Project: "Raising awareness and capacity for leaders and officials at central and local levels on GHG inventory to support the implementation of NAMAs and to develop low carbon cities in Vietnam

TRAINING MATERIAL

GHG INVENTORY AND MONITORING

Hanoi, 2016

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I. OVERVIEW ON GHG INVENTORY

1.1. International circumstance

1.1.1 United Nations Framework Convention on Climate Change

The Earth is surrounded by atmospheric layers, which are including naturally greenhouse gases (GHG) (mainly CO_2, CH_4, N_2O). When the concentration of GHGs is kept at a stable, natural level, the thermal balance on Earth is maintained, ensuring the existence and development of ecosystems, protecting life and environment. From pre-industrial period, especially in recent decades, the activities such as industrial development, fossil fuel burning, energy production and consumption, industrial production, mining , deforestation and forest extraction, land use change, agricultural production and animal husbandry, human waste, etc. have been emitting excessive amounts of GHG into the atmosphere, increasing the GHG concentration, resulting in increased greenhouse effect, surface temperature and atmospheric temperatures rise at unprecedented speed in the past. It is the global warming phenomenon, which causes climate change with the most consequential is sea level rising. Climate change may do serious impacts on the socio-economy, production activities, life, ecosystems and environment as well as the impact on public health at global level. Climate change is one of the greatest challenges for humanity.

The United Nations Framework Convention on Climate Change (UNFCCC) was signed at the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil in June 1992 and officially effective from March 21, 1994. The UNFCCC divides the countries of the world into two groups: Parties are included in Annex I - developed countries and transition economies countries, which are large GHG emitters in the past and present, causing climate change (Annex I countries), and the non-Annex I Parties - developing countries. The Annex I countries have the responsibility and obligation to quantitatively reduce greenhouse gas emissions from each committed period, carry out annual national greenhouse gas inventories and provide financial support, capacity building for non-Annex I Parties in the development and implementation of their mitigation options. The non - Annex I Parties have no responsibility to quantitatively reduce GHG emissions as Annex I countries but are obliged to periodically report on GHG emissions under the National Communications, Biennial updated Reports (hereafter referred to as the National Climate Change Reports) to the UNFCCC Secretariat and implement mitigation options with the support from the Annex I.

The goal of the UNFCCC is to stabilize atmospheric GHG at level that would prevent dangerous human interference with the climate system. That level must be achieved within a sufficient timeframe to allow ecosystems to naturally adapt to climate change, ensure sustainable development.

1.1.2 Kyoto Protocol

To implement the UNFCCC, the Kyoto Protocol to UNFCCC (here after referred to as the Kyoto Protocol) was adopted at the Third Conference of the Parties (COP3) in Kyoto, Japan in December 1997 and officially entered into force on February 16, 2005. During the first commitment period of 2008 to 2012 of the Kyoto Protocol (KP), Annex I countries must achieve their commitments to reduce GHG emissions to 5.2 percent in comparison with the 1990 level. The second commitment period of the KP from 2013 to 2020 requires Annex I countries to reduce and limit the quantitative GHG emissions to at least 18 percent of total GHG emissions in comparison with the 1990 level. The GHGs controlled by the KP, are included CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3.

To continue implementing the second commitment period of KP from 2013 to 2020, the 8th Conference of the Parties to the KP (CMP8) was held in Doha, Qatar on December 8, 2012, had ratified the Doha Amendment to the KP. The main content of the Doha Amendment is that developed countries (Annex I Parties) must commit to reduce their total GHG emissions by at least 18 percent below the 1990 level during the second commitment period of the KP. The main purpose of ratifying the Doha Amendment is to establish a global legal basis for GHG emission limitation and reduction to keep the global average temperature rise below 2ºC in comparison with the pre-industrial period in the end of this century. UNFCCC’s Secretariat requested the Parties to the KP to consider and approve the Doha Amendment so that this document can takes effect by December 2015. As of 15 July 2015, there were 38 Parties to the Kyoto Protocol ratifying the Doha Amendment.

1.1.3 GHG inventory in the world

1.1.3.1. General international provisions on GHG inventory

Article 4.1 and Article 12.1 of the UNFCCC stipulated that Parties must develop and submit their National Communications (NCs) to the UNFCCC’s Secretariat. In implementation of Decision No.10/CP.2 of COP2 (1996), Decision No.2/CP.7 of COP7, Decision No.17/CP.8 of COP8 (2002) together with the relevant technical guidelines, the countries have responsible and obligation to develop and submit their NCs including the results of the GHG inventory to the UNFCCC’s Secretariat.

Decision No.2/CP.17 dated March 15, 2012 of COP17 regulated that Parties have responsible and obligation to develop and submit their Biennial Updated Reports (BURs) including the content on the GHG inventory to the UNFCCC’s Secretariat from 2014.

As regulated, the GHG inventories must follow the methodologies of the Intergovernmental Panel on Climate Change (IPCC). The default Emission Factors

(EFs) of the IPCC can be used for GHG inventories. In addition, countries are also encouraged to research and develop their national specific EFs. The GHG inventories' result is one of the most important contents of the NCs and BURs.

The purpose of GHG inventory is to evaluate total GHG emissions of a country in a base year, identifying the main GHG emissions/sink sources in country. Based on the GHG inventory's results, the country could develop and analyse the potential, nationally appropriate mitigation options to contribute in the implementation of UNFCCC, and to implement strategies, policies to repond to climate change as well as greengrowth and low carbon economy development.

1.1.3.2. Institutional arrangements for GHG inventory system of some other countries

In order to carry out the regular GHG inventory activities and to prepare national reports related to the GHG inventory to the UNFCCC's Secretariat, countries must set up their institutional arrangement to carry out their GHG inventory. Based on the IPCC's guidelines, GHG inventories are implemented in five sectors: energy; industrial processes; agriculture; land use, land use change and forestry (LULUCF) and waste.

Regarding the institutional arrangements for GHG inventory system, at present, there are two models of organizing the GHG inventory system which are decentralized and centralized models.

The followings are some specific examples on the institutional arrangements for national GHG inventory system in the world in centralized and decentralized models. Korea organizes their national GHG inventory system in a decentralized model while Japan, the United Kingdom and Thailand use centralized systems.

a) Korea:

- The main body in the GHG inventory is the Korean GHG inventory Management Committee chaired by the Vice Minister of Environment and 15 representatives from relevant Ministries.

- This Committee has the function of verificating and approving the results of GHG inventory regularly carried out by Ministry of Environment, which plays as the National Focal Point on GHG inventory.

- GHG inventory and Research Centre of Korea (GIR) under Ministry of Environment has responsibilities to coodirnate from implementing the GHG inventories.

- Ministries and agencies involved in the system shall collect on their own information and activity data under their respective management to synthesize and implement GHG inventory.

+ The Ministry of Commerce, Industry, Energy and the Ministry of Land, Transport and Construction carry out GHG inventory in the energy sector.

+ The Ministry of Commerce, Industry, Energy carry out GHG inventory in the industrial processes sector.

+ Ministry of Agriculture, Food and Rural Issues carry out GHG inventory in the Agriculture and LULUCF sectors.

+ Ministry of Environment carry out GHG inventory in the waste sector.

- Quality Control (QC) activities are carried out by the Ministries; GIR conducts an internal assessment of their GHG inventory results and QC performation when necessary.

- The GHG inventory results of the sectors carried out by the Ministries were sent to the GIR and the Korean Statistical Unit for evaluation, synthesis

- Based on the results of the GHG inventory, the GIR shall prepare a periodic GHG inventory report and send to Ministry of Environment. Ministry of Environment shall submit it to the National GHG Inventory Committee for approval before sending it to the UNFCCC's Secretariat.

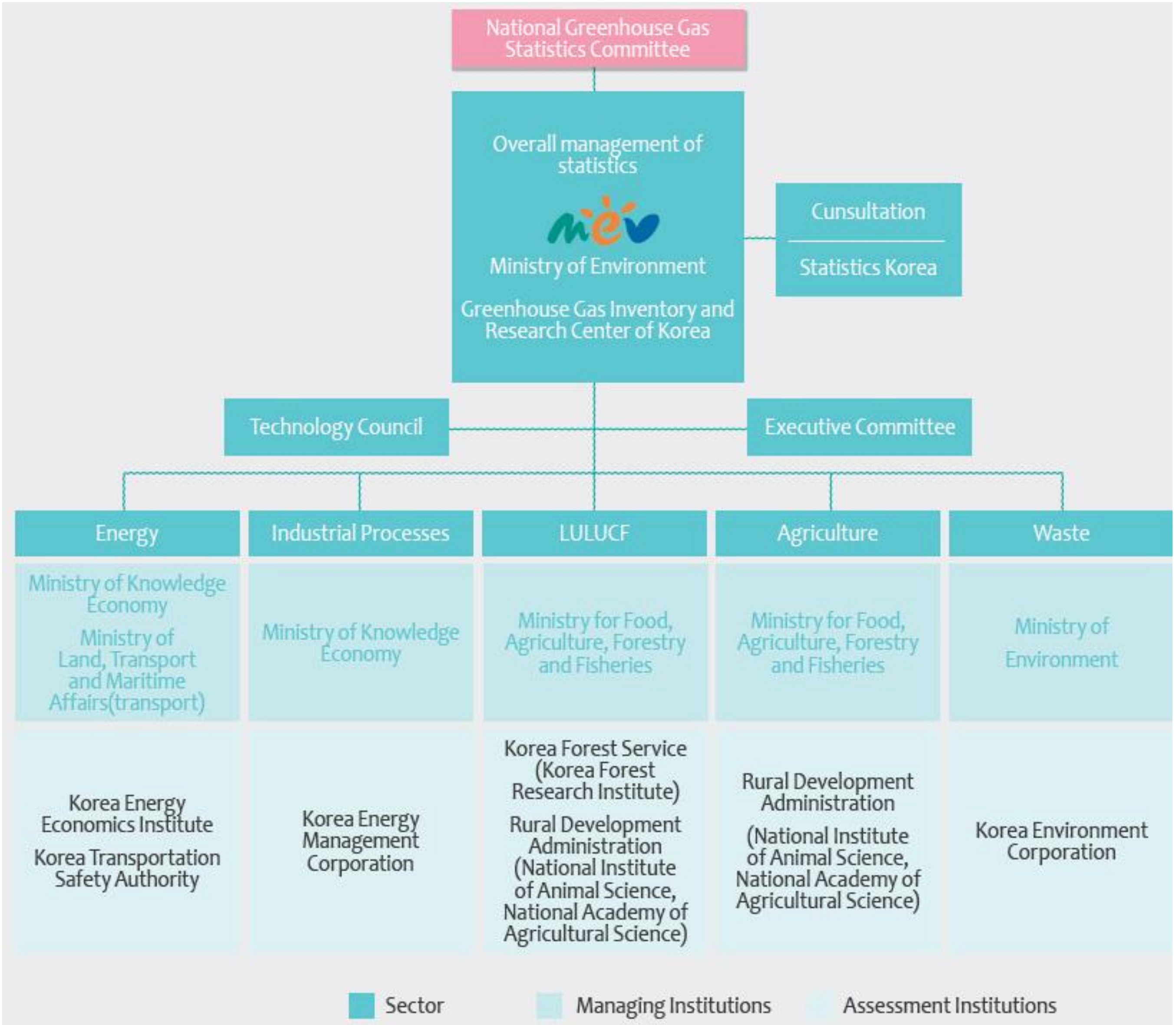


Figure 1.1: National GHG inventory system of Korea

b) Japan:

- Ministry of Environment is the body assigned by the Government of Japan to chair, organize the GHG inventories.

- Greenhouse Gas Inventory Office of Japan (GIO) under Ministry of Environment is the agency responsible for implementation of activities of GHG inventories.

- To support the deployment of GHG inventories, Japan established the Committee for the Greenhouse Gas Emissions Estimation Methods including representatives from the relevant Ministries: Environment; Economy, Commerce and Industry; Agriculture, Forestry and Fisheries; Traffic; Land; Health, Labor and Welfare; Finance; Information and Communication and some scientists have experience on GHG inventory

- The function and task of the Committee are to consult the Ministry of Environment on the using methodologies and evaluate the results of the GHG inventories.

- Every year, the Ministry of Environment of Japan sends a official letter informing relevant Ministries and agencies about the GHG inventory plan for the selected base year. On the basis of the request of the Ministry of Environment of Japan, the relevant Ministries and agencies shall provide their activity data and specialized information to GIO.

- After receiving the relevant activity data and information, the GIO conducts GHG inventory using the IPCC guidelines with methodologies have been approved by the Commission; develops annual national reports on GHG emissions/removals and sends the reports to the UNFCCC's Secretariat.

- All of the activity data and GHG inventory results are archived by GIO

- The implementation of Quality Assurance (QA) activities are carried out by the GHG Inventory Quality Assurance Working Group, which composed of experts not directly involved in the GHG inventory process, after the national GHG inventory reports have been sent to the UNFCCC's Secretariat.

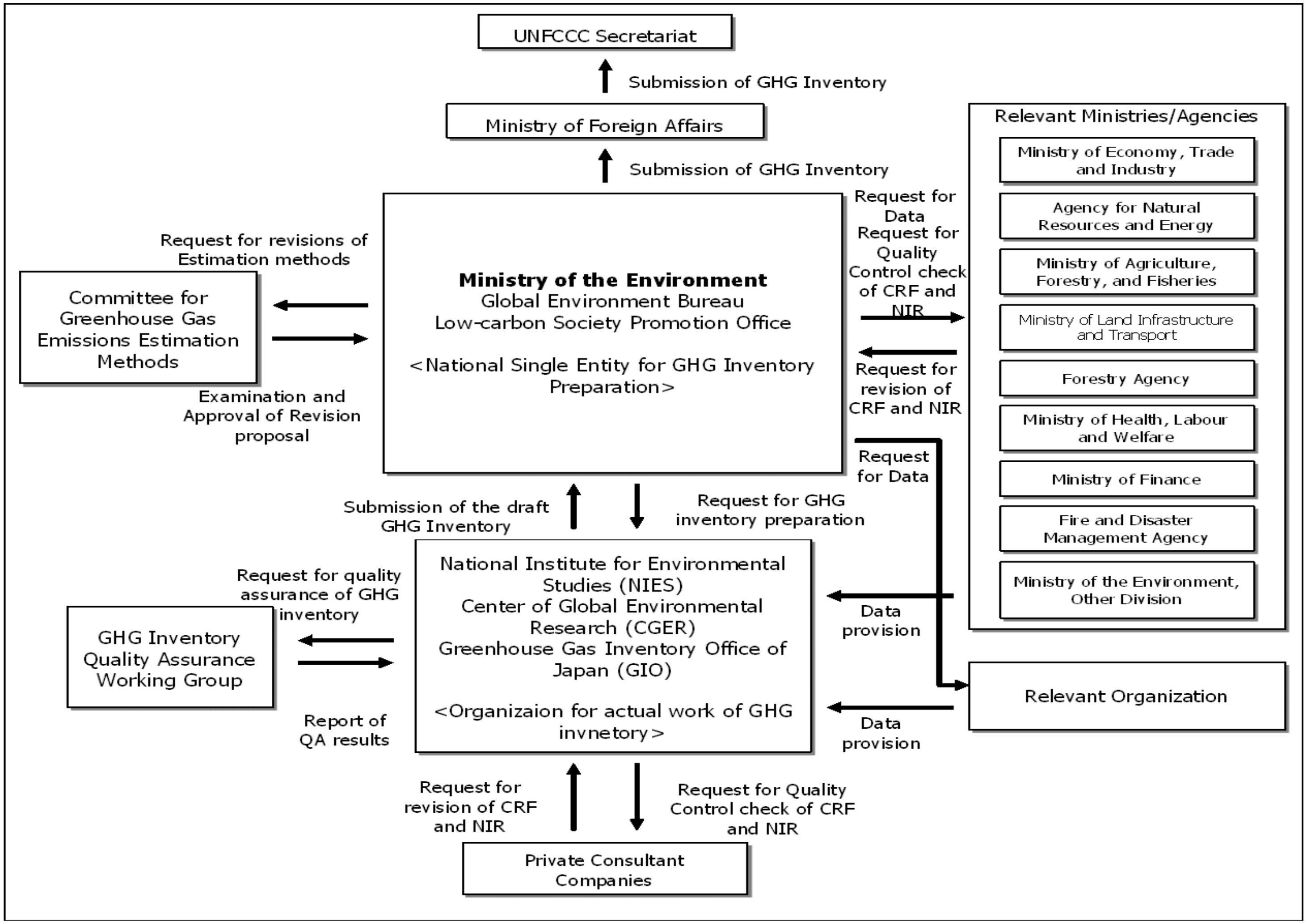


Figure 1.2. National GHG inventory system of Japan [1]

[1] Source: Japan GHG inventory report 2012

c) United Kingdom (UK):

- The UK Department of Energy and Climate Change (DECC) has responsible for organizing the GHG inventories.

- The Ricardo-AEA company is signed five-year authorized contract with DECC to:

+ Plan

+ Collect and process operational data

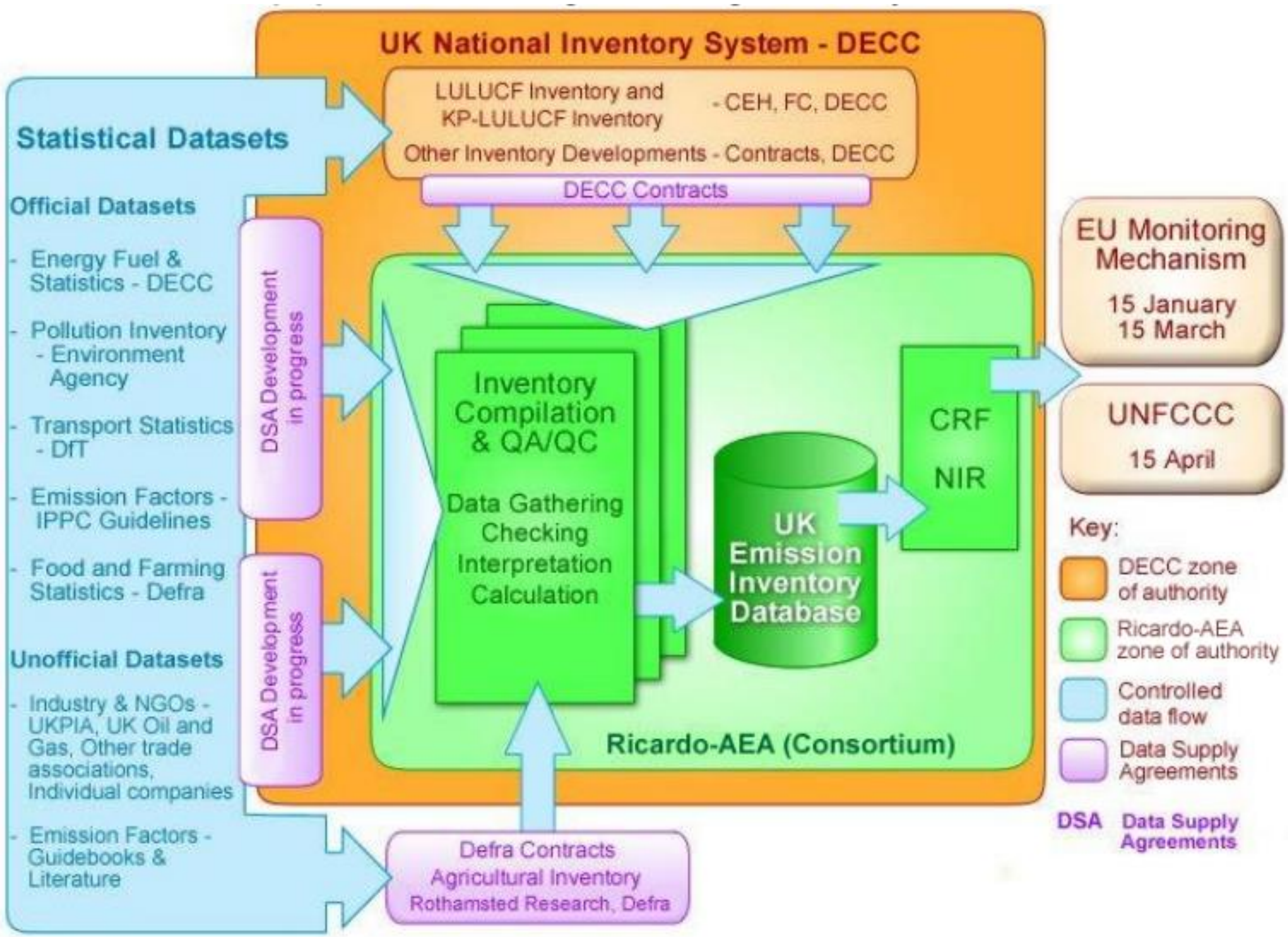
+ QA/QC

+ Coordinate to implement GHG inventory

+ Develop GHG inventory reports.

- Government agencies and organizations have responsibilities for providing activity data for Ricardo-AEA to synthesize and prepare for the periodic GHG inventories.

- The DECC approves the GHG inventory reports developed by Ricardo-AEA and sends them to the UNFCCC's Secretariat.



Hình 1.3. National GHG inventory system of UK[2]

[2] Source: UK GHG inventory report, 1990-2012, 2014

d) Thailand:

- The Ministry of Natural Resources and Environment of Thailand is assigned to be the focal point of the Government to chair, organize the GHG inventories.

- To carry out GHG inventory following IPCC's guidelines, GHG inventory working groups including relevant experts, scientists have been established.

+ Thailand GHG management organization (TGO) under the Ministry of Natural Resources and Environment of Thailand conducts GHG inventories and QC work while QA work is carried out by a group of experts not participating in the GHG inventory process.

+ The Ministries, agencies and organizations involved in the GHG inventory system including Ministry of Energy; Ministry of Industry; Ministry of Agriculture; Royal Forest Department, Pollution Management Department, etc. provide activity data and related information in their field of management to TGO for the implementation of the GHG inventory.

- TGO prepares GHG inventory report and sends to the Office of Planning, Policy, Natural Resources and Environment under the Ministry of Natural Resources and Environment for GC and approval before submitting to the UNFCCC's Secretariat.

