National Greenhouse Gas Database Management System (NGHGDMS)

User Guideline

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Version: 4.0

ACKNOWLEGEMENT

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We would like specially to extend our sincere thanks to National Consultant, Dr Saysoth Keoduangsine, and his team who developed NGHGDMS and produced this guideline.

Many thanks also extend to National and International MRV Experts on Monitoring, Reporting and Verification (MRV) Dr Mone Nouan and Dr Naoki Matsuo respectively for their supports, advice, comments, and constructive feedback.

FORWARD

We are pleased to introduce the Guideline of the National Greenhouse Gas Database Management System (NGHGDMS). This guideline aims to provide technical GHG team members and line ministry users who provide GHG data and manage GHG system.

On behalf of the Department of Climate Change, I would like to express my profound appreciation to Division of Greenhouse Gas Monitor and Mitigate for its support in development of NGHGDMS. I would like to extend my sincere thanks to developer team National and International experts on MRV who provided advice and recommendation during NGHGDMS development. I strongly believe that all stakeholders working in GHG emission reduction will use the NGHGDSM for data analysis to monitor GHG impacts and to support the National Communications (NC) and Biennial Transparency Reports (BTR).

Department of Climate Change

Ministry of Natural Resources and Environment

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ACRONYMS

BUR	Biennial Update Reports
BTR	Biennial Transparency Reports
DCC	Department of Climate Change
IPCC	Intergovernmental Panel on Climate Change
Lao PDR	Lao People Democratic Republic
MAF	Ministry of Agriculture and Forestry
MES	Ministry of Education and Sports
MLSW	Ministry of Labor and Social Welfare
MH	Ministry of Health
MEM	Ministry of Energy and Mines
MONRE	Ministry of National Resource and Environment
MPWT	Ministry of Public Work and Transportation
NGHGDMS	National Greenhouse Gas Database Management System
UNEP	United Nations Environment Programme
AD	Activity Data
AWMS	Animal Waste Management System
BOD	Biochemical Oxygen Demand
C	Carbon
C2F6	Hexafluoroethane
CF4	Tetrafluoromethane
CH4	Methane
CO	Carbon Monoxide
CO2	Carbon dioxide
COD	Chemical Oxygen Demand
dm	Dry matter
Gg	Gigagram
ha	Hectare
HFC	Hydrofluorocarbon
hl	Hectolitre

k	kilo
kg	kilogram
kha	kilo hectare
kt	kilo tonne
LTO	Landing/Take Off
LUCF	Land-Use Change and Forestry
LULUCF	Land Use, Land-Use Change and Forestry
m3	cubic meter
MCF	Methane Correction Factor
Mg	Megagram
Mha	Mega hectare
MSW	Municipal Solid Waste
N	Nitrogen
N2O	Nitrous Oxide
NFP	National Focal Point
NH3	Ammonia
NMVOC	Non-Methane Volatile Organic Compound
NOX	Nitrogen Dioxide
PFC	Perfluorocarbon
RA	Reference Approach
SE	Sectoral Expert
SF6	Sulphur Hexafluoride
SO2	Sulphur Dioxide
SWDS	Solid Waste Disposal Site
t	Tonne
Tg	Tera-gram
TJ	Terajoules
XML	Extensible Markup Language
year t	Inventory year

1. INTRODUCTION

National Greenhouse Gas Database Management System (NGHGDMS) is managed by Department of Climate Change (DCC) of Ministry of National Resource and Environment (MoNRE) and supported by Capacity Building Initiative for Transparency Fund (CBIT) via the United Nation Environment Programe(UNEP).

The CBIT supports the government of Lao PDR mainly in strengthening its Enhanced Transparency Framework by means of improving the accuracy, completeness and consistency of its Greenhouse Gas inventories, and increasing its capacities to domestically track and evaluate mitigation measures and related finance support received, as well as generating the technical inputs needed for a medium and long-term planning contributing to improve climate related decision-making in the country.

This NGHGDMS system enables line ministries and agencies to input data into the system in line with their responsibilities identified under institutional arrangements, and the DCC as coordinating agency to manage it, including review the data, clean, and use for analysis and reporting. NGHGDMS also enables Lao PDR to prepare more frequent updates of its inventory data to comply with the new requirements of the Biennial Transparency Reports (BTR).

