.23
3B	Land	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3C	Aggregate sources and non-CO2 emissions sources on land	4.76	5.03	5.10	5.31	5.52	5.51	5.68	5.82	6.00	5.39	5.55	5.33
3D	Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4A	Solid waste disposal	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4B	Biological treatment of solid waste	0.016	0.016	0.016	0.016	0.017	0.017	0.017	0.018	0.018	0.018	0.019	0.019
4C	Incineration and Open burning of waste	0.131	0.123	0.125	0.129	0.129	0.131	0.132	0.134	0.137	0.139	0.139	0.141
4D	Wastewater treatment and discharge	0.499	0.470	0.480	0.510	0.524	0.543	0.561	0.582	0.606	0.626	0.640	0.659
Total (Gg)		8.25	8.60	8.74	9.05	9.32	9.30	9.49	9.65	9.83	9.02	9.14	8.98
Total with FOLU (Gg CO2-eq)		2457.67	2561.74	2604.46	2697.69	2778.62	2770.65	2829.47	2876.47	2927.94	2688.24	2725.11	2675.98
Total without FOLU (Gg CO2-eq)		2457.67	2561.74	2604.46	2697.69	2778.62	2770.65	2829.47	2876.47	2927.94	2688.24	2725.11	2675.98

Table 124 – CO2-eq Emissions

Emission source		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1A1	Energy Industries	299	299	319	333	421	440	451	451	535	558	502	512
1A2	Manufacturing Industry	186	186	189	192	232	226	237	264	243	249	262	287
1A3	Transport	1892	1892	1930	1999	2176	2197	2004	2208	2006	2013	2027	2205
1A4	Other	314	314	325	330	384	387	412	408	428	465	438	449
2A1	Cement production	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2D1	Lubricants	4	4	4	4	2	4	6	2	4	5	6	6
2F	Subst. for ODS	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	6
3A	Livestock	5371	5530	5490	5557	5342	5367	5679	5443	5518	5702	5882	6,100
3B	Land	27019	27019	27019	27019	27019	27019	27019	27019	27019	27019	27019	27019
3C	Aggregate sources and non-CO2 emissions sources on land	5832	7017	7014	7151	7157	7358	7353	7548	7800	8333	8434	9236
3D	Other	0	0	0	0	0	0	0	0	0	0	0	0
4A	Solid waste disposal	539	563	590	616	643	667	693	720	751	787	829	876
4B	Biological treatment of solid waste	9	9	9	10	10	10	11	11	11	12	11	12
4C	Incineration and Open burning of waste	836	859	880	899	918	935	950	987	1006	1024	1000	1017
4D	Wastewater treatment and discharge	372	383	392	403	422	439	457	478	490	502	497	512
	Total with FOLU	42672	44074	44161	44514	44725	45049	45271	45539	45809	46668	46908	48238
	Total without FOLU	15654	17055	17142	17496	17707	18030	18253	18521	18791	19649	19889	21219

Table 125 – Cont. CO2-eq Emissions

Emission source		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1A1	Energy Industries	512	613	716	880	1001	1120	1144	1079	917	1658	2767	3,256
1A2	Manufacturing Industry	287	300	331	341	607	682	713	701	641	578	458	746
1A3	Transport	2205	2364	2553	2698	2777	2897	3316	3812	3831	4139	4626	5,094
1A4	Other	449	458	522	557	587	607	657	596	536	535	506	506
2A1	Cement production	NO	NO	53	371	347	370	431	487	507	510	653	1,421
2D1	Lubricants	6	7	7	8	9	9	12	10	12	9	28	29
2F	Subst. for ODS	6	18	36	57	84	114	148	186	220	262	320	372
3A	Livestock	6100	6396	6426	6491	6557	6400	6285	6207	6286	5625	5363	5,385
3B	Land	27019	27019	27019	27019	27019	131011	131011	131011	131011	131011	131011	131,011
3C	Aggregate sources and non-CO2 emissions sources on land	9236	9734	10153	10626	11180	11736	12295	12823	12892	12711	12706	13,013
3D	Other	0	0	0	0	0	0	0	0	0	0	0	0
4A	Solid waste disposal	876	919	953	994	1036	1077	1084	1099	1161	1225	1288	1,346
4B	Biological treatment of solid waste	12	11	12	12	13	13	13	14	13	14	14	14
4C	Incineration and Open burning of waste	1017	953	965	996	1000	1011	1019	1035	1058	1075	1079	1,093
4D	Wastewater treatment and discharge	512	480	492	512	517	532	540	551	571	580	593	598
	Total with FOLU	48238	49272	50236	51562	52734	157580	158667	159611	159657	159932	161412	163882
	Total without FOLU	21219	22253	23218	24543	25715	26569	27656	28600	28646	28921	30401	32871