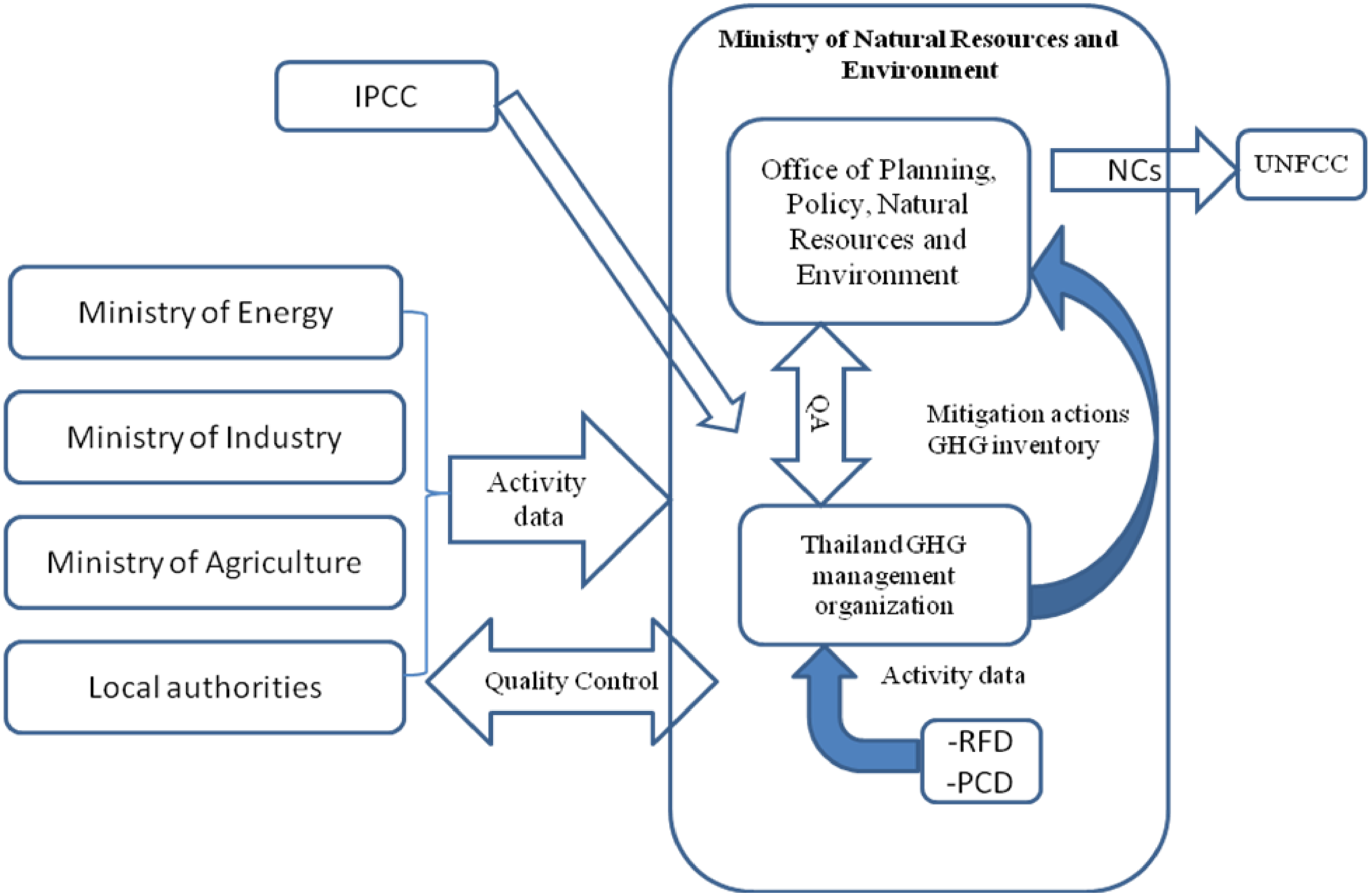


Figure 1.4. National GHG inventory system of Thailand[3]

[3] Source: Thailand's National GHG inventory report 2012

1.2. Country circumstance

1.2.1. UNFCCC and KP participation

Vietnam ratified the UNFCCC on November 16, 1994, the KP on September 25, 2002 and the Doha Amendment on June 22, 2015. As a Party of the UNFCCC and the KP, Vietnam is obligated to develop and submit NCs and BURs including the GHG inventory results to the UNFCCC's Secretariat periodically.

1.2.2. GHG inventory

1.2.2.1. GHG inventory task

As stipulated in Article 41-GHG emissions management of Vietnam's Law on Environmental Protection in 2014, the Ministry of Natural Resources and Environment (MONRE) was assigned to develop the national system of GHG inventory and coordinate with relevant Ministries and agencies to carry out GHG inventories.

MONRE has been assigned to be National focal point for implementing the UNFCCC and KP. MONRE is also the Standing body of the National Committee for Climate Change, which is assigned to lead the development of the National Reports to the UNFCCC's Secretariat and to monitor and inventory GHG emissions. Functions and tasks related to the GHG inventory of MONRE are briefly prescribed as follows:

- Decree No.25/2008/NĐ-CP dated March 4, 2008, Decree No.19/2010/NĐ-CP dated March 5, 2010, Decree No.89/2010/NĐ-CP dated 16 August 2010 and Decree No.21/2013/NĐ-CP dated March 4, 2013 of the Government regulating the functions, tasks, jurisdictions and organizational structure of MONRE; Decision No.47/2007/QĐ-TTg dated April 06, 2007 of the Prime Minister approving the plan for the implementation of the KP; Decision No.2139/QĐ-TTg dated December 05, 2011 of Prime Minister approving the National Strategy on Climate Change; Decision No.1393/QĐ-TTg dated September 25, 2012 of Prime Minister approving the National Green Growth Strategy; Decision No.1775/QĐ-TTg dated November 21, 2012 of the Prime Minister approving the Plan on GHG emission management; Management of carbon trading activities to the world market;

- Decision No.43/2010/QĐ-TTg dated June 02, 2010 of the Prime Minister issuing the National Statistical Indicator System (NSIS) and Circular No. 02/2011/TT-BKHDT dated January 10, 2011 of the Ministry of Planning and Investment regulating the content of the NSIS; lists and contents of the Statistical indicator system at provincial, district and commune levels.

MONRE has assigned the Department of Meteorology, Hydrology and Climate Change (DMHCC) to lead, coordinate with agencies and organizations internal and external MONRE to develop National Reports with the content on the GHG inventory results of selected base years.

The Ministry of Industry and Trade, the Ministry of Agriculture and Rural Development, the Ministry of Transportation, the Ministry of Construction, the Ministry of Planning and Investment (General Statistics Office) have directly involved in the GHG inventory activities. However, currently the Government Decrees regulating the functions, tasks, powers and organizational structure of these Ministries have not yet mentioned the tasks and responsibilities to join and cooperate with the MONRE to implement the periodical GHG inventories in their fields of management.

1.2.2.2. GHG inventory organization in recent years

- MONRE, in collaboration with Ministries and agencies developed NCs, BURs including the content GHG inventory and sent them to UNFCCC's Secretariat on behalf of Government of Vietnam.

- The NCs, BURs including the content GHG inventory was developed under the direction and supervision of the National Steering Committee for the implementation of UNFCCC and KP. This Committee is chaired by MONRE's leaders, with the participation of Ministry of Foreign Affairs (MOFA), Ministry of Planning and Investment (MPI), Ministry of Finance (MOF), Ministry of Science and Technology (MOST), Ministry of Industry and Trade (MOIT), Ministry of Agriculture and Rural Development (MARD), Ministry of Transportation (MOT), Ministry of Construction (MOC), Ministry of Information and Communication (MIC).

- DMHCC has been assigned to lead and coordinate with other agencies and units inside and outside MONRE to implement the GHG inventory. The working groups on GHG inventory, including experts from relevant Ministries, agencies and organizations have been established.

DMHCC has leaded, coordinated and supervised the overall implementation of the GHG inventories for base years 2005 and 2010 under the Project "Capacity building on Greenhouse Gas Inventory in Vietnam", funded by Japan International Cooperation Agency (JICA) from 2012 to 2014. MONRE internal agencies participated in the Project were as follows: General Department of Environment; Institute of Meteorology, Hydrology and Climate Change; Institute for Strategy and Policy on Natural Resources and Environment; experts from relevant Ministries, agencies, and some related organizations. The 2005 and 2010 GHG inventory reports were reviewed by the Technology and Science Council at ministerial level, which have been formed from representatives and experts from the relevant Ministries for appraisal and approval.

1.2.2.4. Results of GHG inventories

MONRE leaded and coordinated with relevant Ministries, agencies and organizations to conduct the GHG inventories for the base years 1994, 2000, 2005 and 2010. The results of GHG inventories for base years 1994, 2000 and 2010 were reported in the first NC in 2003 (used base year 1994), the second NC in 2010 (used base year 2000) and the first BUR in 2014 (used base year 2010). The GHG inventories were carried out in 5 sectors: Energy, Industrial processes; Agriculture; Land use, land use change and forestry (LULUCF); Waste as well as GHG emission projections for 2020, 2030 in 04 sectors: energy, agriculture, LULUCF, waste using IPCC guidelines

In the period of 1994-2010, total GHG emissions in Vietnam (including LULUCF) increased rapidly from 103.8 million tons of CO_2 equivalent to 246.8 million tons of CO_2 equivalents, of which the energy sector increased the fastest from 25.6 million tons of CO_2 equivalent to 141.1 million tons of CO_2 equivalent and also the highest emitting sector in 2010

Total GHG emissions from energy, agricultural, LULUCF and waste sectors are projected at 466 million tons of CO_2 equivalent in 2020, increasing to 760.5 tons of CO_2 equivalent in 2030. Energy is projected to remain the largest source of GHG emissions.

Table 1.1. Total GHG emissions in 1994, 2000 and 2010

Unit: million tonnes CO_2eq

Sector	1994	2000	2010
Energy	25.6	52.8	141.1
Industrial processes	3.8	10.0	21.2
Agriculture	52.4	65.1	88.3
LULUCF	19.4	15.1	-19.2
Waste	2.6	7.9	15.4
Total	**103.8**	**150.9**	**246.8**

o *Sources: The Initial BUR, MONRE, 2014*

Table 1.2. GHG emission projections for 2020 and 2030

Year / Sector	2010 (mil. CO_2 eq)	2020 (mil. CO_2 eq)	2030 (mil. CO_2 eq)
Energy	141.1	381.1	648.5
Industrial processes	88.3	100.8	109.3
Agriculture	-19.2	-42.5	-45.3
LULUCF	15.4	26.6	48.0
Total	**225.6**	**466.0**	**760.5**

Sources: The Initial BUR, MONRE, 2014

Based on the results of the GHG inventories for the base year of 2010, 28 GHG emission categories were analyzed without LULUCF and 33 categories of GHG emissions with LULUCF

1.2.2.3. National GHG inventory system in Vietnam

On December 22, 2015, the Prime Minister issued Decision No.2359/QĐ-TTg approving the National GHG Inventory System (NGIS) in Vietnam

NGIS are including:

a) MONRE is the focal point of NGIS, has responsibilities to:

- Lead and coordinate with relevant Ministries and organizations to carry out GHG inventories under the development of the National Reports on Climate Change:

+ Develop the plan to carry out GHG inventory every two years, including QA and QC;

+ Select the using methodologies, emission factors and develop relevant guidelines for GHG inventory in country;

+ Update and finalize forms for collecting activity data, related information for GHG inventory;

+ Coordinate with MPI to organize the collection of activity data and related information (in accordance with the Annexes of this Decision);

+ Provide MPI activity data and related information (in accordance with Annex VII of this Decision) within its field of management;

+ Organize to carry out GHG inventories, QC, QA, develop technical reports on GHG inventories;

+ Organize to assess technical reports on GHG inventories for the development of national reports on climate change.

- Organize the implementation, ensure the operation of the Steering Committee for Implementation of UNFCCC and KP in the evaluation and approval processes of national reports on climate change including the results of periodic GHG inventories;

- Submit to the Prime Minister, Chairman of the National Committee on Climate Change for approval and permission to submit the National Climate Change Reports to the UNFCCC's Secretariat;

- Send results of every two year GHG inventory to MPI for statistics, archiving, disseminating and using according to regulations.

b) Coordinating agencies in the NGIS

- MPI:

+ Coordinate with the MONRE in guiding relevant Ministries, agencies, provincial/municipal People's Committees and concerned enterprises to supply activity data and information (in accordance with the Annexes of this Decision) for carrying out the GHG inventories every two year as required;

+ Aggregate, provide activity data and information to the Focal point of NGIS, which performs biennial greenhouse gas inventories;

+ Manage, archive, provide and use activity data, related information and GHG inventory results according to regulations.

- MOIT:

+ Coordinate with the MPI to organize the collection and provision of activity data and related information (in accordance with Annexes I, IV and IX of this Decision) for the inventories;

+ Collaborate with the MONRE to conduct GHG inventory every two years;

+ Develop plans and organize for capacity building on inventory and monitoring GHG emissions;

+ Manage the process of collecting, aggregating activity data, relevant information and participate in QC procedure.

- MOT:

+ Coordinate with the MPI to organize the collection and provision of activity data and related information (in accordance with Annex II of this Decision) for the inventories;

+ Collaborate with the MONRE to conduct GHG inventory every two years;

+ Develop plans and organize for capacity building on inventory and monitoring GHG emissions;

+ Manage the process of collecting, aggregating activity data, relevant information and participate in QC procedure.

- MARD:

+ Coordinate with the MPI to organize the collection and provision of activity data and related information (in accordance with Annexes V and VI of this Decision) for the inventories;

+ Collaborate with the MONRE to conduct GHG inventory every two years;

+ Develop plans and organize for capacity building on inventory and monitoring GHG emissions;

+ Manage the process of collecting, aggregating activity data, relevant information and participate in QC procedure.

- MOC:

+ Coordinate with the MPI to organize the collection and provision of activity data and related information (in accordance with Annex III of this Decision) for the inventories;

+ Collaborate with the MONRE to conduct GHG inventory every two years;

+ Develop plans and organize for capacity building on inventory and monitoring GHG emissions;

+ Manage the process of collecting, aggregating activity data, relevant information and participate in QC procedure.

- MOF:

Allocate budgets for carrying out the GHG inventory every two years in accordance with the Law of State Budget and current guiding documents..

- Provincial/municipal People's Committees:

+ Coordinate with the MPI to organize the collection and provision of activity data and related information (in accordance with Annex VIII of this Decision) for the inventories;

+ Develop plans and organize for capacity building on inventory and monitoring GHG emissions;

+ Manage the process of collecting, aggregating activity data, relevant information and participate in QC procedure.

- Relevant organizations and enterprises:

Provide activity data and related information on organizations and enterprises'activities under the guidance of the MPI.

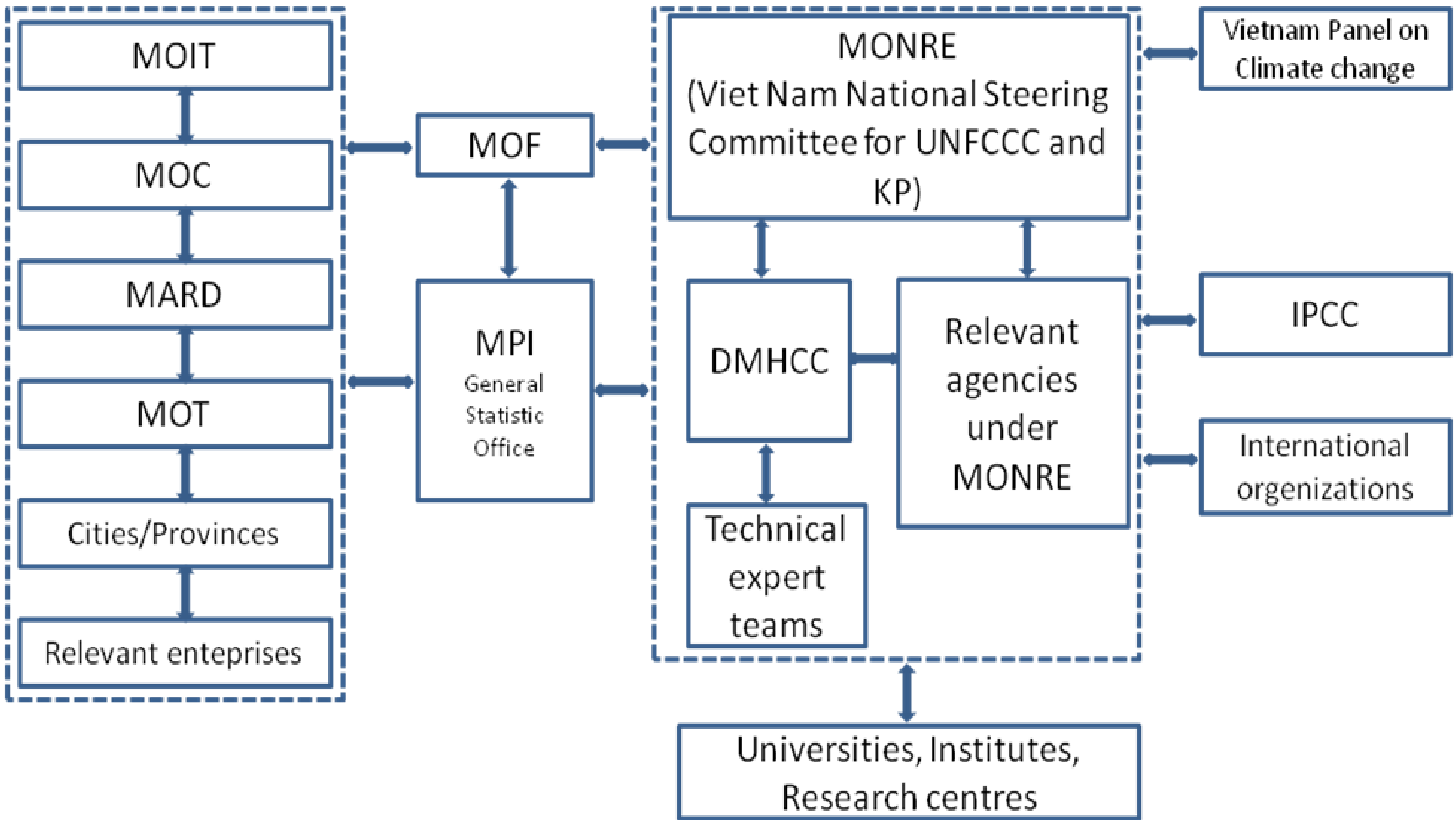


Figure 1.5. National GHG inventory system of Vietnam

II. Implementation of GHG inventory

2.1. Process, method, data source

2.1.1. GHG inventory process

The preparation of the national GHG inventory consists of 6 steps as following:

Step 1: Develop a work plan for national GHG inventory;

Step 2: Collect, analyze, check GHG inventory data and reduce uncertainty; determine the appropriate methods and emission factors (EFs) to be used for each source;

Step 3: Prepare pre-estimates and draft reports;

Step 4: Assess the key emissions sources and uncertainties;

Step 5: Organize a final workshop to introduce the results of national GHG inventory for reviewing and collecting comments;

Step 6: Submit the greenhouse gas inventory report to the UNFCCC's Secretariat.

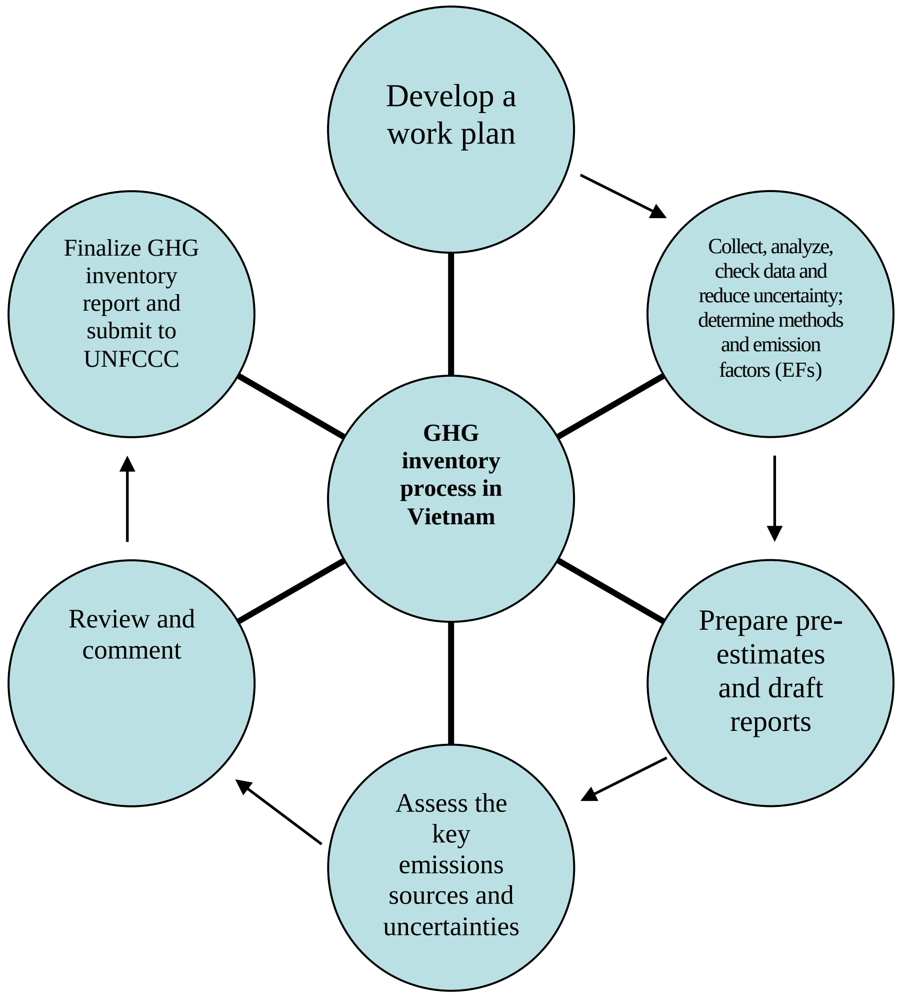


Figure 2.1. GHG inventory process

2.1.2. Identify methodology and date source

GHG inventories in Vietnam has been used methods which conform to the international guidelines, namely, the *Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories* (hereinafter referred to as the Revised 1996 IPCC Guidelines), the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (hereinafter referred to as the GPG 2000) and the *IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry* (hereinafter referred to as the GPG-LULUCF)

Mostly national statistics data and official data provided by government institutions were used as activity data. For most categories, the project team used the default values provided by the IPCC guidelines described above. Country specific emission factors were used for categories which research results were available. A summary of the methods and data used for each sector is presented in the table below.

Table 2.1. Overview of the methods and data sources used

Sector	Method	Data source		
		Activity data	Emission factor	Other parameters
Energy	Tier 1	National statistics (the national Energy balance)	IPCC default emission factors	Country specific calorific values for solid fuels
Industrial Processes	Tier 1	National statistics	IPCC default emission factors	None
Agriculture	Mostly Tier 1, some Tier 2	National statistics, data provided from industry/ government institutions	Mostly IPCC default emission factors, some country specific data	IPCC default values
LULUCF	Combination of Tier 1 and Tier 2	National statistics, data from government and provinces, data from research papers	IPCC default emission factors, data from research papers	Data from research papers also used
Waste	Mostly Tier 1, some Tier 2	National statistics, data from government and provinces, data from research papers	Mostly IPCC default emission factors, data from research papers also used	Data from research papers also used

2.2. GHG inventory for energy sector

2.2.1. Overview

2.2.1.1. GHG emissions

GHG emissions are estimated in two subsectors, namely Fuel Combustion (CO_2, CH_4, N_2O), Fugitive Emissions (CO_2, CH_4, N_2O)..

Table 2.2. GHG emissions from Energy sector

GHG emission categories	**2013**			
	CO_2	**CH_4**	**N_2O**	**Total ($GgCO_2eq$)**
1 Energy Total				
1A Fuel Combustion				
1A1 Energy Industries				
1A1a Electricity production				
1A1b Oil refinery				
1A2 Manufacturing Industries and Construction				
1A2a Iron and steel				
1A2b Chemical and petrolium				

1A2c Cement and building materials				
1A2d Food and tobacco				
1A2e Textiles and leather				
1A2f Paper, pulp and printing				
1A2g Other industries				
1A3 Transportation				
1A3a Aviation				
1A3b Road				
1A3c Railway				
1A3d Waterway				
1A4 Other categories				
1A4a Commercial/Services				
1A4b Residential				
1A4c Agriculture, forestry and fisheries				
1A Non-Energy Use				
1B Fugitive emissions				
1B1 Solid fuels				
1B1a Underground coal mining				
1B1b Surface coal mining				
1B2 Oil and Natural Gas				
1B2a Oil				
1B2b Natural Gas				

2.2.1.2. Data source

Data for GHG inventory of the energy sector will be collected from two main sources:

- Energy Balance Table

- Energy statistics have been compiled by the International Energy Agency and some data collected from energy authorities.

2.2.2. GHG emission estimation

2.2.2.1. Fual combustion – (1A)

CO_2 emissions result from the oxidation of the carbon in fuels during combustion. In perfect combustion conditions, the total carbon content of fuels would be converted to CO_2. CH_4 is produced in small quantities from fuel combustion due to incomplete combustion of hydrocarbons process. The production of CH_4 is dependent on the temperature in the boiler/kiln/stove. N_2O is formed through the reaction of NO, which is formed through combustion, with nitrogen-containing volatile components in fuels. It has been determined that lower combustion temperatures cause higher N_2O emission.

a) Energy industries (CO_2, CH_4, N_2O) – (1A1)

Energy Industries include activities such as energy production and transformation, including electricity generation, petroleum refining, gas processing plant, etc.