The NGHGDMS is a web-based application developed based on UNFCCC guidelines and using the 2006 IPCC software methodologies, but it has been selected the specific subsectors from main 5 GHG emission sectors (Energy, IPPU, AFOLU, Waste and others).

Therefore, using this NGHGDMS should be follow the specific guideline which is suitable for concept of Lao PDR.

1.1 Climate of Lao PDR

Climate associates with calculation of GHG emission, particularly for AFOLU sectors. Lao PDR is in South Est-Asia, its climate is mostly tropical which is influenced by the monsoon pattern. There is a distinct rainy season from May to October, followed by a dry season from November to April. The climate in Laos is very warm, with an annual average of 32 degrees[1]. Therefore, GHG emission is calculated based on location characteristic and this climate pattern.

1.2 Main Greenhouse Gases

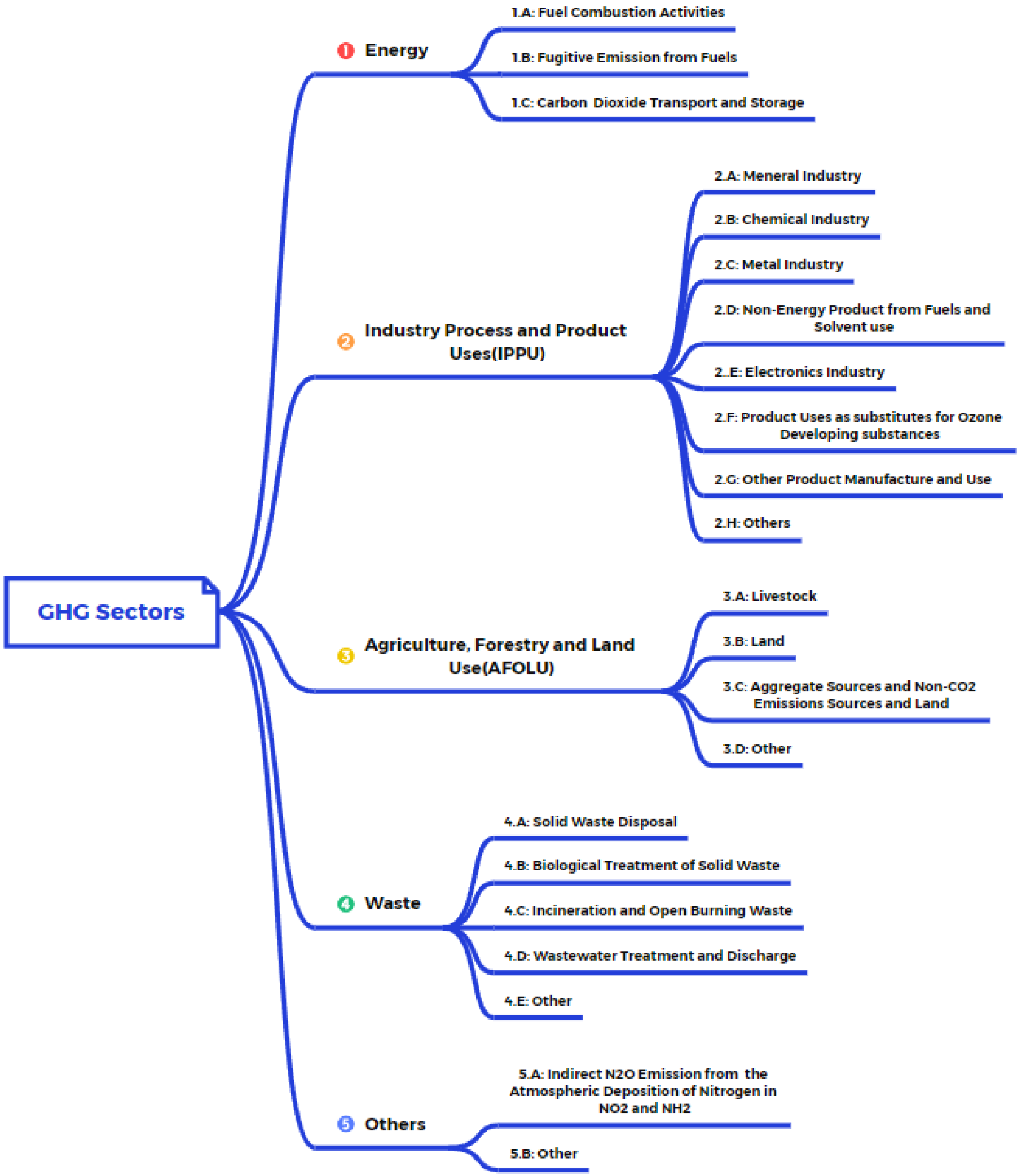
The following greenhouse gases are covered in this Guideline. The gases listed below with chemical and estimated Unit have identified by the IPCC and is available in Lao PDR.