For CO_2 emission: According to the GPG decision tree, Vietnam should apply the tier 2 approach of using a detailed plant based and/or technology-based data. However, because there is no fuel combustion data by plant or source category in Vietnam, the tier 1 method of collecting actual consumption statistics by fuel type and economic sub-sector was applied. Then, total CO_2 emissions are summed across all fuels and all sub-sectors.

CO_2 emissions = ∑[(Fuel consumption x Carbon Emission factor) – Carbon stored] x Fraction Oxidised x 44/12 (II-1)

Carbon stored (GgC) = Non-Energy Use (unit) x Conversion factor (TJ/unit) x Carbon Emission Factor (tC/TJ) x Fraction Carbon Stored (II-2)

For Non- CO_2 emission: Because direct emissions measurements are not available and fuel consumption data are not available for technology types in Vietnam, tier 1 method was used to calculate non-CO_2 emissions.

II.1.1.1.1 Non-CO2 emissions = ∑(Emissions Factorab x fuel Consumptionab)

II.1.1.1.2 a = fuel type, b = sector activity (II-3)

II.1.1.1.3

Activity data

The data to be collected are summarized in the table below.

Table 2.3. Fuel consumption in energy industries

Source	**Anthracite (1000 tonnes)**	**Bituminous (1000 tonnes)**	**Crude oil (1000 tonnes)**	**DO (1000 tonnes)**	**FO (1000 tonnes)**	**Natural gas ($10^6 m^3$)**	**Biomass** (Million kcal)
- **Electricity**							

production							
- Oil refinery							

Emission factor

Since Vietnam has not yet had country-specific EF for fuel combustion, the default emission factor in the revised 1996 IPCC guideline was used to calculate emissions. Country-specific calorific values for coal products were developed in the JICA funded research in 2013. The results of this research was used in the inventory for anthracite and bituminous coal.

Table 2.4. EFs, calorific values and each fraction for Energy Industry

Fuel	**CO_2 EF (tC/TJ)**	**CH_4 EF ($kgCH_4$/TJ)**	**N_2O EF (kgN_2O/TJ)**	**Calorific value (kcal/unit)**	**Unit**	**Fraction Carbon stored**	**Fraction oxidized**
Anthracite	26.8	1	1.4	5,043	kg	-	0.98
Bituminous	25.8	1	1.4	5,805	kg	-	0.98
Crude Oil	20.0	3	0.6	10,180	kg	-	0.99
DO	20.2	3	0.6	10,150	kg	0.50	0.99
FO	21.1	3	0.6	9,910	kg	-	0.99
Gas (including associated gas)	15.3	1	0.1	9,000	10^3m^3	0.33	0.995
Biomass	-	30	4	3,302	TWE	-	-

(TWE : Ton of Wood Equivalent)

[Data source: Energy Balance Table in 2010, Institute of Energy, Revised 1996 IPCC Guideline, Calorific values of coals in 2010 Vietnam, Institute of Energy Science]

b) Manufacturing industries and Construction (CO_2, CH_4, N_2O) – 1A2

Manufacturing industries and construction include activities such as Iron and steel; chemical and petroleum; cement and building materials; foods and tobacco; textile and Leather; Paper, pulp and printing and other activities (mining, non-ferrous metals, transport equipment, machinery, wood and wood products, construction, not elsewhere specified activities). Input fuel for these sectors is coal, petroleum product, natural gas and non-commercial energy. GHG emissions from this catergory mainly come from the combustion of fuel during the production process.

Methodology

For CO_2 emission: According to the GPG decision tree, Vietnam should apply the tier 2 approach of using detailed plant based and/or technology-based data. However, because there is no fuel combustion data by plant or source category in Vietnam, the tier 1 method of collecting actual consumption statistics by fuel type and economic sub-sector was applied.

CO_2 emissions = ∑[(Fuel consumption x Carbon Emission factor) – Carbon stored] x Fraction Oxidised x 44/12 (II-4)

Carbon stored (GgC) = Non-Energy Use (unit) x Conversion factor (TJ/unit) x Carbon Emission Factor (tC/TJ) x Fraction Carbon Stored (II-5)

However, in current energy balance table of Vietnam, non-energy use by sub-category does not collect. The amounts of Carbon stored in sub-category have been reported as zero. However, non-energy use has been collected as one of the category of the energy balance table of Vietnam. Therefore, estimating carbon stored in products can be calculated for this category.

For Non- CO_2 emission: Because direct emissions measurements are not available and fuel consumption data are not available for technology types in Vietnam, tier 1 method was used to calculate non-CO_2 emission.

Non-CO_2 emissions = ∑(Emissions $Factor_{ab}$ x fuel $Consumption_{ab}$) (II-6)

a = fuel type, b = sector activity

Activity data

Table 2.5. Fuel consumption for Manufacturing industries and Construction

Category	Anthracite	Bituminous	Sub-bituminous	Coke	Peat	Kerosene	DO	FO	LPG	Natural gas	Biomass (Mil. kcal)
	(10^3 tonnes)	(10^3 tonnes)	(10^3 tonnes)	(10^3 tonnes)	(10^3 tonnes)	(10^3 tonnes)	(10^3 tonnes)	(10^3 tonnes)	(10^3 tonnes)	(10^6 m^3)	
Iron and steel											
Chemical and Petroleum											
Cement & building and Materials											
Foods											
Textile and Leather											
Paper and printing											
Other											

Emission factor

The default EFs in the IPCC guidelines was used to calculate emissions, because Vietnam does not have country- specific carbon content and EF for fuel consumption.

Table 2.6. Emission factor, Calorific value and each fraction for Manufacturing industries and Construction

Category	**CO_2 EF (tC/TJ)**	**CH_4 EF ($kgCH_4$/TJ)**	**N_2O EF (kgN_2O/TJ)**	**Calorific value (kcal/unit)**	**Unit**	**Fraction Carbon stored**	**Fraction oxidized**
Anthracite	26.8	10	1.4	5,043	kg	-	0.98
Bituminous	25.8	10	1.4	5,805	kg	-	0.98
Coke	29.5	10	1.4	6,508	kg	-	0.98
Peat	28.9	2	1.5	4,536	kg	-	0.99
Kerosene	19.6	2	0.6	10,320	kg	-	0.99
DO	20.2	2	0.6	10,150	kg	0.50	0.99
FO	21.1	2	0.6	9,910	kg	-	0.99
LPG	17.2	2	0.6	10,880	kg	0.80	0.99
Natural gas (including associated gas)	15.3	5	0.1	9,000	10^3 m^3	-	0.995
Biomass	-	30	4	3,302	TWE	-	-

(TWE : Ton of Wood Equivalent)

[Data source: Energy Balance Table in 2010, Institute of Energy, Revised 1996 IPCC Guideline, 2006 IPCC Guideline, Calorific values of coals in 2010 Vietnam, Institute of Energy Science]

c) Transport (CO_2, CH_4, N_2O) – (1A3)

Transport includes the following activities:

- Aircraft for international civil aviation and domestic air transport;
- Road Transportation (cars, light duty trucks, heavy duty trucks and buses, motorcycles, etc.);
- Railways;
- Water-borne navigation for domestic and international; and
- Other transportation activities, such as gas pipeline transport.

International Bunker Fuels, which include navigation and civil aviation fuel emissions from international transport activities (i.e. bunker fuels), should be reported separately and excluded from the national totals. International bunker fuels in the aircraft were divided into domestic and international according the fuel consumption of aircraft in Vietnam. The energy consumption data for water navigation are limited or not available in Vietnam.

Methodology

According to the GPG decision tree, the method applied is as follows:

- Aircraft: Data on individual aircraft LTOs are not available in Vietnam and LTO data are not available at an aggregate level so the tier 1 method was used.

- Road vehicles: In Vietnam, road transport fuel combustion data are available but country-specific emission factors are not available so tier 1 method was used to calculate CO2 emissions. For non-CO2 emission, tier 1 method is also used to calculation because there is not a well-documented national method and fuel data are not available by vehicle type.

- Railways: Locomotive- specific activity data and emission factor and fuel statistics by locomotive type are not available in Vietnam. So the tier 1 method was used to estimate.

- Water-borne navigation: Vietnam has only fuel consumption data available by fuel type for this sub-sector. National carbon content data and CH4 and N2O emission factors are not available in Vietnam so the tier 1 method was used

For CO_2 emissions:

CO_2 emissions = ∑[(Fuel consumption x Carbon Emission factor) – Carbon stored] x Fraction Oxidised x 44/12 (II-7)

For Non- CO_2 emissions:

Non-CO_2 emissions = ∑(Emissions $Factor_{ab}$ x fuel $Consumption_{ab}$) (II-8)
a = fuel type, b = sector activity

Carbon stored (GgC) = Non-Energy Use (unit) x Conversion factor (TJ/unit) x Carbon Emission Factor (tC/TJ) x Fraction Carbon Stored (II-9)

Activity data

Table 2.7. Fuel consumption for Transport

Category (10³ tonnes)	Mogas	Jet fuel		**DO**	**FO**
		Domestic	**International**		
Airway					
Road					
Rail					
River and Seaway					
Other					

Emission factor

The default emission factor in the revised 1996 IPCC guideline was used to calculate emissions, because Vietnam has not country- specific carbon content and emissions factor for fuel consumption.

Table 2.8. Emission factor, Calorific value and each fraction for Transport

Fuel	**CO_2 EF (tC/TJ)**	**CH_4 EF ($kgCH_4$/TJ)**	**N_2O EF (kgN_2O/TJ)**	**Calorific value (kcal/unit)**	**Unit**	**Fraction Carbon stored**	**Fraction oxidized**
Mogas	18.9	20 (road), 5 (river and seaway)	0.6	10,500	kg	-	0.99
Jet fuel	19.5	0.5	2	10,320	kg	-	0.99
DO	20.2	5	0.6	10,150	kg	0.50	0.99
FO	21.1	5	0.6	9,910	kg	-	0.99

Data source: Energy Balance table, Institute of Energy, Revised 1996 IPCC Guideline.

d) Commercial / Institutional (CO_2, CH_4, N_2O) – 1A4a

This category covers GHG emissions from combustion activities in the commercial and institutional sectors, which comprise, for example, wholesale and retail businesses; health institutions; social and educational institutions; state and local government institutions (e.g., military installations, prisons, office buildings).

Methodology

For CO_2 emission: According to the GPG decision tree, Vietnam should apply the tier 2 approach of using detailed technology-based data. However, because there is no fuel combustion data by plant or source category in Vietnam, the tier 1 method of collecting actual consumption statistics by fuel type and economic sub-sector was applied. Then, CO_2 emissions are summed across all fuels and all sub-sectors.

CO_2 emissions = ∑[(Fuel consumption x Carbon Emission factor) – Carbon stored] x Fraction Oxidised x 44/12 (II-10)

Carbon stored (GgC) = Non-Energy Use (unit) x Conversion factor (TJ/unit) x Carbon Emission Factor (tC/TJ) x Fraction Carbon Stored (II-11)

For Non- CO_2 emission: Because direct emissions measurements are not available and fuel consumption data are not available for technology types in Vietnam, tier 1 method was used to calculate non-CO_2 emission.

Non-CO2 emissions = ∑(Emissions Factorab x fuel Consumptionab) (II-12)

a = fuel type, b = sector activity

Activity data

Table 2.9. Fuel consumption for Commercial/Institutional

Category (10^3 tonnes)	**Anthracite**	**Kerosene**	**DO**	**FO**	**LPG**
Commercial and Institutional					

Emission factor

The default emission factor in the revised 1996 IPCC guideline was used to calculate emissions, because Vietnam has not country- specific carbon content and emissions factor for fuel consumption.

Table 2.10. Emission factor, Calorific value and each fraction for Commercial & Institutional

Fuel	CO_2 EF (tC/TJ)	CH_4 EF (kgCH_4/TJ)	N_2O EF (kgN_2O/TJ)	Calorific value (kcal/unit)	Unit	Fraction Carbon stored	Fraction oxidized
Anthracite	26.8	10	1.4	5,043	kg	-	0.98
Kerosine	19.6	10	0.6	10,320	kg	-	0.99
DO	20.2	10	0.6	10,150	kg	0.50	0.99
FO	21.1	10	0.6	9,910	kg	-	0.99
LPG	17.2	10	0.6	10,880	kg	0.80	0.99

[Data source: Energy Balance table in 2010, Institute of Energy, Revised 1996 IPCC Guideline, Calorific values of coals in 2010 of Vietnam, Institute of Energy Science]

đ) Residential (CO_2, CH_4, N_2O) – 1A4b

This category covers GHG emissions from combustion activities in residential, for example lighting, space heating and the other appliances used for daily life.

Methodology

<u>For CO_2 emission</u>: According to the GPG decision tree, Vietnam should apply the tier 2 approach of using detailed technology-based data. However, because there is no fuel combustion data by plant or source category in Vietnam, the tier 1 method of collecting actual consumption statistics by fuel type and economic sub-sector was applied. Then, CO_2 emissions are summed across all fuels and all sub-sectors.

CO_2 emissions = ∑[(Fuel consumption x Carbon Emission factor) – Carbon stored] x Fraction Oxidised x 44/12 (II-13)

Carbon stored (GgC) = Non-Energy Use (unit) x Conversion factor (TJ/unit) x Carbon Emission Factor (tC/TJ) x Fraction Carbon Stored (II-14)

For Non- CO_2 emission: Because direct emissions measurements are not available and fuel consumption data are not available for technology types in Vietnam, tier 1 method was used to calculate non-CO_2 emission.

Non-CO_2 emissions = $\sum$(Emissions Factor$_{ab}$ x fuel Consumption$_{ab}$) (II-15)
a = fuel type, b = sector activity

Activity data

Table 2.11. Fuel consumption for Residential

Category	Antracite (10^3 tonnes)	Kerosine (10^3 tonnes)	DO (10^3 tonnes)	FO (10^3 tonnes)	LPG (10^3 tonnes)	Biomass (Mil. kcal)
Residential						

Emission factor

The default emission factor in the revised 1996 IPCC guideline was used to calculate emissions, because Vietnam has not country- specific carbon content and emissions factor for fuel consumption.

Table 2.12. Emission factor, Calorific value and each fraction for Residential

Nhiên liệu	CO_2 EF (tC/TJ)	CH_4 EF ($kgCH_4$/TJ)	N_2O EF (kgN_2O/TJ)	Calorific value (kcal/unit)	Unit	Fraction Carbon stored	Fraction oxidized
Anthracite	26.8	300	1.4	5,043	kg	-	0.98
Kerosine	19.6	10	0.6	10,320	kg	-	0.99
DO	20.2	10	0.6	10,150	kg	0.50	0.99
FO	21.1	10	0.6	9,910	kg	-	0.99
LPG	17.2	10	0.6	10,880	kg	0.80	0.99
Biomass	-	300	4	3,302	TWE	-	-
Biogas	-	300	4	5,200	m^3	-	-

TWE : Ton of Wood Equivalent

(Data source: Energy Balance table, Institute of Energy, Revised 1996 IPCC Guideline, Biogas Program for the Animal Husbandry Sector of Vietnam, MARD, Calorific values of coals in 2010 of Vietnam, Institute of Energy Science)

e) Agriculture, Forestry and Fishing (CO_2, CH_4, N_2O) – 1A4c

This category covers GHG emissions from combustion activities from combustion activities in agriculture, forestry, fishing and fish farms for example processing industry of food, wood and aquaculture.

Methodology

For CO_2 emission:

According to the GPG decision tree, Vietnam should apply the tier 2 approach of using detailed technology-based data. However, because there is no fuel combustion data by plant or source category in Vietnam, the method of tier 1 collecting actual consumption statistics by fuel type and economic sub-sector was applied. Then, total CO_2 emissions are summed across all fuels and all sub-sectors.

CO_2 emissions = ∑[(Fuel consumption x Carbon Emission factor) – Carbon stored] x Fraction Oxidised x 44/12 (II-16)

Carbon stored (GgC) = Non-Energy Use (unit) x Conversion factor (TJ/unit) x Carbon Emission Factor (tC/TJ) x Fraction Carbon Stored (II-17)

For Non- CO_2 emission: Because direct emissions measurements are not available and fuel consumption data are not available for technology types in Vietnam, tier 1 method was used to calculate non-CO_2 emission.

Non-CO_2 emissions = ∑(Emissions $Factor_{ab}$ x fuel $Consumption_{ab}$) (II-18)
a = fuel type, b = sector activity

Activity data

Table 2.13. Fuel consumption for Agriculture, Forestry and Fishing

Category (10^3 tấn)	**Anthracite**	**Mogas**	**DO**	**FO**
Agriculture/Forestry/Fishing				

Emission factor

The default emission factor in the revised 1996 IPCC guideline was used to calculate emissions, because Vietnam has not country- specific carbon content and emissions factor for fuel consumption.

Table 2.14. Emission factor, Calorific value and each fraction for Agriculture, Forestry and Fishing

Fuel	CO_2 EF (tC/TJ)	CH_4 EF ($kgCH_4$/TJ)	N_2O EF (kgN_2O/TJ)	Calorific value (kcal/unit)	Unit	Fraction Carbon stored	Fraction oxidized
Anthracite	26.8	300	1.4	5,043	kg	-	0.98
Mogas	18.9	10	0.6	10,500	kg	-	0.99
DO	20.2	10	0.6	10,150	kg	0.50	0.99
FO	21.1	10	0.6	9,910	kg	-	0.99

(Data source: Energy Balance table in 2010, Institute of Energy, Revised 1996 IPCC Guideline, Calorific values of coals in 2010 of Vietnam, Institute of Energy Science)

g) Other (Non-Energy Use) (CO_2, CH_4, N_2O) – 1A

Non-energy is reported as fuel that is not used for energy production. It is the amount of fossil fuel carbon that is stored in non-energy products and the portion of this carbon expected to oxidise over a long time period. All fossil fuels are used for non-energy purposes to some degree.

Natural gas is used for ammonia production. LPGs are used for a number of purposes, including production of solvents and synthetic rubber. A wide variety of products is produced from oil refineries, including asphalt, naphtha's and lubricants. Two by-products of the cooking process, oils and tars, are used in the chemical industry.

Methodology

As with other categories, the method of tier1 was used to calculate.

For CO_2 emissions:

CO_2 emissions = ∑[(Fuel consumption x Carbon Emission factor) – Carbon stored] x Fraction Oxidised x 44/12 (II-19)

For Non- CO_2 emissions:

Non-CO_2 emissions = ∑(Emissions $Factor_{ab}$ x fuel $Consumption_{ab}$) (II-20) a = fuel type, b = sector activity

Carbon stored (GgC) = Non-Energy Use (unit) x Conversion factor (TJ/unit) x Carbon Emission Factor (tC/TJ) x Fraction Carbon Stored (II-21)

Activity data

Table 2.15. Fuel consumption for Non-Energy use

Category (10^3 tonnes)	Other Petroleum Products
Non-Energy use	

Emission factor

The default emission factor in the revised 1996 IPCC guideline was used to calculate emissions, because Vietnam has not country- specific carbon content and emissions factor for fuel consumption.

Table 2.16. Emission factor, Calorific value and each fraction for Non-Energy use

Fuel	CO_2 EF (tC/TJ)	CH_4 EF ($kgCH_4$/TJ)	N_2O EF (kgN_2O/TJ)	Calorific value (kcal/unit)	Unit	Fraction Carbon stored	Fraction oxidized
Other Petroleum Products	20.0	2	0.6	9.910	kg	0.75	0.99

(Data source: Energy Balance Table in 2010, Institute of Energy, Revised 1996 IPCC Guideline)

2.2.2.2. Fugitive emissions – (1B)

The geological processes of coal formation produce CH_4, and CO_2 may also be present in some coal seams. Fugitive emissions are broadly applied here to mean GHG emissions from oil and gas systems except contributions from fuel combustion. Oil and natural gas systems comprise all infrastructure required to produce, collect, process or refine and deliver natural gas and petroleum products to market.

Fugitive emissions are intentional or unintentional release of GHG that may occur during the extraction, processing and delivery of fossil fuels to the point of final use. Fugitive emissions are emitted from mining, processing, storage and transportation of coal, and oil and natural gas systems.

a) Coal Mining and Handling (CH_4) – 1B1

For Coal Mining and Handling, the geological process of coal formation also produces methane, some of which remains trapped in the coal seam until it is mined. Generally, deeper underground coal seams contain more in-situ methane than shallower surface seams. Consequently, the majority of emissions come from deep underground mines. In addition, GHG emissions come from the open-pit mines and post-mining activities.

Methodology

Following the GPG decision tree, the tier 1 approaches was used to estimate the CH_4 emissions.

Underground Mining:

CH_4 emissions(Gg) = CH_4 Emissions Factor (m^3 CH_4/tonne of coal mined) x Underground Coal Production (Mt) x Conversion Factor ($Gg/10^6$ m^3) (II-22)

Surface Mining:

CH_4 emissions(Gg) = CH_4 Emissions Factor (m^3 CH_4/tonne of coal mined) x Surface Coal Production (Mt) x Conversion Factor ($Gg/10^6$ m^3) (II-23)

Post - Mining:

Underground CH_4 Emission (Gg) = CH_4 Emissions Factor (m^3 CH_4/tonne of coal mined) x Underground Coal Production (Mt) x Conversion Factor ($Gg/10^6$ m^3) (II-24)

Surface CH_4 emissions(Gg) = CH_4 Emissions Factor (m^3 CH_4/tonne of coal mined) x Surface Coal Production (Mt) x Conversion Factor ($Gg/10^6$ m^3) (II-25)

Activity data

Coal production data:

Table 2.17. Indigenous production of Coal

	Underground coal (10^3 tấn)	**Surface coal (10^3 tấn)**
Indigenous production of Coal		

Emission factor

The default emission factor of the 1996 IPCC guideline was used except CH_4 emission factor underground mining. Emission factor for surface mining and post mining is presented in the IPCC as a range. Because of lack of expert opinion, the mean of the range was chosen as the emission factor.

<u>*CH_4 emission factor for underground mining:*</u> Emission factor is the country-specific emission factor Value = 3.8 m^3/tonne [*data source: No.7688/BCT-ATMT*] <u>*CH_4 emission factor for surface mining:*</u> Emission factors are in the range of: 0.3 to 2.0 m^3/tonne Average value = 1.15 m^3/tonne <u>*CH_4 emission factor for post-mining:*</u> Underground CH_4 emission factors are in the range of: 0.9 to 4.0 m^3/tonne Average value = 2.45 m^3/tonne Surface CH_4 emission factors are in the range of: 0 to 0.2 m^3/tonne Average value = 0.1 m^3/tonne

b) Oil and Natural Gas (CO_2, CH_4, N_2O) – 1B2

Methane emissions within oil and gas systems include emissions during normal operation, such as emissions associated with venting and flaring during oil and gas production, chronic leaks or discharges from process vents; emissions during repair and maintenance; and emissions during system upsets and accidents.

Methodology

<u>(a). Natural Gas Systems</u>: According to GPG decision tree, actual measurement and sufficient data, in Vietnam, are not available to estimate emission using rigorous emission source models. Moreover, detailed infrastructure data are also not available. So the method of tier 1 was used to calculate emissions.

<u>(b). Crude oil production and Transport</u>: In one hand, according to GPG decision tree, it is impossible to collect or estimate data for the vented, flared and utilized conserved and rejected volumes of associated and solution gas production. So the method of tier 1 was used to calculate emissions.

<u>c. Crude oil refining and Upgrading</u>: Dung Quat, the first oil refinery plant was put in to use in 2009.

Activity data

Table 2.18. Indigenous production of Oil and Gas

	Cruel oil (10^3m^3)	**Natural gas (10^6m^3)**
Indigenous production		

Table 2.19. Raw gas feed

	Year	**Associated gas ($10^6 m^3$)**
Gas processing Plant		

Emission factor

For emission factor in this category, since it don't have the country-specific emission factor in Vietnam and the default emission factor of each subcategory had not defined in 1996 IPCC guidelines, using the default emission factor of 2006 IPCC guidelines.