Gas's name	Chemical formula	Unit
carbon dioxide	(CO_2)	
methane	(CH_4)	
nitrous oxide	(N_2O)	
hydrofluorocarbons	(HFCs)	
perfluorocarbons	(PFCs)	
Sulphur hexafluoride	(SF_6)	
nitrogen trifluoride	(NF_3)	

1.3 Sectors and Categories

Each sector comprises individual categories (e.g., AFOLU) and sub-categories (e.g., livestock, land and so on). GHGDMS has been developed from sectors and sub-category level which based on IPCC methodologies, the sectors and sub sectors are descripted as following chart. And total emission is calculated by sum up emissions and removal for each sector.

[1] https://www.worlddata.info/asia/laos/climate.php



1.4 Purpose of this Guideline

This guidance provides explanation on using Data Enty Template for GHG data entry, method of the approved activity data to be collected, emission factor, which is suitable for Lao PDR, and following by provision of instructions on calculating the greenhouse gas (GHG) emissions of each sectors and subcategories which based on IPCC guideline and IPCC 2006 methodology. This guidance is concerned solely the direct GHG emissions from 4 sectors, Energy, IPPU, AFULO, Waste and Other for Lao PDR.

This guideline is designed to help the GHGDMS coordination team and end-users to enter the approved GHG data into the system and manage them.

1.1 Scope of this Guideline

As stated earlier that this guideline is based on IPCC 2006 guideline and IPCC Emission Factor database, it is specifically using for Lao PDR, but it cannot be suitable for other countries or regions.

GHG emission data to be entered into the GHGDMS should be gone to the approved process of relevant line ministries (or concerned party). Particularly from a raw data source to final approval stage. The data to be interred into system is called “Activity Data”. The emission factors using in this system are default emission values from IPCC guideline and IPCC emission factor database. And all GHG formulas are based on IPCC methodological approach and use Tier-1 method.

This guideline doesn’t provide all subcategories of the sectors because some of them are identical and some are not available in Lao PDR, but this guideline is supposed to updated from time to time when the system’s functions and data is updated.

1.2 Users of this Guideline

This guideline has been prepared for use by Department of Climate Changes of MONRE, as coordinating agency to manage GHGDMS, including review the data, clean, verify and use for analysis, and prepare more frequent updates of its GHG inventory data to comply with the new requirements of the Biennial Transparency Reports (BTR).

This guideline is also for line ministries and agencies who input data into the system in line with their responsibilities identified under institutional arrangements.

1.3 Structure of this Guideline

This section descripts the structure of the guideline which consists of 5 parts as follows:

- Introduction;
- Principle guideline;

- Data entry template;
- Sectors (Energy, IPPU, AFOLU, Waste and Other);
- Reference; and
- Annexes.

Introduction describes the project background, GHG database objectives, climate characteristics of Lao PDR, main GHG, sectors and categories and propose of this guideline.

Principle guideline is to summary how to get activity data, emission factor and how to calculate emission for each sector.

Data entry template is the Excel file which recording the approved activity date for system user to enter the data into the system.

Sectors describes how to calculate of for each emission sectors (Energy, IPPU, AFOLU, and Waste), formulas, activity data and emission factors values with their units include in sector's sections.

Annexes are intended to include additional information beyond and is necessary for this guideline.

2. PRINCIPLE GUIDELINE

This guideline is based IPCC software methodology and 2006 Guidelines, the most common simple methodological approach is to combine information on activity data (AD) with coefficients quantity the emissions for removals per unit activity. These are called emission factor (EF). The basic equation is therefore:

Emissions=AD.EF

For example, in the energy sector fuel consumption would constitute activity data, and mass of carbon dioxide emitted per unit of fuel consumed would be an emission factor.