The default emission factor of the 2006 IPCC guidelines was used to calculate emissions. Emission factor default in IPCC 2006 is presented as a range. Because of lack of expert opinion, the mean of the range was chosen as the emission factor.

Table 2.20. Emission factor for oil and gas operations

Emission source	Unit of measure	CO_2 Emission Factor	Average value	CH_4 Emission Factor	Average value	N_2O Emission Factor	Average value
		($Gg/10^3m^3$)	($Gg/10^3m^3$)	(Gg CH_4)	(Gg CH_4)	(Gg N_2O)	(Gg N_2O)
Dầu							
Oil Production / Venting	$Gg/10^3m^3$ total oil production	1.8E-3 to 2.5E-3	0.00215	8.7 E-3 to 1.2 E-2	0.01035	NA	NA
Oil Production / Flaring	$Gg/10^3m^3$ total oil production	3.4E-2 to 4.7E-2	0.0405	2.1E-5 to 2.9E-5	0.000025	5.4E-7 to 7.4E-7	0.00000064
Oil Production / Fugitives	$Gg/10^3m^3$ total oil production	2.8E-4 to 4.7E-3	0.00249	2.2E-3 to 3.7E-2	0.0196	NA	NA
Natural gas							
Gas Processing / Raw CO_2 Venting	$Gg/10^6m^3$ total raw gas feed	4E-2 to 9.5E-2	0.0675	NA	NA	NA	NA
Gas Processing / Flaring	$Gg/10^6m^3$ total gas production	3E-3 to 4.1E-3	0.00355	2E-6 to 2.8E-6	0.0000024	3.3E-8 to 4.5E-8	0.000000039
Gas Production / Flaring	$Gg/10^6m^3$ total gas production	1.2E-3 to 1.6E-3	0.0014	7.6E-7 to 1E-6	0.00000088	2.1E-8 to 2.9E-8	0.000000025
Gas Production / Fugitives	$Gg/10^6m^3$ total gas production	1.4E-5 to 1.8E-4	0.000097	3.8E-4 to 2.4E-2	0.01219	NA	NA
Gas Processing / Fugitives	$Gg/10^6m^3$ raw gas feed	1.5E-4 to 3.5E-4	0.00025	4.8E-4 to 1.1E-3	0.00079	NA	NA

Data source: Table 4.2.5 , page 4.55 to page 4.62, IPCC 2006

2.3. GHG inventory for Industrial processes

2.3.1. Overview

GHG emissions in industrial processes sector have been estimated from industrial activities which are not related to energy sector. The main emission sources in this sector have been created by industrial production processes which are processes of converting chemically or physically raw materials. In the Industrial Processes sector, it should be only accounted for these source categories.

GHG emissions are estimated for four categories, namely Cement Production (CO_2), Lime Production (CO_2), Ammonia Production (CO_2) and Iron and Steel Production (CO_2).

Table 2.21. GHG emissions from the Industrial Processes sector

	CO_2	CH_4	N_2O	HFC, PFC, SF_6
Total emissions				
A. Mineral and building materials products				
1. Cement Production				
2. Lime Production				
3. Limestone and Dolomite Use				
4. Soda Ash Production and Use				
5. Asphalt Roofing				
6. Road Paving with Asphalt				
B. Chemical Industry				
1. Ammonia Production				
2. Nitric Acid Production				
3. Adipic Acid Production				
4. Carbide Production				
5. Road Paving with Asphalt				
C. Metal Production				
1. Iron and Steel Production				
2. Ferroalloys Production				
3. Aluminium Production				
4. SF_6 Used in Aluminium and				

Magnesium Foundries				
D. Other Production				
1. Pulp and Paper				
2. Food and Drink				
E. Production of Halocarbons and SF_6				
1. By-product Emissions				
Production of HCFC-22				
2. Fugitive Emissions				
F. Consumption of Halocarbons and SF_6				
1. Consumption of HFCs				

2.3.2. Estimation

2.3.2.1. Mineral and building materials Productions – (2A)

a) Cement Production (CO_2) – (2A1)

Cement is an important industry and has a long history of development in Vietnam. Vietnam Cement Corporation was established in 1994 basing on Vietnam Cement Company Union which was formed in 1979.

Emissions of CO_2 occur during the production of clinker that is an intermediate component in the cement manufacturing process. During the production of clinker, limestone, which is mainly (95%) calcium carbonate ($CaCO_3$), is heated (calcinized) to produce lime (CaO) and CO_2 as by-products.

The CaO then reacts with silica, aluminium, and iron oxides in the raw materials to make the clinker minerals (that are dominantly hydraulic calcium silicates) but these reactions do not emit further CO_2.

Methodology

According to the decision tree in the GPG 2000, when cement production is the key emission source, the most appropriate method used to estimate CO_2 emissions is the tier 2 method using clinker production data, as CO_2 emissions occur during the process of production of clinker. However, due to the absence of actual clinker production data, Tier 1 method is still applied for this subcategory in 2010 inventory.

$$CO_2 \text{ Emissions} = EF_{Clinker} * \text{Estimated Clinker Production}$$

Activity data

For the GHG inventory for 2013, due to the lack of official data, clinker production is estimated from the cement product and imported clinker. Cement production data is collected from the Vietnam Statistical Yearbook 2013 provided by the GSO. In addition, data on the amount of imported and exported clinker is collected from the "Cement Industry Report 2014" of the Vietnam Cement Association.

Estimated Clinker Production = Cement production * Clinker Fraction – Imported Clinker + Exported Clinker.

CO_2 emissions = $EF_{Clinker}$ * Clinker Production * Default CKD adjustment coefficient

Due to country-specific clinker fraction value does not exist in Vietnam, therefore the default value of 75% was used in accordance with IPCC2006 (page 2.13, Book 3, IPCC 2006 guideline) because both portland and blended cement are manufactured in Vietnam, but can not be disaggregated by type. The data of cement production and imported clinker have been illustrated in the following table:

Table 2.22. Cement production and imported clinker

	Cement production	**Imported Clinker**	**Exported Clinker**
	1.000 tonnes	1.000 tonnes	1.000 tonnes
2005	30,808	4,375.5	-
2010	55,801	2,259	-
2013	57,516	0	11,060
Source/ Note	Vietnam Statistical Yearbook 2014 (page184)	Cement Industry Report 2014 – Vietnam Cement Association (page 11)	Cement Industry Report 2014 – Vietnam Cement Association (page 11)

Estimated Clinker Production in 2013 was calculated as follows:

Estimated Clinker Production **= 57,516*0.75 + 11,060 = 54,197 (thousand tonnes)**

Emission factor

Country specific emission factors are not available, hence the default value of 0.646 (64.6%) was used for CaO content in clinker in accordance with 1996 IPCC Guideline.

$EF_{Clinker}$ = Multiplication factor * CaO content in Clinker *CKD

Table 2.23. Emission factor for Cement production

	Unit	Valua	Source
Multiplication factor	ton CO_2/ton CaO	0.785	Molecular weight ratio of CO_2 to CaO
CaO content in clinker	ton CaO /ton clinker	0.65	Page 2.11, Book 3, 2006 IPCC guidelines
CKD adjustment coefficient		1.02	Page 2.11, Book 3, 2006 IPCC guidelines
$EF_{clinker}$	ton CO_2/ ton clinker	0.52	Estimated as above mentioned

b) Lime production (CO_2) (2A2)

Lime production emits CaO through the thermal decomposition (calcinations) of the calcium carbonate ($CaCO_3$) in limestone to produce quicklime (CaO), or through the decomposition of dolomite ($CaCO_3.MgCO_3$) to produce dolomitic 'quick' lime (CaO.MgO). Good practice to estimate emissions from lime production is to determine the complete production of CaO and CaO.MgO from data on lime production.

Methodology

The 2006 IPCC guidelines sets out different Tiers for calculating GHG emissions from lime production. For Tier 2 and 3, the calculations require a clear distinction between lime kiln dust (LKD) and lime finished product. Since there is no data on LKD, the calculation of GHG emissions for lime production in 2013 was used Tier 1. The calculation formulation given by 2006 IPCC guidelines are as follows:

CO_2 Emissions = EF (Quicklime (High-calcium quicklime)) * Quicklime Production + EF (Dolomitic Quicklime) * Dolomitic Quicklime Production

According to 2006 IPCC guidelines, if production data are not broken down by type of lime, the default proportion for lime types: high-calcium/dolomitic lime is 85/15 and the proportion of hydraulic lime should be assumed as zero unless other information is available. The ratio 85/15 was applied to estimate the 2013 emissions because the data is not broken down by type of lime.

Because there is no information about the proportion of the content of CaO and CaO.MgO, the default emission factor was used in accordance with Table 2.4 in Book 3, 2006 IPCC guidelines (page 2.22).

Emission factor for lime types would be determined by the following formulas:

EF1 = Stoichiometric Ratio (CO_2/CaO) * CaO content

EF1: emission factor for high-calcium quicklime

EF2 = Stoichiometric Ratio (CO_2/CaO.MgO) * (CaO.MgO) content

EF2: emission factor for dolomitic quicklime

Activity data

Table 2.24. Lime production by type

Year	**Lime production (tonnes)**	**High-calcium quicklime production (tonnes)**	**Dolomitic Quicklime Production (tonnes)**

Emission factor

The default factors provided by GPG 2000, table 3.4 are used for the estimation of emission as follows:

Table 2.25. Emission factors of quicklimes

Emission factor for high calcium quicklime	0.75 tonne CO_2 /tonne (Default)
Emission factor for dolomitic quicklime	0.77 tonne CO_2 /tonne (Default)

c) Limestone and Dolomite Use (CO_2) – (2A3)

Limestone and Dolomite are basic raw materials having commercial applications in a number of industries including metallurgy (e.g. iron and steel), glass manufacture, agriculture, construction and environment pollution control. In industry applications involving the heating of limestone or dolomite at high temperature, CO_2 is generated.

It is highly likely that significant amount of limestone and dolomite has been consumed for above mentioned purposes. However, due to lack of information for estimation, GHG emission from limestone and dolomite use is reported as “NE” – Not Estemated.

d) Soda Ash Production and Use (CO_2) – (2A4)

Soda ash (sodium carbonate Na_2CO_3) is a white crystalline solid that is used as a raw material in a large number of industries including glass manufacture, soap and detergents, pulp and paper production and water treatment. Carbon dioxide is emitted from the use of soda, and may be emitted during production, depending on the industrial process used to manufacture soda ash.

However, soda ash has not been produced domestically in 2010 and due to lack of information of used soda ash for estimation, GHG emission from this category is reported as “NE” - Not Estemated.

2.3.2.2. Chemical Productions – (2B)

a) Ammonia Production (CO_2) – (2B1)

Ammonia is one of the major chemical industries, and is the main source of material for the production of nitrogen compounds. Ammonia is used in many different applications such as fertilizer production, heating, pulp mill, nitric acid and nitrate acid productions. Anhydrous ammonia is produced by catalytic steam reforming of natural gas or other fossil fuels. As can be seen in the following reactions with methane as a feedstock, CO_2 is produced

$C + H_2O = CO + H_2$

$CH_4 + H_2O = CO + 3H_2$

$N_2 + 3H_2 = 2\ NH_3$

Methodology

GHG emissions from ammonia production are divided into two categories: emissions from fuel combustion and emissions from input materials (mostly natural gas is used as fuel and input material for the production process). In the case that these two categories of emissions can not be separated, 2006 IPCC guidelines recommend to estimate all of this emissions into the industrial processes sector (page 3.11, vol. 3). The Tier of calculation is selected depends on the specific conditions in each country. For Vietnam, since there is no specific data for each ammonia production plant, the emissions calculation process is Tier 1. The 2006 IPCC guidelines’s calculated formula for Tier 1 is as follows:

$$\mathbf{E_{CO2} = AP * FR * CCF * COF * 44/12 – R_{CO2}}$$

In which: E_{CO2} = CO_2 emisions, kg

AP = Amonia production, ton

FR = Fuel required per ton of product, GJ/ton amonia

CCF = Carbon content of the fuel, kg C/GJ

COF = C oxidation rate of fuel

R_{CO2} = amount of CO_2 recovery for another purpose (Ure production), kg

In cases that countries do not have their own specific emission factor, the default emission factors can be used as recommended by the 2006 IPCC guidelines, as follows:

Table 2.26. Default values for ammonia production using natural gas

Factor	FR	CCF	COF	**CO_2 Emision factor**
Value	37.5 GJ/ton NH_3	15.3 kg/GJ	1	2.104 ton CO_2/ton NH_3

For $R_{CO2,}$ in case there is no value for the amount of urea produced, this value can be considered zero (page 3.12, vol. 3).

b) Nitric acid production (N_2O) – (2B2)

Vietnam has not produced nitric acid. Therefore, greenhouse gas emissions from this activity are recorded as "NO".

c) Adipic Acid Production (N_2O) – (2B3)

There is a fact that in Vietnam till now there is no adipic acid production. Therefore, the GHG emission from adipic acid is reported as “NO”.

d) Carbide production (CO_2) – 2B4: Calcium Carbide

Calcium carbide is made by heating calcium carbonate and subsequently reducing CaO with carbon (e.g. petrol coke). Both steps lead to emissions of CO_2 (First process is the same as Lime production process).

Also note that the CaO (lime) might be produced at another plant from the outside of the carbide plant. In this case, the emissions from the CaO step should be reported as emissions from lime production (2A2).

When calcium carbide is used, it also emits CO_2.

$CaCO_3 \rightarrow CaO + CO_2$ (this process is the same as Lime production process).

$CaO + 3C \rightarrow CaC_2 + CO$ ($\rightarrow CO_2$) (this is the process of using lime to produce calcium carbide).

$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2 \rightarrow 2CO_2$ (this is the process of using calcium carbide).

Due to the lack of information for estimation, emission from calcium carbide production and use process cannot be estimated. Therefore, GHG emission from this sub-category is reported as “NE”.

đ) Carbide production (CO_2) 2B4: Silicon Carbide

In the production of silicon carbide, CO_2 is released as a by-product from a reaction between quartz and carbon. Petrol coke is used as carbon source. According to the expertise estimation, there is a fact that in Vietnam till now there is no silicon carbide production, therefore the GHG emission from silicon carbide production is reported as "NO".

2.3.2.3. Metal Productions – (2C)

a) Iron and steel production (CO_2) – (2C1)

Crude iron is produced by the reduction of iron oxide ores mostly in blast furnaces, generally using the carbon in coke or charcoal as both the fuel and reductant. In most iron furnaces, the process is aided by the use of carbonate fluxes (limestone).

The iron and steel production produces mainly CO_2 and CH_4. N_2O has also emitted in the steel processing, but the emissions are minimal and can be ignored during the calculation (2006 IPCC guidelines does not provide detail for estimating N_2O emissions from iron and steel production).

Methodology

GHG emissions from iron and steel production consist of two types: 1) coke production; and 2) iron and steel production. Emissions from coke production are calculated and reported in Energy sector. For emissions from iron and steel production, there are emissions from fuel combustion for energy generation (reported in Energy sector) and emissions due to reactions in the furnace to generate iron and steel (non-energy emissions and reported in industrial processes sector).

The 2006 IPCC guidelines provide three Tiers for calculating CO_2 emissions from iron and steel production (Tier 1 to Tier 3) and two Tiers for calculating CH_4 emissions from steel production (Tier 1 and Tier 3). Since the provided data is the total amount of steel produced in 2013, Tier 1 was applied for calculating CO_2 and CH_4 emissions. The formula for emission calculation is as follows:

$$\mathbf{E_{CO2} = BOF * EF_{BOF} + EAF * EF_{EAF} + OHF * EF_{OHF}}$$

In which:

BOF = amount of steel is produced by the basic furnace technology (Basic oxygen Furnace), ton

EAF = amount of steel is produced by electric arc furnace technology (Electric arc Furnace), ton

OHF = amount of steel is produced by open heating technology (Open hearth Furnace), ton

EF = Emission factors of technologies, ton CO_2/ton steel

Emission factor

According to the program for developing some hi-tech industries of the MOIT, up to 2016, Vietnam steel industry mainly use arc furnace technology. (http://congnghiepcongnghecao.com.vn/tin-tuc/cong-nghe/t20106/lo-luyen-thep-cong-nghe-nao-cho-tuong-lai-.html)

Therefore, the emission factor of the arc furnace technology is used and is defined as follows:

$$\mathbf{EF = 1 * EF_{EAF} = 0.08*1 = 0.08 \text{ ton } CO_2/\text{ton steel}}$$

b) Aluminium Production (CO_2) – (2C3)

Currently, in the world, the production of aluminum foil is mainly carried out by using electrolyte melting with cryolite catalysis (Hall-Heroult). Two main technologies in aluminum production today are: Prebaked technology and Soderbarg technology.

Chemical equation of reaction is as follows:

$$\mathbf{2Al_2O_3 + 3C \rightarrow 4Al + 3CO_2}$$

There are two main emission sources in aluminum production are:

- CO_2 emissions from carbon consuming process on the anode of the electrolytic furnace;
- PFCs (tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6)) emissions from the process of primary aluminium smelting (formed during the phenomenon known as the anode effect)

In Vietnam, so far there have been two proposed projects:

- The first project is to convert bauxite ore to alumina at Tan Rai, Lam Dong province planned into operation in 2013.
- The second project is to convert bauxite ore to alumina at Nhan Co, Dac Nong province planned into operation in 2014.

However, both projects are currently producing only aluminum oxide (Al_2O_3), which is then exported overseas. The process of aluminum smelting (from Al_2O_3 to Al) has not yet been implemented in our country. Meanwhile, the production of alumina is nearly no emission and the IPCC has not provided guidelines for calculating GHG emissions in this production. Therefore, the emission from this source is reported as “NO”.

c) SF_6 Used in Aluminium and Magnesium Foundries – (2C4)

There is no aluminium and magnesium production in Vietnam. Therefore, the emission from this source was reported as “NO”.

d) Production of Halocarbons and SF_6 – (2E)

During the production of Halocarbons and SF_6, emission may occur in the form by product emission and fugitive emission. However, there is no Halocarbons and SF_6 production in Vietnam. Therefore, the emission from this source was reported as "NO".

đ) Consumption of Halocarbons and SF_6 – (2F)

Partially fluorinated hydrocarbon (HFCs), perfluorinated hydrocarbon (PFCs), and sulphur hexafluoride (SF_6) are serving as alternatives to ozone depleting substances (ODS) being phased out under the Montreal Protocol. In fact, it will be focused on emissions of PFCs and HFCs as well SF_6 in terms of contribution to global warming effect. These consumptions are as follows:

- refrigeration and air conditioning
- fire suppression and explosion protection
- aerosols
- solvent cleaning
- foam blowing
- other applications (HFCs and PFCs may be used in sterilization equipment, for tobacco expansion application, and as solvents in the manufacture of adhesives, coating and inks).

Primary uses of SF_6 include:

- Gas insulated switch gear and circuit breakers
- Fire suppression and explosion protection
- Other applications (an insulating medium, tracer, in leak detectors, and in various electronic applications, etc.)

From 2010, consumption of halon and some CFCs should be eliminated completely in developing countries including Vietnam in accordance with the Montreal protocol. In the recent years, the consumption of HFC and PFC are increased to replace Ozone delepte substances (ODS).

HFCs, known as Hydroflourcarbon, are fluoride-containing substances that are used extensively in the manufacture and efrigerants application in chillers. HFCs do not penetrate the ozone layer so they are currently recommended to replace CFCs and HCFCs in the chiller manufacture industry. Vietnam has not yet produced HFCs, so emissions are only occured during the use of this chemical.

Methodology

Emissions from the use of HFCs are collected and calculated by the National Ozone Office of Vietnam. The calculation method is based on the formula:

$$E_{HFC} = \sum_i M_i * EF_i$$

In which: E_{HFC} = Emissions from HFCs, ton CO_2eq;

M_i = amount of HFC type i consume in a year, ton

EF_i = GWP of HFC type i

Activity data

Table 2.27. Amount of HFCs consume in Vietnam

HFCs	Amount (ton)
HFC-23	
HFC-32	
HFC-125	
HFC-134a	
HFC-152a	
HFC-227ea	
HFC-404a	
HFC-407c	
HFC-410a	
HFC-507c	
Total	

d. Emision factor

Using EF according to IPCC guidelines.

Table 2.28. Emisson factor of HFCs

HFCs	**GWP_{100yr}**
HFC-23	14.800
HFC-32	675
HFC-125	3.500
HFC-134a	1.430
HFC-152a	124

HFC-227ea	3.220
HFC-404a	3.922
HFC-407c	1.774
HFC-410a	2.088
HFC-507c	3.985
Total	

2.4. GHG inventory for Agriculture sector

2.4.1. Overview

In GHG inventory for Agriculture sector, GHG emission estimation is carried out for six categories, namely Enteric Fermentation (CH_4), Manure Management (CH_4, N_2O), Rice Cultivation (CH_4), Agricultural Soils (N_2O), Prescribed Burning of Savannas (CH_4, N_2O) and Field Burning of Agricultural Residues (CH_4, N_2O).

Table 2.29. GHG emission sources in agriculture sector

			(Unit: Gg CO_2 eq.)
Categories	**CH_4**	**N_2O**	**Total**
A. Enteric Fermentation			
1.Cattle			
2.Buffalo			
3.Sheep			
4.Goat			
5.Horse			
6.Swine			
7.Poultry			
B. Manure Management			
1.Cattle			
2.Buffalo			
3.Sheep			
4.Goat			
5.Horse			
6.Swine			

7.Poultry			
8. Anaerobic lagoons			
9. Liquid Systems			
10. Solid Storage and Dry Lot			
11. Other (specify)			
- Daily spread			
- Anaerobic treatment			
- Anaerobic Digester			
C. Rice Cultivation			
1. Irrigated			
2. Rain fed			
D. Agricultural Soils			
1. Direct Emissions			
2. Pasture range & Paddock			
3. Indirect Emissions			
E. Burning of Savannas			
F. Field Burning of Agricultural Residues			
1. Cereals			
2. Pulse			
3. Tuber and Root			
4. Sugar Cane			
G.Other			

2.4.2. GHG emission estimation

2.4.2.1. Enteric Fermentation (CH_4) – (4A)

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

Methodology

Methane emissions from enteric fermentation are estimated by using Tier 1 methodology because the collected activity data has not available to support the level of detail required for the characterization of each livestock species in Tier 2 methodology, and because country specific emission factors has not been developed with Vietnam.

$$E = \Sigma_i A_i * EF_i$$

E = Total CH_4 emissions from enteric fermentation (Gg CH_4/year)
EF = emission factor for specific population, (kg/head/yr)
A = population of livestock (head)
Index i = livestock categories

Activity data

Table 2.30. Number of Animals

Livestock Type	Number of Animals (head)	Data source
Dairy Cattle		
Non-dairy Cattle		
Buffalo		
Sheep		
Goats		
Horses		
Swine		
Poultry		

Emission factor

The emission factors of dairy and non-dairy cattle are the default value of Asia in the Revised 1996 IPCC Guidelines. The emission factors of other livestock are the default value of developing country in the Revised 1996 IPCC guidelines.

Table 2.31. Emission factor of Enteric Fermentation (CH_4)

Livestock Type	Emission factor (kg CH_4/head/year)	Data source
Dairy Cattle	56	Table 4-4, Page 4.11 (Revised 1996 IPCC Guidelines) (Asia)
Non-dairy Cattle	44	
Buffalo	55	Table 4-3, Page 4.10 (Revised 1996 IPCC Guidelines) (Developing country)
Sheep	5	
Goats	5	

Horses	18	
Swine	1	

2.4.2.2. Manure Management (CH_4, N_2O) – (4B)

a) CH4

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

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

Methodology

Methane emissions from manure management are estimated by using Tier 2 methodology based on country-specific MCF (CH_4 conversion factors), Bo (maximum CH_4 producing capacity), VS (volatile solid excretion per day) and manure management system usage data.

$$E = \Sigma_{ik} A_{ik} * EF_{ik}$$

E = CH_4 emissions from manure management

EF = emission factor for the defined livestock population by climate region (kg/head/yr)

A = population of livestock (head)

Index i = livestock categories

Index k = climate region (temperate, warm)

Activity data

Table 2.32. Number of Animals in temperate and warm region

Livestock Type	**Unit**	Temperate	Warm	**Source**
Dairy Cattle	Head			
Non-dairy Cattle	Head			
Buffalo	Head			
Sheep	Head			

Goats	Head			
Horses	Head			
Swine	Head			
Poultry	Head			

According to the definition of climate region provided in the Revised 1996 IPCC guidelines, temperate is that the annual average temperature is from 15 to 25°C inclusive, and warm is greater than 25°C. The classification of each province into climate region is the follows.

Table 2.33. Classification of climate region

Climate region	Region	Province
Temperate	Red River Delta	Hà Nội, Hà Tây, Vĩnh Phúc, Bắc Ninh, Quảng Ninh, Hải Dương, Hải Phòng, Hưng Yên, Thái Bình, Hà Nam, Nam Định, Ninh Bình
	Northern midlands and mountain areas	Hà Giang, Cao Bằng, Bắc Kạn, Tuyên Quang, Lào Cai, Yên Bái, Thái Nguyên, Lạng Sơn, Bắc Giang, Phú Thọ, Điện Biên, Lai Châu, Sơn La, Hoà Bình
	North Central area and Central coastal area	Thanh Hoá, Nghệ An, Hà Tĩnh, Quảng Bình, Quảng Trị, Thừa Thiên Huế
	Central Highlands	Kon Tum, Gia Lai, Đắk Lắk, Đắk Nông, Lâm Đồng
Warm	North Central area and Central coastal area	Đà Nẵng, Quảng Nam, Quảng Ngãi, Bình Định, Phú Yên, Khánh Hoà, Ninh Thuận, Bình Thuận
	South East	Bình Phước, Tây Ninh, Bình Dương, Đồng Nai, Bà Rịa - Vũng Tàu, TP.Hồ Chí Minh
	Mekong River Delta	Long An, Tiền Giang, Bến Tre, Trà Vinh, Vĩnh Long, Đồng Tháp, An Giang, Kiên Giang, Cần Thơ, Hậu Giang, Sóc Trăng, Bạc Liêu, Cà Mau

Emission factor

Equation below shows how to calculate the emission factor for CH_4 from manure management

$$EF_i = VS_i * 365\ days/year * Bo_i * 0.67\ kg/m^3 * \Sigma_{jk}\ MCF_{jk} * MS_{ijk}$$

Where:

EF_i = annual emission factor for defined livestock population i, in kg

VS_i = daily VS excreted for an animal within defined population i, in kg

Bo_i = maximum CH_4 producing capacity for manure produced by an animal within defined population i, m^3/kg of VS

MCF_{jk} = CH_4 conversion factors for each manure management system j by climate region k

MS_{ijk} = fraction of animal species/category i's manure handled using manure system j in climate region k.

The value of Volatile Solid Excretion Rates (VS) by each livestock type is taken from the default values of the Revised 1996 IPCC guidelines. As to non-dairy cattle, although the average weight of non-dairy cattle assumed for the default value of Asia in the Revised 1996 IPCC guidelines is 319kg, the average weight of non-dairy cattle of Vietnam is 196kg. Therefore, the default value of "Young" (200kg) is used for non-dairy cattle.

Table 2.34. Volatile Solid Excretion Rates (VS)

Livestock Type	Value (kg/head/day)	Source
Dairy Cattle	2,82	Revised 1996 IPCC guidelines, Table B-1, Asia
Non-dairy Cattle	1,58	Revised 1996 IPCC guidelines, Table B-1, Asia, Young
Buffalo	3,90	Revised 1996 IPCC guidelines, Table B-5, Asia
Sheep	0,32	Revised 1996 IPCC guidelines, Table B-7, Developing Countries
Goats	0,35	Revised 1996 IPCC guidelines, Table B-7, Developing Countries
Horses	1,72	Revised 1996 IPCC guidelines, Table B-7, Developing Countries
Swine	0,30	Revised 1996 IPCC guidelines, Table B-6, Asia
Poultry	0,02	Revised 1996 IPCC guidelines, Table B-7, Developing Countries

The value of Bo (maximum CH_4 producing capacity for manure produced) by each livestock type is taken from the default values of the Revised 1996 IPCC guidelines.

Table 2.35. Maximum CH_4 producing capacity for manure produced by an animal (Bo)

Livestock Type	Value (m^3/kg của VS)	Source
Dairy Cattle	0,13	Revised 1996 IPCC guidelines, Table B-3, Asia
Non-dairy Cattle	0,1	Revised 1996 IPCC guidelines, Table B-1, Asia, Young
Buffalo	0,1	Revised 1996 IPCC guidelines, Table B-5, Asia
Sheep	0,13	Revised 1996 IPCC guidelines, Table B-7, Developing Countries
Goats	0,13	Revised 1996 IPCC guidelines, Table B-7, Developing Countries
Horses	0,26	Revised 1996 IPCC guidelines, Table B-7, Developing Countries
Swine	0,29	Revised 1996 IPCC guidelines, Table B-6, Asia
Poultry	0,24	Revised 1996 IPCC guidelines, Table B-7, Developing Countries

The value of MCF (methane conversion factor) by each manure management system is taken from the default values of the Revised 1996 IPCC guidelines and good practice guidance. The value for Anaerobic Lagoon and Anaerobic Digester are set based on expert judgment.

Table 2.36. CH_4 conversion factor (MCF)

Manure management system	Temperate	Warm	Source
Daily spread	0.5%	1.0%	GPG2000,Table4.10
Aerobic treatment	0.1%	0.1%	GPG2000, Table4.11
Anaerobic Lagoon	50.0%	50.0%	Expert judgment by TSAG (Mr. Cuong)
Anaerobic Digester	12.5%	12.5%	Expert judgment by TSAG (Mr. Cuong), median of 10-15%
Pasture range and paddock	1.5%	2.0%	GPG2000, Table4.10

The values of MS (fraction of manure handled using manure system) are taken from “Disposal of livestock waste of farming households in 2008 by methods of disposal, urban rural, region, income quintile and sex of household head” of Household Living Standards Survey 2010 (General Statistics Office). Since there is no data for 2013, the data for 2008 are used for 2013.

The fraction of manure management system by region is classified into two climate region which are temperate and warm for estimating CH_4 emissions by each climate region. The value of MS of temperate region is the average of Red River Delta, North East, North West, North Central and Central Highlands. The value of MS of warm region is the average of South Central, South East and Mekong River Delta.

Table 2.37. Disposal of livestock waste of farming households by methods of disposal

Region	Climate region	Method of disposal					
		Total	For fertilizer	Eliminating to drain, sewer	Eliminating to fields, pond, lake, river, stream near house	Biogas	Others
Whole country	-	100.0	2.3	61.4	9.9	16.4	10.0
Red River Delta	temperate	100.0	3.2	66.9	13.7	8.9	7.3
North East	temperate	100.0	1.2	84.8	5.1	4.8	4.1
North West	temperate	100.0	1.1	61.6	8.9	20.7	7.7
North Central	temperate	100.0	0.8	78.0	7.2	6.8	7.2
Central Highlands	warm	100.0	3.0	44.7	15.9	20.2	16.2
South Central	temperate	100.0	1.9	62.7	7.7	17.7	10.1
South East	warm	100.0	5.0	38.2	11.2	20.4	25.2
Mekong River Delta	warm	100.0	3.2	14.4	11.3	52.9	18.2

Table 2.38. Fraction of manure management system by climate region (MS)

Climate region	For fertilizer (Dairy spread)	Eliminating to drain, sewer (Anaerobic treatment)	Eliminating to fields, pond, lake, river, stream near house (Anaerobic Lagoon)	Biogas (Anaerobic digester)	Others (Pasture range & Paddock)
Whole country	2.3	61.4	9.9	16.4	10.0
Temperate	1.9	67.2	10.2	12.3	8.5
Warm	3.4	38.4	10.1	30.3	17.8

CH_4 emission factors of manure management by livestock type by climate region calculated using VS, Bo, MCF and MS described above is the follows.

Table 2.39. Emission factor of Manure Management (CH_4)

Emission factor (kg/head)	Temperate	Warm
Dairy Cattle	6.113	8.296
Non-dairy Cattle	2.635	3.576
Buffalo	6.504	8.826
Sheep	0.694	0.941
Goats	0.759	1.030

Horses	7.457	10.120
Swine	1.451	1.969
Poultry	0.080	0.109

b) N_2O

Nitrous oxide is also produced during the storage and treatment of manure before it is applied to land. While manure is stored, some manure nitrogen is converted to N_2O through the activity of microorganisms. Nitrous oxide emissions to the atmosphere from the land surface, due to the application of manure to soils are accounted for under "direct N_2O emissions from agricultural soils". Unmanaged manure that is deposited directly on land by grazing animals is referred to as a 'pasture range, and paddock' management system (i.e., animals grazing on pasture or grassland, animals that forage or are fed in paddocks, and animals kept in pens around homes). Nitrous oxide emissions from this unmanaged manure occur directly and indirectly from the soil, and should be reported under 'pasture range and paddock under Agricultural soils (4.D)".

Methodology

Nitrous oxide emissions from manure management are estimated by using IPCC default values because there are no data available with Tier 2 methodology such as country-specific N-excretion/intake values and manure management system usage data..

$$(N_2O - N)_{(mm)} = \sum_{(S)}\{[\sum_{(T)}(N_{(T)} * Nex_{(T)} * MS_{(T,S)})] * EF_{3(S)}\}$$

$(N_2O\text{-}N)_{(mm)}$ = N_2O-N emissions from manure management in the country (kg N_2O-N/yr)

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

$Nex_{(T)}$ = Annual average N excretion per head of species/category T in the country (kg N/animal/yr)

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

$EF_{3(S)}$ = N_2O emission factor for 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

Activity data

The activity data is the amount of N treated by each manure management system by each livestock category. This activity data are estimated by livestock population ($N_{(T)}$), annual average N excretion per head ($Nex_{(T)}$) and fraction of total annual excretion for each livestock category in each manure management system ($MS_{(T,S)}$).

Livestock population ($N_{(T)}$)

Number of livestocks by each climate region (temperate and warm)

Annual average N excretion per head ($Nex_{(T)}$)

Annual average N excretion per head is the default value of "Asia and Far East" in the Revised 1996 IPCC guidelines.

Table 2.40. Nitrogen excretion per head of animal

Livestock Type	Nitrogen excretion (kg N/animal/yr)	Data source
Dairy cattle	60	Table B-1 (Revised 1996 IPCC Guidelines, Vol.III Reference Manual (Asia & Far East)
Non-dairy cattle	40	
Poultry	0.6	
Sheep	12	
Swine	16	
Other animals	40	

Table 2.41. Fraction of manure management system by climate region

Climate region	For fertilizer	Eliminating to drain, sewer	Eliminating to fields, pond, lake, river, stream near house	Biogas	Others
	(Dairy spread)	(Anaerobic treatment)	(Anaerobic Lagoon)	(Anaerobic digester)	(Pasture range & Paddock)
Whole country	2.3	61.4	9.9	16.4	10.0
Temperate	1.9	67.2	10.2	12.3	8.5
Warm	3.4	38.4	10.1	30.3	17.8

Emission factor

The emission factor by each management system category is the default value of the Good Practice Guidance 2000.

Table 2.42. Emission factor of each animal waste management system (AWMS)

Animal Waste Management System (AWMS)	Emission Factor For AWMS EF_3 (kg N_2O–N/kg N)	Data source
Anaerobic lagoons	0.001	Good Practice Guidance (2000)
Aerobic treatment	0.02	

Daily spread	0	(Table4.12, 4.13)
Anaerobic Digester	0.001	
Pasture range and paddock	-	

2.4.2.3. Rice Cultivations (CH_4) – (4C)

Anaerobic decomposition of organic material in flooded rice fields produces CH_4, which escapes to the atmosphere primarily by diffusive transport through the rice plants during the growing seasons. The seasonally integrated CH_4 flux depends upon the input of organic carbon, water regimes, time and duration of drainage, soil type etc

Methodology

Methane emissions from rice cultivation are estimated by using IPCC method with country-specific emission factors.

$$\textbf{Emission (Tg/yr)} = \Sigma_i \Sigma_j \Sigma_k (EF_{ijk} * A_{ijk} * 10^{-12})$$

EF_{ijk} = a seasonally integrated emission factor for i, j, and k conditions, in g CH_4/m^2
A_{ijk} = annual harvested area for i, j, and k conditions, in m^2/yr
i, j, and k = represent different ecosystems, water management regimes, and other conditions under which CH_4 emissions from rice may vary (e.g. addition of organic amendments).

Activity data

Table 2.43. Rice cultivation and irrigated area

	Area (thousand ha)	Source
Total irrigated area		
Northern		
Central		
Southern		

Table 2.44. Factors of rainfed rice area

Unit: thousand ha

	Area (thousand ha)	Source
Total irrigated area		
Northern		

Central		
Southern		

Emission factor

According to the GPG2000, the adjusted seasonally integrated emission factor can be calculated by the following equation:

$$EF_i = EF_c \bullet SF_w \bullet SF_o \bullet SF_s$$

EF_i = Adjusted seasonally integrated emission factor for a particular harvested area
EF_c = Seasonally integrated emission factor for continuously flooded fields without organic amendments
SF_w = Scaling factor to account for the differences in ecosystem and water management regime
SF_o = Scaling factors should vary for both types and amount of amendment applied.
SF_s = Scaling factor for soil type, if available

EF_c (Seasonally integrated emission factor for continuously flooded fields without organic amendments**)**

The EF_c by each area is taken from field experiences carried out by the Research Center for Climate Change and Sustainable Development and has been used for estimating CH_4 emissions from rice paddy during preparing "Vietnam –Second National Communication to Climate change under UNFCCC".

Table 2.45. Seasonally Integrated Emission Factor for Continuously Flooded Rice without Organic Amendment

Water Management Regime Continuously Flooded Irrigated	Seasonally Integrated Emission Factor for Continuously Flooded Rice without Organic Amendment (g/m^2)	Data source
Northern	37.50	Research Center for Climate Change and Sustainable Development
Central	33.59	
Southern	21.72	

SF_w (Scaling factor to account for the differences in ecosystem and water management regime)

The default scaling factors of GPG2000 are applied. Since it is assumed that all irrigated rice paddy is continuously flooded due to lack of information, scaling factor used in the emission estimation is 1.0.

The scaling factor of upland rice is 0, which is provided by GPG2000. The scaling factor of rainfed rice is 0.8, which is the default value for flood prone of rainfed rice in GPG2000.

Table 2.46. IPCC Default CH_4 emission scaling factors for rice ecosystems and water management regimes relative to continuously flooded fields

<table>
<tr><th>Category</th><th colspan="2">Sub-category</th><th>Scaling factor (SFw)</th><th>Description</th></tr>
<tr><td>Upland</td><td colspan="2">None</td><td>0</td><td>Fields are never flooded for a significant period of time, no significant quantities of CH_4</td></tr>
<tr><td rowspan="2">Lowland</td><td>Irrigated</td><td>Continuous Flooded</td><td>1.0</td><td>Fields have standing water throughout the rice growing season and may only dry for harvest</td></tr>
<tr><td>Rainfed</td><td>Flood prone</td><td>0.8</td><td>The water level may rise up to 50 cm during the cropping season</td></tr>
</table>

(Table 4-20, Page 4-80, Good Practice Guidance 2000)

SFo (Scaling factors should vary for both types and amount of amendment applied)

It is assumed that organic amendments are poorly applied in Vietnam. Thus 1.0 is chosen as scaling factor for this.

SFs (Scaling factor for soil type)

Since there is no data available on scaling factor for soil type, this factor is not used.

2.4.2.4. Agricultural Soils (N_2O) – (4D)

a) Direct Emissions (N_2O) (4D1)

Nitrous oxide (N_2O) is produced naturally in soils through the microbial processes of nitrification and denitrification. A number of agricultural activities add nitrogen to soils, increasing the amount of nitrogen available for nitrification and denitrification, and ultimately the amount of N_2O emitted. The N_2O emissions that result from anthropogenic N inputs occur through both a direct pathway

The direct N_2O emissions from agricultural soils due to applications of N and other cropping practices accounts for anthropogenic nitrogen inputs from the application of synthetic fertilizers and animal manure, the cultivation of N-fixing crops, incorporation of crop residues into soils and soil nitrogen mineralization due to cultivation of organic soils.

Methodology

According to the GPG decision tree, direct N_2O emissions from agricultural soil are estimated by using Tier 1a methodology.

Direct N_2O emissions from agricultural soil (tier 1a)

$$N_2O_{Direct}\text{-}N = [(F_{SN}+F_{AW}+F_{BN}+F_{CR})*EF_1] + (F_{OS}*EF_2)$$

N_2O_{Direct}-N = Emission of N_2O in unit of Nitrogen (kg N/yr)

F_{SN} = Annual amount of synthetic fertilizer nitrogen applied to soils adjusted to account for the amount that volatilizes as NH3 and NOx

FAW = Annual amount of animal manure nitrogen intentionally applied to soils adjusted to account for the amount that volatilizes as NH3 and NOx

FBN = Amount of nitrogen fixed by N-fixing crops cultivated annually

FCR = Amount of nitrogen in crop residues returned to soils annually

FOS = Area of organic soils cultivated annually

EF1 = EF for emissions from N inputs (kg N_2O-N/kg N input)

EF_2 = EF for emissions from organic soil cultivation (kg N_2O-N/ha-yr)

Conversion of N_2O-N emissions to N_2O emissions for reporting purposes is performed by using the following equation; $N_2O = N_2O\text{-}N * 44/28$.

Activity data

There are five kinds of activity data in this category, which are F_{SN}, F_{AW}, F_{BN}, F_{CR} and F_{OS}.

<u>F_{SN} (N from synthetic fertilizer application)</u>

$$F_{SN} = N_{FERT} * (1 - Frac_{GASF})$$

F_{SN} = Synthetic nitrogen applied (kg N/yr);
N_{FERT} = synthetic fertilizer use (kg N/yr);
$Frac_{GASF}$ = fraction of synthetic fertilizer nitrogen applied to soils that volatilizes as NH_3 and NOx (kg NH_3-N and NOx-N/kg of N input); Default: 0.1 kg NH_3-N and NOx-N/kg of synthetic fertilizer N applied

F_{SN} can be taken from N_{FERT} (The amount of N from synthetic fertilizer used) and $Frac_{GASF}$ (fraction of synthetic fertilizer nitrogen applied to soils that volatilizes as NH_3 and NOx).

The data of N_{FERT} is taken from the Nitrogen consumption in the statistics of International Fertilizer Industry Association (IFA).

$Frac_{GASM}$ is taken from the default value in the GPG2000, which is 0.1 kg NH_3-N and NOx-N/kg of synthetic fertilizer N applied.

Table 2.47. Total nitrogen consumption (N_{FERT})

Unit: tN

	Year	Data source
Total nitrogen consumption		

F_{AM} (N from Animal Manure application)

$$E_{AM} = \sum_T (N_{(T)} * N_{ex\ ()}) * (1 - Frac_{GASM})[1-(Frac_{FUEL-AM} + Frac_{PRP})]$$

F_{AM} = amount of animal manure nitrogen intentionally applied to soils after adjusting to account for the amount that volatilizes (kg N/yr);

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

Nex = amount of nitrogen excreted by the livestock T (kg N/yr);

$Frac_{GASM}$ = fraction of livestock nitrogen excretion that volatilizes as NH_3 and NOx (kg NH_3-N and NOx-N/kg of N excreted) default : 0.2 kg NH_3-N + NOx-N/kg of N excreted by livestock

$Frac_{FUEL-AM}$ = fraction of livestock nitrogen excretion contained in excrements burned for fuel (kg N/kg N totally excreted); default: 0.0 kg N/kg N excreted

$Frac_{PRP}$ = fraction of livestock nitrogen excretion and deposited onto soil by grazing livestock (kg N/kg N excreted)

F_{AM} can be taken from $N_{(T)}$ (number of livestock), $N_{ex(T)}$ (amount of nitrogen excreted by the livestock), $Frac_{GASM}$ (fraction of livestock nitrogen excretion that volatilizes as NH_3 and NOx), $Frac_{FUEL-AM}$ (fraction of livestock nitrogen excretion contained in excrements burned for fuel) and $Frac_{PRP}$ (fraction of livestock nitrogen excretion and deposited onto soil by grazing livestock).

The data of $N_{(T)}$ is same as the activity data used in 4A Enteric fermentation and 4B Manure management.

Although the category “other” of the above statistics does not correspond to “pasture, range and paddock” accurately, it is assumed that the category “other” includes the amount of manure excreted to the area of pasture, range and paddock and emissions from category “other” are reported as those from pasture, range and paddock in order to avoid underestimating emissions from agricultural soils.

The value of $Frac_{GASM}$ and $Frac_{FUEL-AM}$ are taken from the default values in the GPG2000.

F_{BN} (N fixed by crops)

$$F_{BN} = 2 * Crop_{BF} * Frac_{NCRBF}$$

F_{BN} = N fixed by N-fixing crops (kg N/yr);
$Crop_{BF}$ = seed yield of pulses and soybeans (kg dry biomass/yr);
$Frac_{NCRBF}$ = fraction of nitrogen in N-fixing crop (kg N/kg of dry biomass);
FBN can be taken from CropBF (seed yield of pulses and soybeans, dry matter base) and FracNCRBF (fraction of nitrogen in N-fixing crop).

$Crop_{BF}$

The production data of soybeans, peanut and beans (wet matter base) is obtained from Statistical Yearbook of General Statistical Office and FAOSTAT.

The dry matter fraction of each crop type to convert from the amount of production in wet matter base to dry matter base is taken from the GPG2000 and Revised 1996 IPCC guidelines.

Table 2.48. Crop production

Crop type	N-fixing crop	Production (thousand tonnes)	Data source
Maize			
Rice			
Millet			
Soybeans			
Potatoes			
Sweet Potato			
Cassava			
Sugar Cane			
Peanut			
Beans			
Cotton			
Jute			
Papyrus			
Sesame			
Tobacco			

Table 2.49. Dry matter fraction of each crop type

Crop type	Dry matter	Data source

	fraction	
Maize	0.78	Median value of the range in GPG2000, Table4-16
Rice	0.85	Median value of the range in GPG2000, Table4-16
Millet	0.885	Median value of the range in GPG2000, Table4-16
Soybeans	0.865	Median value of the range in GPG2000, Table4-16
Potatoes	0.45	Median value of the range in Revised 1996 IPCC guidelines, Table4-17
Sweet Potato	0.45	The value of potatoes is used.
Cassava	0.45	The value of potatoes is used.
Sugar Cane	0.15	Median value of the range of sugar beet in Revised 1996 IPCC guidelines, Table4-17
Peanut	0.86	GPG2000, Table4-16
Beans	0.86	Median value of the range in GPG2000, Table4-16
Cotton	0.93	US GHG Inventory Report for the period 1990-2014 (published April 2004)
Jute	0.86	Bangladesh Climate Change Report (2010)
Papyrus	0.85	The value of Rice is used
Sesame	0.87	The value of Tobacco is used
Tobacco	0.87	US GHG Inventory Report for the period 1990-2014 (published April 2004)

$Frac_{NCRBF}$

$Frac_{NCRBF}$ which is the fraction of nitrogen in N-fixing crop (kg N/kg of dry biomass) is the average value calculated based on the data of Nitrogen fraction of each N-fixing crop provided from Soil and Fertilizer Research Institute (SFRI).