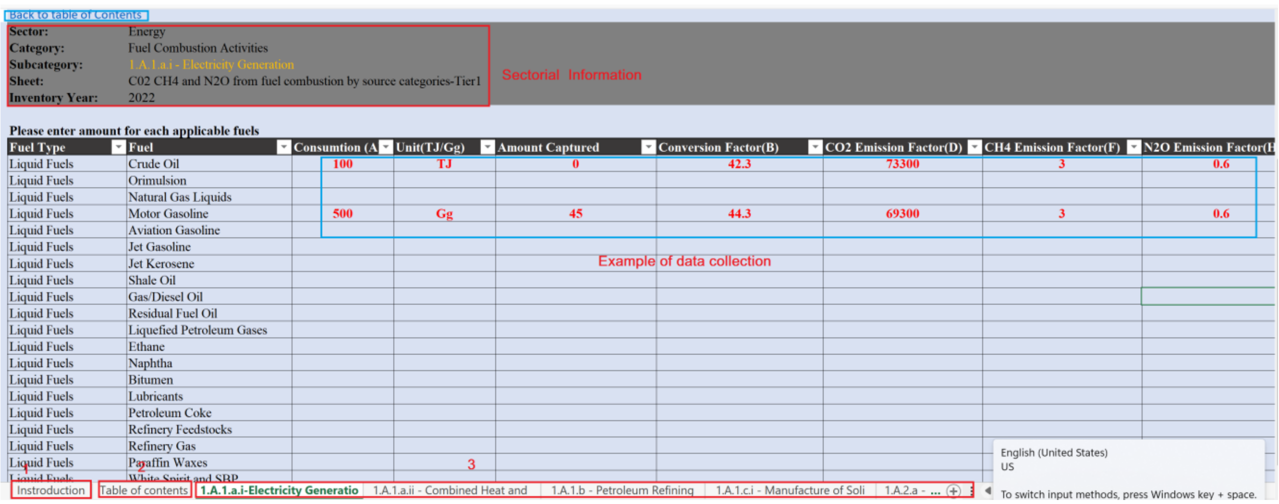
Tiers: a tier represent a level of methodological complexity. Usually there are three tiers: Tier 1 is the basic method, Tier 2 intermediate and Tier 3 most demanding in terms of complexity and data requirements. This guideline is used Tier 1 to calculate the emission for Lao PDR.

Emission factors: Lao PDR use Tier 1 methods for all categories and are possibly designed to use readily available national statistics if it is available. Therefore, for time being the emission factor of Tier 1 is default emission factors provided using in this guideline.

3. DATA ENTRY TEMPLATE

Data Entry Template (DET) is data collection form for recording the approved Activity Data (AD) and relevant emission factors (EF) of each subcategory to support for data entry after being approved from relevant line ministries/stakeholder. The DET includes three (3) type sheets:

- 1. Introduction: includes introduction of DET and instruction how to fill in the data into this DET;
- 2. Table of content: is links of each sector and sub-category sheets; and
- 3. Sectorial data sheets: data sheets of all subcategories of 4 sectors.


Back to table of Contents

Sector: Energy
Category: Fuel Combustion Activities
Subcategory: 1.A.1.a.i - Electricity Generation
Sheet: C02 CH4 and N2O from fuel combustion by source categories-Tier1
Inventory Year: 2022

Sectorial Information

Please enter amount for each applicable fuels

Fuel Type	Fuel	Consumption (A	Unit(TJ/Gg)	Amount Captured	Conversion Factor(B)	CO2 Emission Factor(D)	CH4 Emission Factor(F)	N2O Emission Factor(E
Liquid Fuels	Crude Oil	100	TJ	0	42.3	73300	3	0.6
Liquid Fuels	Orimulsion							
Liquid Fuels	Natural Gas Liquids							
Liquid Fuels	Motor Gasoline	500	Gg	45	44.3	69300	3	0.6
Liquid Fuels	Aviation Gasoline							
Liquid Fuels	Jet Gasoline							
Liquid Fuels	Jet Kerosene							
Liquid Fuels	Shale Oil							
Liquid Fuels	Gas/Diesel Oil							
Liquid Fuels	Residual Fuel Oil							
Liquid Fuels	Liquefied Petroleum Gases							
Liquid Fuels	Ethane							
Liquid Fuels	Naphtha							
Liquid Fuels	Bitumen							
Liquid Fuels	Lubricants							
Liquid Fuels	Petroleum Coke							
Liquid Fuels	Refinery Feedstocks							
Liquid Fuels	Refinery Gas							
Liquid Fuels	Paraffin Waxes							
Liquid Fuels	White Spirit and SBP							

Example of data collection

1 Introduction | 2 Table of contents | 3 1.A.1.a.i-Electricity Generatio | 1.A.1.a.ii - Combined Heat and | 1.A.1.b - Petroleum Refining | 1.A.1.c.i - Manufacture of Soli | 1.A.2.a - ...