Table 2.50. Nitrogen fraction of each N-fixing crop

Crop type	Unit	value	Reference
Residue of soybean	%	1.500	Fertilizer Hand Book, Soils and Fertilizer Research Institute, Agricultural Publish House, 2009
Stem, leaf, husk, unfill pruit in matural soybean	%	0.460	Cao Ky Son, 2002, Viet Nam
Leaf of matural peanut	%	2.950	Wang Zaixu, 1982; Cai Changbei, 1988 - China
Stem of matural peanut	%	1.150	
Stem, leaf, husk, unfill pruit in matural peanut	%	1.500	Cao Ky Son, 2002, Viet Nam

Average	**%**	**1.512**	

F_{CR} (N in crop residues returned to soils)

$$F_{CR} = 2*[Crop_O * Frac_{NCRO} + Crop_{BF} * Frac_{NCRBF]} * (1 – Frac_R) * (1 – Frac_{BURN})$$

F_{CR} = N in crop residues returned to soils (kg N/yr);
$Crop_O$= production of all other (i.e., non-N fixing) crops (kg dry biomass/yr);
$Frac_{NCRO}$ = fraction of nitrogen in non-N-fixing crop (kg N/kg of dry biomass)
$Crop_{BF}$ = seed yield of pulses and soybeans (kg dry biomass/yr);
$Frac_R$ = fraction of crop residue that is removed from the field as crop (kg N/kg crop-N); default: 0.5 kg N/kg crop-N
$Frac_{BURN}$ = fraction of crop residue that is burned rather than left on field. default : 0.25 kg N/kg crop-N (developing countries)

F_{CR} can be taken from $Crop_O$ (production of non-N fixing crops, dry matter base), $Crop_{BF,}$ $Frac_{NCRO}$ (fraction of nitrogen in non-N-fixing crop), $Frac_{NCRBF,}$ $Frac_R$ (fraction of crop residue that is removed from the field as crop) and $Frac_{BURN}$ (fraction of crop residue that is burned rather than left on field).

The production data of non-N fixing crops (wet matter base) can be obtained from Statistical Yearbook of General Statistical Office and FAOSTAT (See Table 74, Crop production). $Frac_{NCRO}$ which is the fraction of nitrogen in non-N-fixing crop (kg N/kg of dry biomass) is the average value calculated based on the data of Nitrogen fraction of each non-N-fixing crop provided from SFRI.

FracR and $Frac_{BURN}$ are taken from the default values in the GPG2000.

Table 2.51. Nitrogen fraction of each non-N-fixing crop

Crop type	Unit	value	Reference
Paddy rice	%	0.400	Le Van Can, 1975. Fertilizer hand book
Straw of paddy rice	%	0.300	Fertilizer Hand Book, Soils and Fertilizer Research Institute, Agricultural Publish House, 2005
Straw of rainfed rice	%	0.400	Fertilizer Hand Book, Soils and Fertilizer Research Institute, Agricultural Publish House, 2006
Maize	%	0.800	Le Van Can, 1975. Fertilizer hand book
Stem of Maize	%	0.480	Fertilizer Hand Book, Soils and Fertilizer Research Institute, Agricultural Publish House, 2008
Potato	%	0.300	Le Van Can, 1975. Fertilizer hand

			book
Tropical grass	%	0.700	Le Van Can, 1975. Fertilizer hand book
Leaf of maturial cassava	%	2.480	Fertilizer Hand Book, Soils and Fertilizer Research Institute, Agricultural Publish House, 2005 refere by Cours (1951 - 1953)
Stem of maturial cassava	%	0.660	C.J Asher, D.G.Edwards và R.H.Howeler (1980)
Average	**%**	**0.724**	

F_{OS} (Area of organic soils cultivated annually)

The data of cultivated organic soils (Histosol) are estimated by the area of peat soil by province and Share of the area of peat land for agriculture production. The area of peat soil by province is taken from "Hien.B.H and L.X.Sinh.2004. Inventory and Assessment nutrient content and using of peat soil for safe agriculture production in major regions of Vietnam. Final report of SFRI. MARD. Hanoi. 2004." provided by SFRI. The area of peat land by use type in Kiên Giang and Cà Mau is taken from "Vu.T.P. et al.2011, Table 6, Report on potential for emission reduction through peatland management in Vietnam" provided by SFRI as well. The national total area of organic soil used for agriculture production is estimated by multiplying the national total area of peat soil by the share of the area of peat soil for agriculture production in Kiên Giang and Cà Mau province.

Table 2.52. Area of peat soil by province

Province	Area (ha)
Hoà Bình	18
Hà Nội	612
Quảng Ngãi	66
Gia Lai	52
Đắk Lắk	414
Lâm Đồng	289
Bình Phước	20
Đồng Nai	184
Long An	240
Đồng Tháp	317
Kiên Giang	5,475
Cà Mau	20,167
Total	**27,853**

Table 2.53. Area of peat land by use type in Kiên Giang and Cà Mau

Peatland use type	Area (ha)	Share

	Kiên Giang	Cà Mau	Total	
Conserved peatlands	2,707	2,600	5,307	23.2%
Agriculture production	0	205	205	0.9%
Forestry production	400	3,027	3,427	15.0%
Peatland exploitation	237	0	237	1.0%
Un-used peatland	13,456	202	13,658	59.8%
Total	**16,800**	**6,034**	**22,834**	**100.0%**

Table 2.54. Parameters in the calculation of direct N_2O emissions

Parameter	Value	Unit	Data source
$Frac_{BURN}$	0.25	kg N/kg crop-N	Default value; Table 4-19, page 4.89, Revised 1996 IPCC Guidelines, Reference Manual
$Frac_{R}$	0.5	kg N/kg crop-N	Default value, page 4.59, GPG2000
$Frac_{FUEL}$	0.0	kg N/kg N excreted	Default value , Table 4-19, page 4.89, Revised 1996 IPCC Guidelines, Reference Manual
$Frac_{GASF}$	0.1	kg NH_3-N + NOx-N/kg of synthetic fertilizer N applied	Same as above
$Frac_{GASM}$	0.2	kg NH_3-N + NOx-N/kg of N excreted by livestock	Same as above
$Frac_{NCRBF}$	0.015	kg N/kg of dry biomass	Average value of Nitrogen fraction of N-fixing crops provided by SFRI.
$Frac_{NCRO}$	0.007	kg N/kg of dry biomass	Average value of Nitrogen fraction of non-N-fixing crops provided by SFRI.

Table 2.55. Amount of N input

Type of N input to soil	Amount of N Input (kg N/yr)
Synthetic fertilizer (F_{SN})	
Animal waste (F_{AW})	
N-fixing crops (F_{BN})	
Crop residue (F_{CR})	

Emission factor

Two emission factors are needed to estimate direct N_2O emissions from agricultural soils. The first (EF_1) indicates the amount of N_2O emitted from the various nitrogen additions to soils, and the second (EF_2) estimates the amount of N_2O emitted from cultivation of organic soils.

Table 2.56. Emission factors to estimate direct N_2O emissions from agricultural soils

Emission Factor	value	unit	Data source
EF_1 for F_{SN}	1.25%	kg N_2O-N/kg N	Table 4.17, page 4.60, GPG2000
EF_1 for F_{AM}	1.25%	kg N_2O-N/kg N	Table 4.17, page 4.60, GPG2000
EF_1 for F_{BN}	1.25%	kg N_2O-N/kg N	Table 4.17, page 4.60, GPG2000
EF_1 for F_{CR}	1.25%	kg N_2O-N/kg N	Table 4.17, page 4.60, GPG2000
EF_2	16	kg N_2O-N/ha	for Tropical Organic Soils Table 4.17, page 4.60, GPG2000

b) Pasture range & Paddock (N_2O) – (4D2)

Estimation of direct N_2O emissions from pasture, range, and paddock manure is presented in section "N_2O Emissions from Manure Management". However, that direct N_2O emissions from pasture, range and paddock manure are to be reported in the 4D - agricultural soils category.

Methodology

According to the GPG decision tree, N_2O emissions from manure management should be estimated by using IPCC default values because there are no data available with Tier 2 methodology such as country-specific N-excretion/intake values and manure management system usage data.

$$\mathbf{(N_2O - N)_{(mm)} = \sum_{(S)} \{[\sum_{(T)}(N_{(T)} * Nex_{(T)} * MS_{(T,S)})] * EF_{3(S)}\}}$$

$(N_2O\text{-}N)_{(mm)}$ = N_2O-N emissions from manure management in the country (kg N_2O-N/yr)

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

$Nex_{(T)}$ = Annual average N excretion per head of species/category T in the country (kg N/animal/yr)

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

$EF_{3(S)}$ = N_2O emission factor for 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.

Activity data

- Number of head of livestock species/category T in the country ($N_{(T)}$)

- Annual average N excretion per head ($Nex_{(T)}$)

Annual average N excretion per head is the default value of "Asia and Far East" in the Revised 1996 IPCC guidelines.

Table 2.57. Nitrogen excretion per head of animal

Livestock Type	Nitrogen excretion (kgN/animal/yr)	Data source
Dairy cattle	60	Table B-1 (Revised 1996 IPCC Guidelines, Vol.III Reference Manual (Asia & Far East)
Non-dairy cattle	40	
Poultry	0.6	
Sheep	12	
Swine	16	
Other animals	40	

Fraction of total annual excretion for Pasture/Range System Usage ($MS_{(T,S)}$) is taken from "Disposal of livestock waste of farming households in 2008 by methods of disposal, urban rural, region, income quintile and sex of household head" of Household Living Standards Survey 2010 (General Statistics Office). Since there is no data for 2013, the data for 2008 are used for 2013.

Emission factor

The emission factor by pasture range and paddock system is the default value of the GPG2000.

Table 2.58. Emission factor for pasture range and paddock

Animal Waste Management System (AWMS)	Emission Factor For AWMS EF_3 (kg N_2O–N/kg N)	Data source
Pasture range and paddock	0.02	Table 4.12, Page 4.43 (Good Practice Guidance-2000)

c) Indirect Emissions (N_2O) – 4D3

The N_2O emissions that result from anthropogenic N inputs occur through a direct pathway (i.e. directly from the soils to which N is applied), and through a number of indirect pathways, including the leaching and runoff of applied N in aquatic systems, and the volatilization of applied N as ammonia (NH_3) and oxides of nitrogen (NO_x) followed by deposition as ammonium (NH_4) and NO_x on soils and water. This category covers N_2O emissions through indirect pathways.

Methodology

M Indirect N_2O emissions are estimated by using IPCC default methodology and default EF because there is no country-specific data available.

Indirect N_2O emissions are the total of "N_2O from atmospheric deposition", "N_2O from leaching and runoff" and "N_2O from discharge of human sewage".

$$N_2O_{indirect-N} = N_2O_{(G)} + N_2O_{(L)} + N_2O_{(S)}$$

$N_2O_{indirect-N}$ = Emissions of N_2O in units of nitrogen

$N_2O_{(G)}$ = N_2O produced from volatilization of applied synthetic fertilizer and animal manure N, and its subsequent atmospheric deposition of NO_x and NH_3 (kg N/yr);

$N_2O_{(L)}$ = N_2O produced from leaching and runoff of applied fertilizer and animal manure N (kg N/yr);

$N_2O_{(S)}$ = N_2O produced from discharge of human sewage N into rivers or estuaries (kg N/yr.

Atmospheric deposition ($N_2O_{(G)}$)

$$N_2O_{(G)} - N = [(N_{FERRT} * Frac_{GASF}) + \sum_T(N_{(T)} * N_{ex(T)}) * Frac_{GASM})] * EF_4$$

$N_2O_{(G)}$ = N_2O produced from atmospheric deposition of N, kg N/yr
N_{FERT} = total amount of synthetic nitrogen fertilizer applied to soils, kg N/y;
$\Sigma_T(N_{(T)}*Nex_{(T)})$ = total amount of animal manure nitrogen excreted, kg N/yr;
$Frac_{GASF}$ = fraction of synthetic N fertilizer that volatilizes as NH_3 and NOx (kg NH_3-N and NOx-N/kg of N input); default: 0.1 kg NH_3-N + NOx-N/kg N
$Frac_{GASM}$ = fraction of animal manure N that volatilizes as NH_3 and NOx (kg NH_3-N and NOx-N/kg of N excreted); default: 0.2 kg NH_3-N + NOx-N/kg N
EF_4=EF for atmospheric deposition (kg N_2O-N/kg NH_3-N and NOx-N emitted); default: 0.01 kg N_2O-N/kg NH_3-N and NOx-N

Leaching/runoff of applied or deposited nitrogen ($N_2O(L)$):

$$N2O_{(L)} - N = [N_{FERT} + \sum_T(N_{(T)} * Nex_{(T)})] * Frac_{LEACH})] * EF_5$$

$N_2O_{(L)}$ = N_2O deposited from leaching/runoff of N, kg N/yr
N_{FERT} = total amount of synthetic nitrogen fertilizer applied to soils, kg N/y;
$\Sigma_T(N_{(T)}*N_{EX(T)})$ = total amount of animal manure nitrogen excreted, kg N/yr;
$Frac_{LEACH}$ = fraction of nitrogen input to soils that is lost through leaching and runoff (kg N/kg of nitrogen applied); default: 0.3 kg N/kg of fertilizer or manure N
EF_5 = EF for leaching/runoff (kg N_2O-N/kg N leaching/runoff); default: 0.025 kg N_2O-N/kg N leaching/runoff.

Human consumption followed by municipal sewage treatment ($N_2O(S)$):

N_2O produced from human sewage ($N_2O_{(S)}$) is reported under the Waste sector.

Activity data

N_{FERT} (Total amount of synthetic nitrogen fertilizer applied to soils) is taken from the Nitrogen consumption in the statistics database of FAO (FAOSTAT).

The data of $N_{(T)}$ (number of livestock) is same as the activity data used in 4A Enteric fermentation and 4B Manure management. The data of $N_{ex(T)}$ ((amount of nitrogen excreted by the livestock) is same as the activity data used in 4B Manure management (N_2O).

Table 2.59. Parameters in the calculation of indirect N_2O emissions

Parameter	Value	Unit	Data Source
$Frac_{GASF}$	0.1	kg NH_3-N + NOx-N/kg of synthetic fertilizer N applied	Default value in Table 4-19, Revised 1996 IPCC Guidelines Reference Manual
$Frac_{GASM}$	0.2	kg NH_3-N + NOx-N/kg of N excreted by livestock	Same as above
$Frac_{LEACH}$	0.3	kg N/kg of fertilizer or manure N	Default value in Table 4-24, Revised 1996 IPCC Guidelines Reference Manual

Emission factor

Default emission factors in the Revised 1996 IPCC guidelines are used for estimating indirect N_2O emissions from N used in Agriculture because there is no country-specific data in Vietnam.

Table 2.60. Emission factors of atmospheric deposition and leaching & runoff

Emission Factor	value	Unit	Data source
EF_4	0.01	kg N_2O-N/kg NH_4-N & NOx-N deposited	Table 4.23, page 4.105, GPG2000
EF_5	0.025	kg N_2O-N/kg N leached & runoff	Table 4.17, page 4.105, GPG2000

d) Prescribed Burning of Savannas (CH_4, N_2O, NOx, CO, NMVOC) – (4E)

The savanna is tropical and subtropical vegetative formations with grass coverage occasionally interrupted by some shrubs, small trees of grass. Savannas are intentionally burned during the dry season primarily for agricultural purposes such as ridding the grassland of weeds and pests, promoting nutrient cycling, and encouraging the growth of new grasses for animal grazing. Savanna burning releases methane, carbon monoxide (CO), nitrous oxide, oxides of nitrogen and non-methane volatile organic compounds (NMVOCs).

Methodology

Emissions from savanna burning are estimated by using the equations based on it in the Revised 1996 IPCC guidelines.

STEP1

*Biomass Burned (t dm) = Area of savanna burned annually * Aboveground Biomass Density (t dm/ha)*

STEP2

*Carbon Released from Live Biomass (t C) = Biomass burned (t dm)*Fraction that is live*Fraction Oxidized*Carbon Content of Live Biomass (t C/t dm)*

STEP3

*Carbon Released from Dead Biomass (t C) = Biomass burned (t dm)*Fraction that is dead*Fraction Oxidized*Carbon Content of Dead Biomass (t C/t dm)*

STEP4

Total Carbon Released (t C) = C Released from Live Material (t C) + C Released from Dead Material (t C)

*CH_4 Emissions = Carbon Released * emission ratio * 16/12*
*N_2O Emissions = Carbon Released * N/C ratio * emission ratio * 44/28*
*CO Emissions = Carbon Released * emission ratio * 28/12*
*NOx Emissions = Carbon Released * N/C ratio * emission ratio* *46/14

Activity data

In Vietnam, there are two kind of savanna type, one is shrub land and the other is grass.

Table 2.61. Area of savanna burned

Type of land	**Year**
Grassland	
Shrub land	

Aboveground Biomass Density

The aboveground biomass density is country-specific values taken from "Research of carbon stock of vegetation and shrubs: basis for determining baseline of carbon forestry project /reforestation clean development mechanism in Viet nam" by Dr. Vũ Tấn Phương. Research undertaken by Research Centre for Forest Ecology and Environment (RCFEE) and Japan Overseas Forestry Consultants Association (JOFCA) in 2004 in Cao Phong and Lac Son districts of Hoa Binh province and Ha Trung, Thanh Thanh and Ngoc Lac districts of Thanh Hoa province.

Table 2.62. Aboveground Biomass Density estimated

Shrub savanna	(t/ha)
Erianthus arundinaceus	20
height is 2-3m	14
height is below 2m	10
Average	**14.67**

Grass savanna	(t/ha)
grass Oplismenus compositus	6.5
Imperata cylindrica	4.9
Lophopogon intermedius	4
Average	**5.1**

Fraction of biomass actually burned

The fraction of biomass actually burned is the default range (0.80-0.85) of the Revised 1996 IPCC guidelines.

The lowest value of the default range is used for shrub savanna, and the highest value is used for grass land.

Table 2.63. Fraction of biomass actually burned for shrub savanna and grass land savanna

Type of Savanna	Fraction of biomass actually burned	Data source
Shrub savanna	0.8	Lowest value of the default range in the Revised 1996 IPCC guidelines, Reference Manual (page 4.79).
Grass land	0.85	Highest value of the default range in the Revised 1996 IPCC guidelines, Reference Manual (page 4.79).

Fraction Oxidized and Carbon Fraction

The data of fraction oxidized and carbon fraction of living and dead biomass are the default values in the Revised 1996 IPCC guidelines.

Table 2.64. Fraction Oxidized and Faction Carbon of living and dead biomass

	Fraction Oxidized	Carbon Fraction
Living Biomass	0.80	0.45
Dead Biomass	1.00	0.40

Source: Revised 1996 IPCC Guidelines – Workbook (Table 4-13)

Emission factor

Emission factors of each gas from savanna burning are the default values of the Revised 1996 IPCC guidelines.

Table 2.65. Emission ratios for savanna burning calculations

Compound	Emission ratios	Data source
CH_4	0.004	Revised 1996 IPCC guidelines for National GHG Inventories: Workbook, page 4.80
CO	0.06	
N_2O	0.007	
NOx	0.121	

The N/C ratio to convert from total carbon released to total nitrogen content released is the default value of the Revised 1996 IPCC guidelines (0.006).

đ) Field Burning of Agricultural Residues (CH_4, N_2O, NOx, CO, NMVOC) – (4F)

Where there is open burning associated with agricultural practices, GHGs are emitted from combustion of the organic matter. GHG emissions from burning of crop residues for purposes of disposal and reduction of the volume of agricultural waste is covered in this section.

Methodology

The methodology is based on 1) total carbon released, which is a function of the amount and efficiency of biomass burned and the carbon content of the biomass and 2) the application of emission ratios of CH_4 and CO to total carbon released and of N_2O and NO_x to total nitrogen released from biomass fires.

Total carbon (nitrogen) released (t-C or t-N) =
** Annual production by each crop (t)*
** the ratio of residue to crop product (fraction)*
** the average dry matter fraction of residue (t-dry matter/t- biomass)*
** the fraction actually burned in the field*
** the fraction oxidized*

** the carbon fraction (t-C/t-dry matter) or the nitrogen fraction (t-N/t-dry matter)*

$$CH_4 \text{ Emissions} = \text{Carbon Released} * \text{emission ratio} * 16/12$$
$$CO \text{ Emissions} = \text{Carbon Released} * \text{emission ratio} * 28/12$$
$$N_2O \text{ Emissions} = \text{Nitrogen Released} * \text{emission ratio} * 44/28$$
$$NOx \text{ Emissions} = \text{Nitrogen Released} * \text{emission ratio} * 46/14$$

Activity data

Annual production by each crop

The data of crop production is taken from Statistical Yearbook of General Statistical Office and FAOSTAT.

Table 2.66. Crop production

Crop type	N-fixing crop	Production (thousand tonnes)	Data source
Maize			
Rice			
Millet			
Soybeans			
Potatoes			
Sweet Potato			
Cassava			
Sugar Cane			
Peanut			
Beans			
Cotton			
Jute			
Papyrus			
Sesame			
Tobacco			

Ratio of residue to crop product

The ratio of residue to crop product by each crop type is taken from the default value of the GPG2000 and Revised 1996 IPCC guidelines.

Table 2.67. Ratio of residue to crop product

Crop type	Residue to Crop product	Data source
Maize	1	Table 4-16, GPG2000
Rice	1.4	Table 4-16, GPG2000
Millet	1.4	Table 4-16, GPG2000
Soybeans	2.1	Table 4-16, GPG2000
Potatoes	0.4	Table 4-16, GPG2000
Sweet Potato	0.4	Same value as potatoes
Cassava	0.4	Same value as potatoes
Sugar Cane	0.2	Table 4-17, Revised 1996 IPCC guidelines The value of sugar beet is used.
Peanut	1	Table 4-16, GPG2000
Beans	2.1	Table 4-16, GPG2000
Cotton	2.76	
Jute	2	
Papyrus	1	
Sesame	2.1	
Tobacco	1	

Dry matter fraction

The dry matter fraction of each crop type to convert from the amount of production in wet matter base to dry matter base is taken from the GPG2000 and Revised 1996 IPCC guidelines.

Table 2.68. Dry matter fraction of each crop type

Crop type	Dry matter fraction	Data source
Maize	0.78	Median value of the range in GPG2000, Table4-16
Rice	0.85	Median value of the range in GPG2000, Table4-16
Millet	0.885	Median value of the range in GPG2000, Table4-16
Soybeans	0.865	Median value of the range in GPG2000, Table4-16
Potatoes	0.45	Median value of the range in Revised 1996 IPCC guidelines, Table4-17
Sweet Potato	0.45	The value of potatoes is used.
Cassava	0.45	The value of potatoes is used.
Sugar Cane	0.15	Median value of the range of sugar beet in Revised 1996 IPCC guidelines, Table4-17

Peanut	0.86	GPG2000, Table4-16
Beans	0.86	Median value of the range in GPG2000, Table4-16
Cotton	0.93	US GHG Inventory Report for the period 1990-2014 (published April 2004)
Jute	0.86	Bangladesh Climate Change Report (2010)
Papyrus	0.85	The value of Rice is used
Sesame	0.87	The value of Tobacco is used
Tobacco	0.87	US GHG Inventory Report for the period 1990-2014 (published April 2004)

Fraction Burned in the field

The fraction burned in the field by each crop is taken from the expert judgment in the preparation of the SNC and the default value of developing country of the Revised 1996 IPCC guidelines (0.25).

Table 2.69. Fraction Burned in the field

Crop type	Value	Data source
Maize	0.3	Expert judgment in the preparation of SNC
Rice	0.55	Expert judgment in the preparation of SNC
Millet	0.25	The default value of developing country, page4.83 of Revised 1996 IPCC guidelines.
Soybeans	0.25	The default value of developing country, page4.83 of Revised 1996 IPCC guidelines.
Potatoes	0.25	The default value of developing country, page4.83 of Revised 1996 IPCC guidelines.
Sweet Potato	0.1	Expert judgment in the preparation of SNC
Cassava	0.35	Expert judgment in the preparation of SNC
Sugar Cane	0.6	Expert judgment in the preparation of SNC
Peanut	0.35	Expert judgment in the preparation of SNC
Beans	0.25	Giá trị mặc định cho nước đang phát triển, trang 4.83, Hướng dẫn của IPCC bản sửa đổi năm 1996
Cotton	0.25	The default value of developing country, page4.83 of Revised 1996 IPCC guidelines.
Jute	0.25	The default value of developing country, page4.83 of Revised 1996 IPCC guidelines.
Papyrus	0.25	The default value of developing country, page4.83 of Revised 1996 IPCC guidelines.
Sesame	0.25	The default value of developing country, page4.83 of Revised 1996 IPCC guidelines.
Tobacco	0.25	The default value of developing country, page4.83 of Revised 1996 IPCC guidelines.