English (United States)
US
To switch input methods, press Windows key + space.

3.1 Record data into DET

This DET is for collect the approved activity data and relevant emission factors of subcategories so for data entry, to do this , follow below steps:

- Go to Table of content (each page has a link to table of contents called "back to table of contents);
- Browser/scroll down for your desire subcategory to be filled the data in;
- Fill data into the form, then Save.

3.2 Use DET for data entry

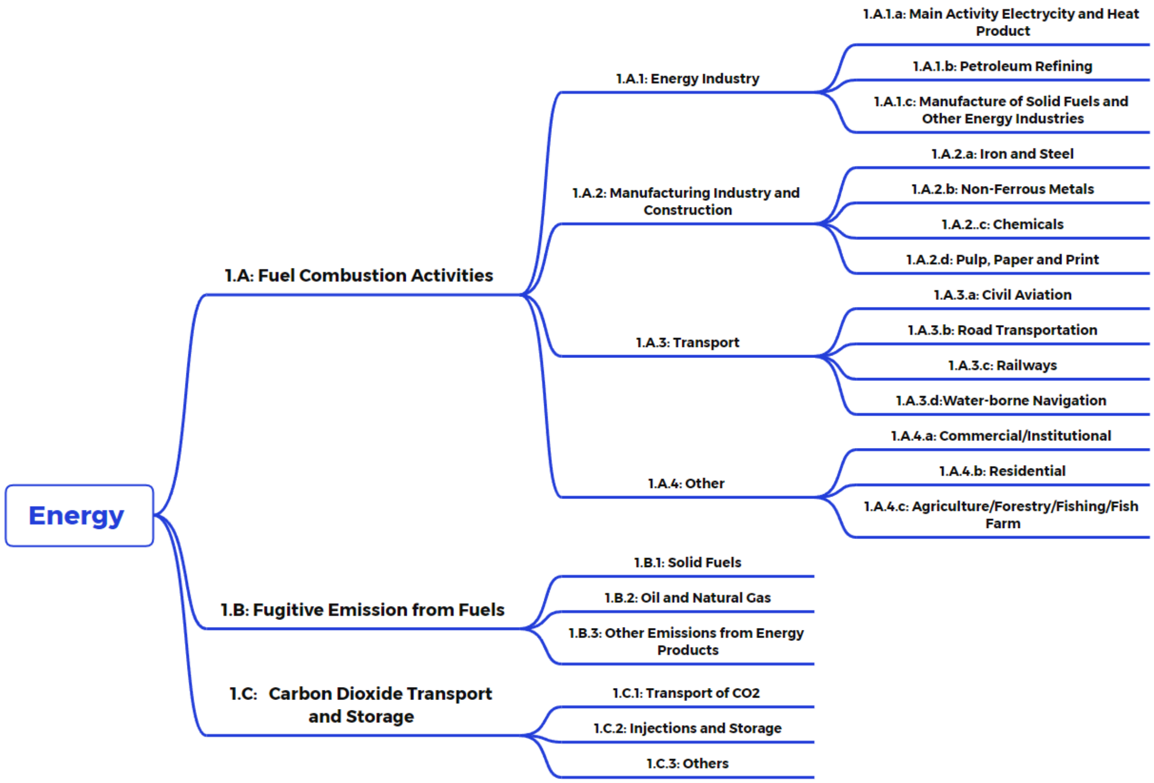
In order to enter the approved data into system on specific subcategory, do following steps:

- Login the system, and open online data entry form of the desired sub-category.
- Open the DET of the same sub-category with the approved activity data.
- Make sure that sub-category on DET and on online form are the same;
- Fill in the data, then Save.