Fraction Oxidized

The data of fraction oxidized is the default value of the Revised 1996 IPCC guidelines (0.9).

Carbon fraction of residues

The data of carbon fraction of residues by each crop type is the default value of GPG2000 and Revised 1996 IPCC guidelines.

Table 2.70. Carbon fraction of residues

Crop type	Value	Data source
Maize	0.4709	Table 4-16, GPG2000
Rice	0.4144	Table 4-16, GPG2000
Millet	0.5	Default value of Revised 1996 IPCC guidelines, Workbook, page4.30
Soybeans	0.5	Default value of Revised 1996 IPCC guidelines, Workbook, page4.30
Potatoes	0.4226	Table 4-16, GPG2000
Sweet Potato	0.4226	The value of potatoes is used
Cassava	0.5	Default value of Revised 1996 IPCC guidelines, Workbook, page4.30
Sugar Cane	0.4235	Table 4-16, GPG2000
Peanut	0.5	Default value of Revised 1996 IPCC guidelines, Workbook, page4.30
Beans	0.5	Default value of Revised 1996 IPCC guidelines, Workbook, page4.30
Cotton	0.45	Default value of Global Value (page 4.82 - IPCC 1996))
Jute	0.45	
Papyrus	0.45	
Sesame	0.45	
Tobacco	0.45	

Nitrogen fraction of residues

The data of nitrogen fraction of residues by each crop type is set based on the data provided by SFRI.

Table 2.71. Nitrogen fraction of residues

Crop type	value	Reference
Maize	0.008	Le Van Can, 1975. Fertilizer hand book
Rice	0.004	Le Van Can, 1975. Fertilizer hand book
Millet	0.007	GPG2000, Table4.16
Soybeans	0.010	Average of Residue of soybean (Fertilizer Hand Book, Soils and Fertilizer Research Institute, Agricultural Publish House, 2009) and Stem, leaf, husk, unfill pruit in maturial soybean (Cao Ky Son, 2002, Viet Nam)

Potatoes	0.003	Le Van Can, 1975. Fertilizer hand book
Sweet Potato	0.003	The value of potato is used.
Cassava	0.016	Average of Leaf of maturial cassava (Fertilizer Hand Book, Soils and Fertilizer Research Institute, Agricultural Publish House, 2005 refere by Cours (1951 - 1953)) and Stem of maturial cassava (C.J Asher, D.G.Edwards và R.H.Howeler (1980))
Sugar Cane	0.004	GPG2000, Table4.16
Peanut	0.019	Average of Leaf of maturial peanut (Wang Zaixu, 1982; Cai Changbei, 1988 - China) and Stem of maturial peanut (Wang Zaixu, 1982; Cai Changbei, 1988 - China) and Stem, leaf, husk, unfill pruit in maturial peanut (Cao Ky Son, 2002, Viet Nam)
Beans	0.010	The value of soybeans is used
Cotton	0.00675	Estimated from the value of the ratio of N/C in the residues and the value of C in the residues. The value of the ratio of N/C in the residues is taken according to the global value (Gloabal value) (page 4.83 – 1996 IPCC)
Jute	0.00675	
Papyrus	0.00675	
Sesame	0.00675	
Tobacco	0.00675	

Emission factor

Emission factors of each gas from agricultural residues are the default values of the Revised 1996 IPCC guidelines.

Table 2.72. Emission ratios for agricultural residues burning calculations

Compound	Emission ratios	Data source
CH_4	0.005	Revised 1996 IPCC guidelines for National GHG Inventories: Workbook - Page 4.84
CO	0.06	
N_2O	0.007	
NOx	0.121	

2.5. GHG inventory for Land-use, Land-use Change and Forestry Sector

2.5.1. Overview

The land use, land-use change, and forestry (LULUCF) sector deals with GHG emissions and removals resulting from land use such as forestry activities and land-use change. GPG-LULUCF suggests to classify its national land into six categories—Forest land, Cropland, Grassland, Wetlands, Settlements, and Other land—and subdivides each of them into two subcategories by distinguishing them on the basis of whether or not land conversion has been occurred.

GHG emissions and removals in this sector consist of carbon stock changes in five carbon pools (aboveground biomass, belowground biomass, dead wood, litter, and soil), direct N_2O emissions from N fertilization, N_2O emissions from drainage of soils, CO_2 emissions from agricultural lime application, and non-CO_2 emissions from biomass burning. In this chapter, above- and below ground biomass are referred to collectively as "living biomass", and dead wood and litter collectively as "dead organic matter".

Table 2.73. Land use change area matrix in a period

Changing period (x-y)		F	C	C	C	G	W	S	O	ha
To / From		Forest land	Rice field	Annual crop	Perennial crop	Grassland	Wetlands	Settlements	Other land	Total
Forest land	F									
Rice Field	Cr									
Annual crop	Ca									
Perennial crop	Cp									
Grassland	G									
Wetlands	W									
Settlements	S									
Other land	O									
Total										

Table 2.74. GHG emission/sink categories in LULUCF sector

GHG EMISSION SOURCE AND SINK CATEGORIES		Total CO_2eq	Net CO_2 emissions from living biomass	CO_2 from dead organic matter	Net CO_2 emissions from soils	CH_4	N_2O
LULUCF							
A. Forest Land	Total						
	1. Forest Land Remaining Forest Land						
	2. Land Converted to Forest Land						
B. Cropland	Total						
	1. Cropland Remaining Cropland						
	2. Land Converted to Cropland						
C. Grassland	Total						
	1. Grassland Remaining Grassland						
	2. Land Converted to Grassland						
D. Wetlands	Total						
	1. Wetlands Remaining Wetlands						
	2. Land Converted to Wetlands						
E. Settlements	Total						
	1. Settlements Remaining Settlements						
	2. Land Converted to Settlements						
F. Other Land	Total						

GHG EMISSION SOURCE AND SINK CATEGORIES		Total CO_2eq	Net CO_2 emissions from living biomass	CO_2 from dead organic matter	Net CO_2 emissions from soils	CH_4	N_2O
	1. Other Land Remaining Other Land						
	2. Land Converted to Other Land						

Data source

Activity data

Table 2.75. Data sources of activity data of LULUCF

IPCC Category	Activity Data(AD)	AD Data Source	Publishing Frequency
5.A. Forest Land	Forest area and volume	Forest area by province from the Forestry Protection Department (FPD).	annually
		Forest area and volume in each forest type for eight eco region from Forestry Inventory and Planning Institute (FIPI)	Every five years (Not published)
5.B. Cropland	Area of perennial crop	General Statistics Office (GSO)	annually
5.A.2- 5.F.2 Land converted to other land use category	Area of land conversion	Calculated from the land use matrix of the GDLA	Every five years

Parameters

- Land remaining same land uses categories

See sections "forest land remaining forest land" and "cropland remaining cropland" for details.

- Land converted to other land uses categories

To estimate carbon stock changes by land conversion, the following parameters are applied. The parameters are derived from appropriate default values provided in IPCC guidelines because country specific information is not available enough for the case of land conversion.

Table 2.76. Parameters of living biomass for calculation of land conversion

Land use		Value	Unit	Source or rational
Before conversion				
Forest land		IE (included in forest land remaining forest land estimation)		
Cropland	Annual cropland	5	tC/ha	Table 3.3.8, Annual cropland
	Perennial cropland	21	tC/ha	Table 3.3.2, Tropical, wet
Grassland		20	t-d.m./ha	*2
	Carbon Fraction	0.4	tC/t-d.m.	GPG LULUCF
Other land use categories		0	tC/ha	Assumed as zero
After conversion				

All land use categories		0	tC/ha	Default assumption in GPG
Carbon stock in biomass after one year				
Forest land		IE (included in forest land remaining forest land estimation)		
Cropland	Annual cropland	5	tC/ha/yr	Table 3.3.8, Annual cropland
	Perennial cropland	2.6	tC/ha/yr	Table 3.3.8, Perennial cropland, Tropical, moist
Grassland	Aboveground net primary production	8.2	t-d.m./ha/yr	Table 3.4.2, Tropical – Moist &Wet
**1: All tables referred here are from Chapter 3, GPG-LULUCF.* **2: Calculated value by National study in 2004, Table 2, Study on carbon stock of living biomass and shrub: the basis to identify the carbon baseline in afforestation/reforestation projects according to CDM in Vietnam* .				

Table 2.77. Parameters of dead organic matter for calculation of land conversion

Item	Value	Unit	Source
Litter stock in forest land	3	t-C/ha	Table 3.2.1 GPG-LULUCF, (litter carbon stock of mature forest, tropical, Broadleaf Deciduous) , upper limit
Dead wood stock in forest land	18.6	t-d.m./ha	Table 3.2.2 GPG-LULUCF, (Average (median) dead wood stock of tropical forest)
DOM stock in non forest land	0	t-C/ha	Established taking into account each Tier.1 method in GPG-LULUCF

Source: Chapter 3, GPG-LULUCF *

2.5.2. Emission estmation

2.5.2.1. Forest land – (5A)

a) Forest land remaining Forest land – (5A1)

Forest land remaining forest land category involves estimation of changes in carbon stock from five carbon pools (i.e. aboveground biomass, belowground biomass, dead wood, and soil organic matter), as well as emissions of non-CO_2 gases from forest fire.

Carbon Stock Change in living biomass

Methodology

Equation (Gain Loss method):

$$\Delta C = (C_{Gain} - C_{Loss})$$

Where:
ΔC: annual change in carbon stocks in living biomass, tones C yr^{-1}
C_{Gain}: annual increase in carbon stocks due to biomass growth, tones C yr^{-1}
C_{Loss}: annual decrease in carbon stocks due to biomass loss, tones C yr^{-1}

$$C_{Gain} = A * G * CF,$$

Where:

A: area of land calculated, ha
G: average annual increment rate in total biomass in units of dry matter, tone d.m. ha^{-1} yr^{-1}
CF: carbon fraction of dry matter, tones C (tone d.m.)$^{-1}$

$$G = G_W * (1 + R), G_W = I_V * BCEFi$$

G_W: average annual above-ground biomass increment, tone d.m. ha^{-1} yr^{-1}
R: ratio of below ground biomass to above ground biomass (root-to-shoot ratio), dimensionless
I_V: average annual net increment in volume for specific vegetation, m^3 ha^{-1} yr^{-1}
BCEFi (= D*BEFi): biomass conversion and expansion factor for expansion of net annual increment in volume (including bark) to above ground biomass growth, tones d.m. $(m^3)^{-1}$, equivalent to basic wood density multiple biomass expansion factor

$$C_{Loss} = L_{wood-removals} + L_{fuelwood} + L_{other\ losses}$$

$L_{wood-removals}$: annual carbon loss due to biomass removals, tones C yr^{-1}
$L_{fuelwood}$: annual carbon loss due to fire wood gathering, tones C yr^{-1}
$L_{other\ loss}$: annual other loss of carbon, tones C yr^{-1}

$$L_{wood-removals} = H * BCEFr * (1 + R) * CF, \qquad L_{fuelwood} = FG * D * CF,$$

$$L_{other\ losses} = A_{disturbance} * B_W * (1 - f_{BL}) * CF$$

H: annual wood removals, roundwood, m^3 yr^{-1}
FG: annual volume of fire wood gathered, m^3 yr^{-1}
BCEFr (= D*BEFr): biomass conversion and expansion factor for conversion of removals in merchanrable volume to biomass removals (including bark), tones d.m. $(m^3)^{-1}$, equivalent to basic wood density multiple biomass expansion factor
D: wood density, tones d.m. $(m^3)^{-1}$
$A_{disturbance}$: area affected by disturbance, ha
B_W: average annual above-ground biomass of land areas affected by disturbance, tone d.m. ha^{-1} yr^{-1}
fd: fraction of biomass lost in disturbance

Activity data

Table 2.78. Source of activity data for Forest land remaining Forest land

Data	Method	Value	Unit	Data source
Forest Area	SC GL-Gain			
Stocking volume per ha in forest land	SC			
Amount of commercial timber harvesting –all	GL-Loss			
Amount of commercial timber harvesting -all -natural forest	GL-Loss			
Amount of commercial timber harvesting -all -plantation forest	GL-Loss			
Illegal logging	GL-Loss			
Fuelwood gathering	GL-Loss			
Area of fire in forest	GL-Loss			
Area of destroyed forest	GL-Loss			
Area of forest land converted to other land use	GL-Loss			

<u>Categorization of forest type</u>

Forest is divided into nine types; evergreen, deciduous, needleleaf, mixed broadleaf and needleleaf, bamboo, mixed wood and bamboo, rocky mountainous, mangrove and plantations. The natural wood forest category is further divided into four sub-categories based on the stock level based on the original dataset at the time of the year 2010 which is from the General Forest Inventory and Statistic Project of Cycle IV (2006-2010) following Decision 1828/QD-BNN-TCLN dated 11 August 2011. In 2010 inventory, Natural forests in 2005 and 2010 were classified according to Circular No. 34/2009/TT-BNNPTNT, which classifies natural forests into the following statuses:

a) Very rich: average volume stock above 300 m3/ha;

b) Rich: average volume stock above in the range 201- 300 m3/ha;

c) Medium: average volume stock above in the range 101 - 200 m3/ha;

d) Poor: average volume stock above in the range 10 - 100 m3/ha;

đ) Forest without volume stock: timber forest having average DBH < 8 cm and volume stock < 10 m^3/ha

However, by 2013, since the National Forest resources Inventory, Assessment and Monitoring Programme (2006-2010) has ended, no data has been collected on 9 forest categories classified as in 2010. It should be based on the area of forest collection from the Forestry Protection Department (FPD), the forest types are divided into 7 categories: (1) wood forest, (2) bamboo forest, (3) mixed forest, (4) mangrove forest, (6) planted forest, (7) forested land without trees. For types of forest from (1) to (6), use the forest area activity data provided by the FPD in the Forests Status Book 2013, published in 2014. For Forest Type (7), this is considered to be the difference between the forest land use matrix of the Vietnam Remote Sensing Center and the FPD.

Forest area data

Table 2.79. Forest and Land converted to Forest land

Area	Land use change	Sign	Forest type	Area (ha)
National total	Remaining Forest Land	FF	Bamboo forest	
			Non tree forest soils	
			Mangrove forest	
			Mixed forest	
			Planted forest	
			Rocky mountainous forest	
			Wood forest	
National total	Cropland converted to Forest land	CF	Bamboo forest	
			Non tree forest soils	
			Mangrove forest	
			Mixed forest	
			Planted forest	
			Rocky mountainous forest	
			Wood forest	
National total	Grassland converted to	GF	Bamboo forest	

Area	Land use change	Sign	Forest type	Area (ha)
	Forest land		Non tree forest soils	
			Mangrove forest	
			Mixed forest	
			Planted forest	
			Rocky mountainous forest	
			Wood forest	
National total	Settlements converted to Forest land	SF	Bamboo forest	
			Non tree forest soils	
			Mangrove forest	
			Mixed forest	
			Planted forest	
			Rocky mountainous forest	
			Wood forest	
National total	Other land converted to Forest land	OF	Bamboo forest	
			Non tree forest soils	
			Mangrove forest	
			Mixed forest	
			Planted forest	

Area	Land use change	Sign	Forest type	Area (ha)
			Rocky mountainous forest	
			Wood forest	
National total	Wetlands converted to Forest land	WF	Bamboo forest	
			Non tree forest soils	
			Mangrove forest	
			Mixed forest	
			Planted forest	
			Rocky mountainous forest	
			Wood forest	
National total	**Total**			

b) Land converted to Forest land – (5A2)

In GPG-LULUCF, land converted within past 20years (=the default transition period of soil carbon stock change due to land conversion) is considered as converted land.

Carbon stock change in living biomass

Similar to calculate changes in carbon stock of living biomass of " Forest Land Remaining Forest Land - (5A1)", using the gain-loss method to calculate changes in carbon stock of living biomass of "Land Converted to Forest Land - (5A2)". Conversion from other land types to forest land will result in increased carbon stocks in living biomass. All carbon stock change due to Land converted to Forest Land was calculated in Section “Forest land remaining Forest land” and reported as “Included Elsewhere (IE)”.

Parameters and activity data on the area of land converted to forest land is similar to that calculated for carbon stocks change in living biomass

Carbon stock change in dead organic matter

In GPG-LULUCF, Tier.1 (default) assumed no change in dead wood carbon and litter carbon in land converting to forest. Since there is no detailed information and dead organic matter pool is expected not significant in Vietnam, Tier.1 was applied and carbon stock change is assumed to be zero.

Carbon stock change in soil

Carbon stock change in mineral soil is no data. CO_2 emission from organic soil is treated as IE because forest land remaining forest land already covers the relevant emission.

Non-CO2 gas emissions from forest fire

All carbon stock change due to forest fire occurred in Land converted to Forest Land was calculated in Section “Forest land remaining Forest land” and reported as “Included Elsewhere (IE)”.

2.5.2.2. Cropland – (5B)

In Category 5B., emissions/removals are occurred in biomass carbon stock change of perennial crop, in biomass and mineral soil carbon stock changes. CO_2 emissions from lime application and oxidation of peat soil due to cultivation or drainage of histosol are also included in the total emissions in category 5B.

a) Cropland remaining Cropland – (5B1)

In this category, carbon stock changes for perennial crop due to growth of living biomass and CO_2 emissions from peat soil used as agricultural production are estimated. Carbon stock changes in dead wood and litter are assumed as not occurred (Tier.1) at cropland remaining cropland areas. Carbon stock in mineral soil organic carbon is assumed not changed (Tier.1) because of lack of information represent long term change in Vietnam.

Carbon stock changes in living biomass for perennial cropland

Methodology and parameters

Tier.1 methodology was used based on Equation 3.2.2 of the GPG-LULUCF and parameters provided in Table 3.3.2 Tropical Moist. (Above-ground biomass carbon stock at harvest: 21 tC/ha, Harvest/Maturity cycle 8 yr, Biomass accumulation rate: 2.6 tC/ha/yr). Perennial crop planted within 8 year are assumed to increase and that over 9 years reach steady state of carbon stock. The threshold of 8 year is based on default maturity cycle provided in Table 3.3.2. No removals/Harvested area was assumed.

Activity data

Activity data in this calculation is area considered newly planted perennial crop within 8 years. That is the annual area data of perennial cropland (fruit tree and industrial perennial crop).

Table 2.80. Area of perennial crop and the estimated removal

Perennial crop area	Unit	GHG inventory in year
8 years ago	kha	
Inventory year	kha	
Increased area within 8 years	kha	
Area regarded steady state	kha	
Removals estimated	kt-CO_2	

Emissions from Organic soil

Carbon stock in mineral soil organic carbon is assumed not changed (Tier.1) because of lack of information represent long term change in Vietnam

Carbon stock change in organic soil

According to the national report estimating GHG emissions from peat soil in Vietnam (Vu et al, 2011), some peat soil area in Vietnam is used as agricultural production and emissions from oxidation by decline of ground water table occurred.

b) Land converted to Cropland – (5B2)

Annual carbon stock changes in living biomass and dead organic matter (from forest land to cropland only) are estimated. In addition, GHG emissions due to on-site biomass burning associated with deforestation (forest land converted to cropland) are estimated as well.

Carbon stock changes in living biomass

Methodology

The Tier 1 method is applied for "Land converted to Cropland" using the IPCC default values of annual growth rate of cropland and the peak above-ground living biomass of grassland. Forest land carbon loss is supposed to be included in Stock change method. In order to calculate the carbon stock per hectare before the conversion, the following equations are used: (Equation 3.2.4 and 3.2.5 of GPG-LULUCF).

Parameters

The values shown in Table 2.81 are used for the estimation of biomass stock changes upon land-use conversion (i.e. peak above-ground living biomass) and subsequent changes in biomass stock due to biomass growth in the converted land (i.e. annual growth rate of annual and perennial cropland). The annual growth rate of paddy field is 0 because GPG-LULUCF does not have default value.

Activity data

Table 2.81. The area of forest land converted into cropland for calculating living biomass lost from the forest

Before converting		After converting	Area (ha)
Category	Sub-category	Category	
Forest land	Wood forest	Cropland	
	Bamboo forest		
	Mixed forest		
	Mangrove forest		
	Rocky mountainous forest		
	Plantation forest		

Table 2.82. The area of forest land converted into cropland for calculating living biomass gain/loss after converting into cropland

Before converting	After converting		Area (ha)
Category	Category	Sub-category	
Forest land	Cropland	Paddy	
		Annual	
		Perennial	

Before converting	After converting		Area (ha)
Category	**Category**	**Sub-category**	
Grassland	Cropland	Paddy	
		Annual	
		Perennial	
Wetlands	Cropland	Paddy	
		Annual	
		Perennial	
Settlements	Cropland	Paddy	
		Annual	
		Perennial	
Other land	Cropland	Paddy	
		Annual	
		Perennial	

Carbon stock changes in Dead Organic matter

Methodology

$$\Delta C = A_{Conversion} * (C_{new} - C_{old})/T$$

$A_{Conversion}$: area of land converted during the transition period, ha
C_{new}: carbon stock, under the new land use category, tones C ha^{-1}
C_{old}: carbon stock, under the old land use category, tones C ha^{-1}
T: time period of the transition period from old to new

Activity data (area)

The activity data is the annual area of land conversion which is also used in living biomass calculation.

Carbon stock changes in Soil Organic matter

Carbon stock change in mineral soil is no data. CO_2 emission from organic soil is treated as IE because cropland remaining cropland already covers the relevant emission.

Non-CO_2 gas emission

GHG emissions from biomass burning due to forest land conversion are calculated. N_2O emission from mineralization associated with land conversion to cropland is reported as NE because the relevant estimation of carbon loss in mineral soil in land converted to cropland is presented as only preliminary estimation at this moment.

2.5.2.3. Grassland – (5C)

In Category 5.C, the carbon stock changes in living biomass pool in shrub and grass vegetation in grassland remaining grassland and in land converted to grassland are calculated. Organic soils area is unused in Vietnam for grazing purpose and do not occur in the grassland category, and carbon stock changes in dead wood and litter are assumed as not occurring at grassland areas.

a) Grassland remaining Grassland – (5C1)

Methodology

Tier.1 was applied and assumes no carbon stock changes happened in dead organic matter and soil organic carbon.

For change of carbon stock in the living biomass in remaining grassland, using the Tier 1, carbon stock in the living biomass in remaining grassland will be stable (ie the carbon accumulation through plant growth balanced with losses through decomposition and fires). Therefore, Type 1 method assumes that there is no change in carbon stocks of living biomass in remaining grassland.

b) Land converted to Grassland – (5C2)

Carbon stock changes in Living Biomass and dead organic matter are estimated. Non-CO_2 emissions due to on-site biomass burning associated with forest land converted to grassland are estimated as well.

Carbon stock changes in living biomass

Methodology and parameters

The same methodology for land converted to cropland is applied.

Table 2.83. The area of forest land converted into grassland for calculating living biomass lost from the forest before converting

Before converting		After converting	Area (ha)
Category	Sub-category	Category	
Forest land	Wood forest	Grassland	
	Bamboo forest		
	Mixed forest		

Before converting		After converting	Area (ha)
Category	Sub-category	Category	
	Mangrove forest		
	Rocky mountainous forest		
	Plantation forest		

Source: Estimated based on data from FPD, MARD, 2013

Bảng 2.84. The area of forest land converted into grassland for calculating living biomass gain/loss after converting into grassland

Before converting		After converting	Area (ha)
Forest land		Grassland	
Cropland	Paddy	Grassland	
	Annual	Grassland	
	Perennial	Grassland	
Wetlands		Grassland	
Settlements		Grassland	
Other land		Grassland	

Carbon stock changes in Dead Organic matter (DOM)

The common approach to land conversion section is applied. See land converted to cropland section.

Carbon stock changes in soil

Mineral soil carbon stock change is not estimated. Organic soil does not exist on grassland category in Vietnam and treated as NE.

Non-CO_2 gas emissions

GHG emissions from biomass burning due to forest conversion are calculated. See biomass burning section.

2.5.2.4. Wetlands – (5D)

According the GPG-LULUCF, wetlands consists on peatland (not used as other land uses) and flooded land. GHG emissions in flooded land remaining flooded land are treated as optional reporting. In Category 5.D, CO_2 emissions from organic soils (peat soil) and carbon stock changes in living biomass in land converted to wetland are estimated.

a) Wetlands remaining Wetlands – (5D1)

Peatland in Vietnam distributed in Red River Delta, Mekong Delta, Central coastal area and some south-east provinces. Peatland is mostly distributed in Mekong delta, particularly in two provinces Kiên Giang and Cà Mau.

CO_2 emissions from peat soil

A country specific study performed in 2011 identified the sources emission including peatland fires (biomass and peat burning), peatland oxidation by decline of groundwater table during dry season and peat exploitation. As no peatland fire considered occurred in the years 2005 and 2010 in Vietnam, the result of CO_2 emission estimation from peatland oxidation and peat exploitation in the report are used to report GHG inventory. As the research was conducted in two main provinces (share of peat area is about 92% in Vietnam), the estimation result in the report (629 kt-CO_2) was expanded by using the total peat land area in Vietnam.

N_2O emissions from peat soil

N_2O emissions from drainage in non agriculture land uses are covered by LULUCF category.

b) Land converted to Wetlands – (5D2)

Only carbon stock changes in Living Biomass, dead organic matter is estimated. The carbon stock changes in mineral soils have not been estimated due to no estimation method provided in GPG-LULUCF and lack of data.

Carbon stock changes in living biomass

Methodology

The same methodology for cropland is applied. In wetlands, it is assumed no biomass growth occurred after conversion.

Activity data (area)

Table 2.85. The area of forest land converted into wetlands for calculating living biomass lost from the forest before converting

Before converting		After converting	Area (ha)
Category	Sub-category	Category	

Before converting		After converting	Area (ha)
Category	Sub-category	Category	
Forest land	Wood forest	Wetlands	
	Bamboo forest		
	Mixed forest		
	Mangrove forest		
	Rocky mountainous forest		
	Plantation forest		

Table 2.86. The area of forest land converted into wetlands for calculating living biomass gain/loss after converting into wetlands

Before converting		After converting	Area (ha)
Forest land		Wetlands	
Cropland	Paddy	Wetlands	
	Annual	Wetlands	
	Perennial	Wetlands	
Grassland		Wetlands	

Carbon stock changes in Dead Organic matter

The common approach to land conversion section is applied. See land converted to cropland section.

Carbon stock changes in organic soil

Since GPG-LULUCF provide no methodology and data for soil pool in land converted to wetlands, any calculation is not performed and reported as NE.

Non-CO_2 gas emissions

GHG emissions from biomass burning due to forest conversion are calculated. See biomass burning section.

2.5.2.5. Settlements – (5E)

In Category 5.E, carbon stock changes in living biomass and dead organic matter in land converted to settlements are estimated.

a) Settlements remaining Settlements – (5E1)

The carbon stock changes in living biomass in "Settlements remaining Settlements" is not estimated because there is no national data about living biomass in Settlements. There are no methodologies and data about dead organic matter and soil of this category provided in GPG-LULUCF. Those two pools are reported as NA, with assuming no carbon stock changes occurred.

b) Land converted to Settlements – (5E2)

Carbon stock changes in Living Biomass and dead organic matter are estimated. The carbon stock changes in Soils have not been estimated due to no estimation method provided in GPG-LULUCF and lack of data.

Carbon stock changes in living biomass

Methodology

The same methodology for cropland is applied. In settlements, it is assumed no biomass growth occurred after conversion.

Activity data (area)

Table 2.87. The area of forest land converted into settlements for calculating living biomass lost from the forest before converting

Before converting		After converting	Area (ha)
Category	**Sub-category**	**Category**	
Forest land	Wood forest	Settlements	
	Bamboo forest		
	Mixed forest		
	Mangrove forest		
	Rocky mountainous forest		
	Plantation forest		

Table 2.88. The area of forest land converted into settlements for calculating living biomass gain/loss after converting into settlements

Before converting		After converting	Area (ha)
Forest land		Settlements	
Cropland	Paddy	Settlements	
	Annual	Settlements	
	Perennial	Settlements	

Before converting	After converting	Area (ha)
Grassland	Settlements	

Carbon stock changes in Dead Organic matter

The common approach to land conversion section is applied. See land converted to cropland section.

Carbon stock changes in organic soil

Since GPG-LULUCF provide no methodology and data for soil pool in land converted to settlements, this pool is reported as NE.

Non-CO_2 gas emissions

GHG emissions from biomass burning due to forest conversion are calculated. See biomass burning section.

2.5.2.6. Other land – (5F)

a) Other land remaining Other land – (5F1)

The carbon stock changes in living biomass in "Other land remaining Other land" is 0 because there is no living biomass in Other land.

b) Land converted to Other land – (5F2)

Only carbon stock changes in Living Biomass, dead organic matters are estimated. The carbon stock changes in Soils have not been estimated due to lack of data.

Carbon stock changes in living biomass

Methodology

The same methodology for cropland is applied. In wetlands, it is assumed no biomass growth occurred after conversion.

Activity data (area)

Table 2.89. The area of forest land converted into Other lands for calculating living biomass lost from the forest before converting

Before converting		After converting	Area (ha)
Category	Sub-category	Category	
Forest land	Wood forest	Other lands	
	Bamboo forest		
	Mixed forest		

Before converting		After converting	Area (ha)
Category	Sub-category	Category	
	Mangrove forest		
	Rocky mountainous forest		
	Plantation forest		

Bảng 2.90. The area of forest land converted into Other lands for calculating living biomass gain/loss after converting into Other lands

Before converting		After converting	Area (ha)
Forest land		Other lands	
Cropland	Paddy	Other lands	
	Annual	Other lands	
	Perennial	Other lands	
Grassland		Other lands	

Carbon stock changes in Dead Organic matter

The common approach to land conversion section is applied. See land converted to cropland section.

Thay đổi trữ lượng các-bon trong đất hữu cơ

Estimation is not performed.

Non-CO_2 gas emissions

GHG emissions from biomass burning due to forest conversion are calculated. See biomass burning section.

2.5.2.7. Other GHG emissions from LULUCF

a) Direct N_2O emissions from N fertilization – (5(I))

The direct N_2O emissions from N fertilization were calculated in the Agricultural sector. Thus this source is reported as “IE (Included Elsewhere)”.

b) N_2O emissions from drainage of soils – (5(II))

Drainage of managed peatsoil causes CH_4 and N_2O emissions from soil. Appendix of GPG-LULUCF provides the methodology estimating these gases on managed wet forest soil and peat extraction.

Methodology

Table 2.91. N_2O EF for wet forest soil and peat exploitation

Land category	EF (kg N_2O-N ha^{-1} yr^{-1})	
Wet forest soil	8	Table 3a.2.1, Tropical climate
Wetlands (peat exploitation)	18	Table 3a.3.4, Tropical climate

Source: GPG-LULUCF

c) N_2O emissions from disturbance associated with land-use conversion to Cropland – (5(III))

Enhanced mineralization (conversion to inorganic form) of soil organic matter normally takes place as result of land conversion to cropland. The mineralization results not only in a net loss of soil carbon but also in associated conversion of nitrogen previously in the soil organic matter to ammonium and nitrate and to give an increase in net N_2O.

As carbon stock change of mineral soil pool is not estimated, this N_2O emission is not estimated as well.

d) CO_2 emissions from agricultural lime application (5(IV))

Application of carbonate containing lime (CaCO3) or dolomite (MgCO3) to agriculture soils is a source of CO_2 emissions.

e) Biomass burning – (5(V))

The source of biomass burning is from forest fire (non-savanna only) and on-site burning associated with forest land conversion. The GHG emissions from biomass burning include CH_4, N_2O, NOx and CO. CO_2 is not included as it is already included in the stock change method.

Methodology

$$L_{fire} = A * B * C * D * 10^{-6}$$

Where:
L_{fire}: quantity of GHG released due to fire, tones of GHG
A: area burned, ha
B: mass of "available" fuel, kg d.m. ha^{-1}
C: combustion efficiency (or fraction of the biomass combusted), dimensionless
D: emission factor, g (kg d.m.)$^{-1}$

Parameter

Table 2.92. Emission factor of GHGs

Greenhouse gas	CH_4	CO	N_2O	NOx	Source

Emission factor (g /kg d.m.)	7.1	112	0.11	0.7	Table 3A.1.16
Gas emission ratio	0.012	0.06	0.007	0.121	Table 3A.1.15

Activity data (area)

Table 2.93. Activity data GHGs emissions from biomass burning

Item	Year	Source
Area of burned (ha)		
Area converted from forest land (ha) (50% of the converted area is burned)		

2.6. GHG inventory for Waste sector

2.6.1. Overview

The waste sector cover CO_2, CH_4 and N_2O from different sources included from waste disposal sites, wastewater treatment, human sewage and waste incineration.

Table 2.94. GHG emission sources in waste sector

Category	GHG emission (Gg)			
	CO_2	CH_4	N_2O	CO_2 eq
6A – CH_4 emission from solid waste disposal sites			/	
6B1 – CH_4 emission from industrial wastewater	/		/	
6B2 – CH_4 emission from domestic wastewater	/		/	
6B – N_2O emission from human sewage	/	/		
6C – CO_2 emission from waste incineration		/		
Total				

2.6.2. Emission estimation

2.6.2.1. Solid waste disposal Sites (CH_4) – (6A)

Methane is emitted during the anaerobic decomposition of organic waste disposed of in solid waste disposal sites (SWDS). Organic waste decomposes at a diminishing rate and takes many years to decompose completely.

Methodology

The Revised 1996 IPCC Guidelines provides two methods to estimate CH_4 emission from solid waste disposal sites, the default method and First

Order Decay (FOD) method. The default method is used when activity data is not available and CH_4 emission is calculated by using IPCC default values, per capita or other methods to estimate activity data.

The equations are used to calculate CH_4 emission from SWDs using FOD method as follows:

EQUATION 8.1

CH_4 generated in year t (Gg/yr) =

$$\sum_x \left[\left(A \bullet k \bullet MSW_T(x) \bullet MSW_F(x) \bullet L_0(x) \right) \bullet e^{-k(t-x)} \right]$$

for x = initial year to t

Where:

t = year of inventory

x = years for which input data should be added

A = $(1 – e^{-k})/k$; normalization factor which corrects the summation

k = Methane generation rate constant (1/yr)

$MSW_{T(x)}$ = Total municipal solid waste (MSW) generated in year x (Gg/yr)

$MSW_{F(x)}$ = Fraction of MSW disposed at SWDs in year x

$L_{0(x)}$ = Methane generation potential [$MCF_{(x)} \cdot DOC_{(x)} \cdot DOC_F \cdot F \cdot 16/12$ (Gg CH_4/Gg waste)

$MCF_{(x)}$ = Methane correction factor in year x (fraction)

$DOC_{(x)}$ = Degradable organic carbon (DOC) in year x (fraction)(Gg C/Gg waste)

DOC_F = Fraction of DOC dissimilated

F = Fraction by volume of CH_4 in landfill gas

16/12 = Conversion from C to CH_4

Sum the obtained results for all years (x)

EQUATION 8.2

CH_4 generated in year t (Gg/yr) = [CH_4 generated in year t – R(t)] . (1-OX)

OX)

Where:

R(t) = Recovered CH4 in inventory year t (Gg/yr)

OX = Oxidation factor (fraction)

Activity data

- Municipal solid waste

Table 2.95. Amount of urban solid waste disposed in landfill sites estimated from year X to year Y

Years	Population in urban area (1,000	Generation factor (kg/capita/day)	Fraction of urban solid waste disposal sites (%)	Total (ton)

	persons)			
X				
….				
Y				

Data on urban solid waste disposed at landfill sites is collected from the environment status reports of provinces/cities and is shown in the table below.:

Table 2.96. Amount of urban solid waste disposed in landfill sites

Year	Amount (ton/yr)
X	
…	
Y	

(Source: Environment status reports of provinces/cities*)*

Table 2.97. Composition of waste

No.	Composition of waste	Rate (%)
1	Food, organic	59.24
2	Garden	2.76
3	Paper	2.7
4	Wood	1.05
5	Textile	3.30
6	Nappies	0.01
7	Plastic, other inert	30.94

Table 2.98. Amount of rural solid waste disposed in landfill sites

Years	Population in rural area (1,000 persons)	Generation factor (kg/capita/day)	Fraction of rural solid waste disposal sites (%)	Total (thous. ton)

Industrial solid waste

For industrial solid waste, activity data were aggregated, collected from five-year (2006 to 2010) environmental status reports by provinces, which showed that the volume of about 3.29 million tonnes conventional industrial solid waste was handled at the landfill sites in 2010. According to the Viet Nam Environment Report 2011 - Solid Waste (MONRE), the annual increase for industrial solid waste is about 10% per year, so the estimated volumes of industrial solid waste disposed in the landfill sites in provinces/cities by 2013 are shown in the following table:

Table 2.99. Amount of industrial solid waste disposed in landfill sites

Year	Amount of industrial solid waste disposed in landfill sites (ton/year)

Emission factor

The following parameters have been used to calculate CH_4 emission from solid waste disposal sites:

- Methane correction factor (MCF) (Default values – IPCC GPG)

+ Unmanaged – deep (≥ 5m waste): 0.8

+ Unmanaged – shallow (<5m waste): 0.4

+ Managed – anaerobic: 1

+ Managed – semi – aerobic: 0.5

In Vietnam, share of “unmanaged – deep” landfill is 40%, “unmanaged – shallow” is 50 %, “managed – anaerobic” is 5% and “managed – semi-aerobic” is 5%. Therefore, average MCF is calculated as 0.52. This value of average MCF is applied to MSW and ISW for all inventory years.

- DOC (degradable organic carbon) for MSW is set based on IPCC GPG.

  - DOC of Paper = 0.4
  - DOC of Garden = 0.17
  - DOC of Food waste = 0.15
  - DOC of Wood or straw = 0.3
  - DOC of Textiles = 0.4

- DOC for industrial waste is calculated as 0.17, which is weighted average of DOC in each type of industrial waste, by using fraction of ISW production by industries in Vietnam in 2009.

- DOCf (fraction of DOC dissimilated) = 0.5

- k (methane generation rate constant)

  - Food waste = 0.2
  - Garden, Paper, Wood and straw = 0.03

- Industrial waste = 0.13 (weighted average of k value in each type of industrial waste calculated by using fraction of ISW production by industries in Vietnam in 2009)

- OX (oxidation factor) = 0

- F (fraction by volume of CH_4 in landfill gas) = 0.5

- R(Recovered CH_4) is set as zero in 2010.

2.6.2.2. CH_4 emission from industrial wastewater (6B1)

Handling of industrial wastewater under anaerobic condition produces CH_4. The CH_4 emission is calculated from industrial wastewater based on COD from wastewater treated on-site of important industries.

Methodology

Assessment of CH_4 production potential from industrial wastewater stream is based on the concentration of degradable organic matter in the wastewater, the volume of wastewater, and the propensity of the industrial sector to treat their wastewater in anaerobic systems. The methodology, which is used to inventory for CH_4 emission from industrial wastewater handling in Vietnam consist of steps as follows:

- List industries that procedure large volumes of organic wastewater;
- Identify the main industries with the largest potential for wastewater CH_4 emission;
- Collect or estimate COD for main industries; and
- Calculate CH_4 emission base on COD from main industries.

The equations are used to calculate CH_4 emission from industrial wastewater follows:

$$\mathbf{WM = \Sigma_i (TOW_i \times EF_i - MR_i)}$$

Where:

- WM: total methane emission from wastewater in kg CH_4
- TOW_i: total organic wastewater type i in kg COD/yr.
- EF_i: emission factor for wastewater type i in kg CH_4/kg COD.
- MR_i: total amount of methane recovered or flared from wastewater type i in kgCH_4. If no data are available, use default value of zero. For Viet Nam 2010 GHG emission inventory, the MR_i value is chosen to be zero.

TOWi (total industrial organic wastewater) is estimated by using equation as follows:

$$TOW_{ind}(\text{kg COD/yr}) = W*O*D_{ind} * (l - DS_{ind})$$

Where:

- TOW_{ind}: total industrial organic wastewater in kg COD/yr
- W: wastewater consumed in m^3/tonne of product
- O: total output by selected industrial in tonnes/yr
- D_{ind}: industrial degradable organic component in kg COD/m^3

wastewater

- DS_{ind}: fraction of industrial degradable organic component removed as sludge. In this report, DS_{ind} value was used to be zero.

EFi (emission factor for industrial wastewater) is estimated by using equation as follows:

$$EF_i = B_{oi} * \sum(WS_{ix} * MCF_x)$$

Where:

- EF_i: emission factor (kg CH_4/kg COD) for industrial wastewater
- B_{oi}: maximum methane producing capacity (kg CH_4/kg COD) (B_o = 0.25, default value – page 6.20 of IPCC 1996)
- WS_{ix}: fraction of industrial wastewater treated (WS = 0.05, default value – table 6-7 of IPCC 1996)
- MCF_x: methane conversion factors (MCF = 0.75, default value – table 6-7 of IPCC 1996).

Activity data

The following data is used to estimate activity data for estimating CH_4 emission from industrial wastewater handling:

- Production of important industries;
- Wastewater generated; and
- Chemical oxygen demand (COD) values in wastewater of some industries.

Emission factor

The following data is used to estimate emission factors for calculating CH_4 emission from industrial wastewater handling:

- EFj: emission factor for each treatment/discharge pathway or system, kg CH_4/kg COD;
- Methane correction factor (MCF) (Default values – IPCC GPG 2000).

2.6.2.3. CH_4 emission from domestic wastewater handling (CH_4) – (6B2)

Handing of domestic wastewater under anaerobic condition produces CH_4. The CH_4 emission is calculated from domestic wastewater based on BOD from wastewater treated on-site.

In developed countries, most domestic wastewater is handled in aerobic treatment facilities and lagoons. In developing countries, a small share of domestic wastewater is collected in sewer systems, with the remainder ending up in pits or latrines.

Methodology

According to the GPG 2000, the steps in inventory preparation for CH_4 from wastewater are as follows:

- Characterize the wastewater system in country;
- Select the most suitable parameters; and
- Apply the IPCC method.

In Vietnam, CH_4 emission from domestic wastewater handling is estimated by using IPCC method and default parameters. The decision tree for CH_4 emission from domestic wastewater handling is shown in figure below:

The equations are used to calculate CH_4 emission from domestic wastewater handling consists:

$$\text{Emissions} = (\text{Total Organic Waste} \bullet \text{Emission Factor}) - \text{Methane Recovery}$$

In which, Total Organic Waste (TOW) is estimated as below:

$$TOW = P * D_{dom}$$

Where:

TOW: Total Organic Waste (kg BOD/yr)

P: Human population (1000 persons)

D_{dom}: Degradable organic component (kg BOD/1000 persons/yr)

Activity data

The activity data is used to calculate CH_4 emission from domestic wastewater handling including:

- Human population
- Degradable organic component (BOD)

For the BOD, default value is 14.6 kg BOD/1000/year (table 6-5 of IPCC 1996 guideline – page 6.23).

Emission factor

The emission factors in this category depend on the type of treatment system or discharge. There are three types of domestic wastewater treatment system correspond to emission factors below:

- Centralized, aerobic treatment plant:

+ Maximum methane producing capacity – B0 = 0.6 (default value in IPCC GPG)

+ MCF = 0 (default value in IPCC GPG)

+ Emission factor – EF = 0 (default value in IPCC GPG);

- Septic system:

+ Maximum methane producing capacity – B0 = 0.6 (default value in IPCC GPG)

+ MCF = 0.75 (default value in IPCC GPG)

+ Emission factor – EF = 0.136 (calculated value).

2.6.2.4. Human sewage (N_2O) – (6B)

Nitrous oxide emission can occur as direct emission from treatment plants or from indirect emission from wastewater after disposal of effluent into waterways, lake or the sea. Direct emission from nitrification and de-nitrification at wastewater treatment plants may be considered as a minor source.

Methodology

The emissions of N_2O from human sewage are calculated as follows:

$$N_2O_{(s)} = Protein * Frac_{NPR} * NR_{PEOPLE} * EF_6$$

Where:

$N_2O(s)$ = N_2O emission from human sewage (kg N_2O-N/yr)

Protein = annual per capita protein intake (kg/person/yr)

NR_{PEOPLE} = number of people in country

EF_6 = emission factor (default 0.01 (0.002 – 0.12)) kg N_2O-N/kg sewage-N produced)

$Frac_{NPR}$ = fraction of nitrogen in protein (default = 0.16 kg N/kg protein)

Emission factor

In the case of Vietnam, majority of human sewage is directly discharged into water body. For the current estimation, it is assumed that all human sewage is discharged. The emission factors used to calculate for N_2O emission from human sewage consist as follows:

- EF_6: emission factor for N_2O emission from discharged to wastewater, kg N_2O-N/kg N (default values: 0.01 – IPCC 1996).

2.6.2.5. Waste Incineration (CO_2) – (6C)

CO_2 emissions resulting from waste incineration of carbon in waste of fossil origin (e.g. plastics, certain textiles, rubber, liquid solvents, and waste oil) should be included in emissions estimates. The carbon fraction that is derived from biomass materials (e.g. paper, food waste, and wooden material) is not included).

Methodology

CO_2 emission from each waste type of waste is estimated using default carbon content and fossil fraction data.

The equations are used to calculate CO_2 emission from waste incineration consists:

$$CO_2 \text{ emission (Gg/yr)} = \sum_i (IW_i * CCW_i * FCF_i * EF_i * 44/12)$$

Where:

i = MSW: municipal solid waste

HW: hazardous waste

CW: clinical waste

SS: sewage sludge

IW_i = Amount of incinerated waste of type i (Gg/yr)

CCW_i = Fraction of carbon content in waste of type i

FCF_i = Fraction of fossil carbon in waste of type i

EF_i = Burn out efficiency of combustion of incinerator for waste of type i (fraction)

44/12 = conversion from C to CO_2

Activity data

In Viet Nam, most solid waste is dumped in the landfill sites. Rate of solid waste burned in incinerator is very low and mainly hazardous medical solid waste (clinical waste) is burned in incinerators of hospitals. As other types of solid waste, data collecting for hazardous medical solid waste burned in incinerators is very difficult. But the amount of hazardous medical solid waste can be estimated by using total number of beds in hospital, volume of waste per bed, and rate of hazardous waste in medical waste.

Table 2.100. Amount of hazardous medical solid waste

No.	Provinces/cities	Number of patient beds*	Amount of hazardous waste/bed/day **	Amount of hazardous waste (ton/day)
	Total			

Table 2.101. Amount of municipal solid waste burned in incinerators

Provinces/cities	Amount of municipal solid waste burned in incinerators (ton/yr)
Total	

Emission factor

The emission factors used to calculate for CO_2 emission from waste incineration consist as follows:

- CCW (fraction of carbon content in clinical waste): CCW = 60% (default value in IPCC GPG);

- FCF (fraction of fossil carbon in clinical waste): FCF = 40% (default value in IPCC GPG);

- - EF (burn out efficiency of combustion of incinerator for clinical waste): EF = 95% (default value in IPCC GPG).