4. ENERGY

According to IPCC guideline[2], the energy sector is the most important sector in greenhouse gas emission inventories which is over 90 percent of the CO2 emissions. CO2 accounts typically for 95 percent of energy sector emissions with methane and nitrous oxide. Stationary combustion is usually responsible for about 70 percent of the greenhouse gas emissions from the energy sector. Mobile combustion (road and other traffic) causes about 30 percent of the emissions in the energy sector. There are three (3) main categories in Energy sector: Fuel Combustion, Fugitive emissions from fuels and carbon dioxide transport and storage, as shown below diagram.

[2] https://www.ipcc-nggip.iges.or.jp/public/2006gl/



- Conversion of energy unit

In energy data compilations, production and consumption of solid, liquid, and gaseous fuels are specified in physical units, e.g., in tones(t) or cubic meters(m). To convert these data to common energy units, e.g., joules(J), requires calorific values. To convert tones to energy units, in this case terajoules (TJ), requires calorific values. Based on the IPCC 2006 Guideline, this Guideline uses default Net Calorific Values (NCVs), expressed in System International (SI) units: terajoules per megagram or tone (e.g., **TJ/Mg or TJ/t** because 1Mg=1t). Some statistical offices use gross calorific values (GCV). The difference between NCV and GCV is the latent heat of vaporization of the water produced during combustion of the fuel. Consequently, for coal and oil, the NCV is about 5 percent less than the GCV, for most forms of natural and manufactured gas, the NCV is about 10 percent less. Therefore, during data entry, a user can choose which calorific value to be used, NCV or GCV. The default Net Calorific Value (Conversion factor) with its lower and upper values can be found in **Annex 3**.

4.1 Fuel Combustion Activities

4.1.1 Electricity Generation

4.1.1.1 Activity data

Activity data of energy sector is collected from recognized national body who are usually the most appropriate and accessible this activity data as list below:

- Relevant Ministries such as Ministry of Energy and Mines and Ministry of Industry and Commerce.
- National energy statistics agencies (national energy statistics agencies may collect data on the amount and types of fuel combusted from individual enterprises that consume fuels).
- Reports provided by enterprises to national energy statistics agencies (these reports are most likely to be produced by the operators or owners of large combustion plants); and
- Suppliers of fuels (who may record the quantities of fuels delivered to their customers and may also record the identity of their customers usually as an economic activity code).

The key Activity data include Energy consumption, this guideline uses Gg as the energy consumption Unit, and CO2 captured whose Unit is Gg CO_2 (1Gg=1000 tonne)

4.1.1.2 Emission factor

Emission factors for CO2, CH4 and N2O for different source categories are based on the IPCC 1996 Guidelines and differ due to differences in combustion technologies applied in the different source categories. The default factors presented for Tier 1 apply to technologies without emission controls. The default emission factors for combustion are given in **Annex 4.**

CO2 Emission factor Unit is Kg of greenhouse gas per TJ on a Net Calorific Basis **(Kg CO2/TJ).**

4.1.1.3 Emissions calculation

Based on IPCC Guideline, emissions of each greenhouse gas from fuel combustion activities are calculated by multiplying fuel consumption by the corresponding emission factor. Fuel consumption data in mass or volume units must first be converted into the energy content of these fuels.

Tier 1 emission estimate and the default emissions factor are using for GHG emission calculation as below formula:

GREENHOUSE GAS EMISSIONS FROM FUEL COMBUSTION ACTIVITIES

$$Emissions_{GHG,\,fuel} = Fuel\ Consumption_{fuel} * Emission\ Factor_{GHG,\,fuel}$$

Where:

$Emissions_{GHG,\,fuel}$ = Emissions of a given GHG by type of fuel (kg GHG)

$Fuel\ Consumption_{fuel}$ = Amount of fuel combusted (TJ)

$Emission\ Factor_{GHG,\,fuel}$ = Default emission factor of a given GHG by type of fuel (kg gas/TJ). For CO_2, it includes the carbon oxidation factor, assumed to be 1.

To calculate the total emissions by gas from the source category, the emissions as calculated are summed over all fuels:

TOTAL EMISSIONS BY GREENHOUSE GAS

$$Emissions_{GHG} = \sum_{fuels} Emissions_{GHG,\,fuel}$$

In case, generation process have CO2 capture technology, so total emission is calculated as below.

TREATMENT OF CO_2 CAPTURE

$$Emissions_s = Production_s - Capture_s$$

Where:

s = source category or subcategory where capture takes place

Captures = Amount captured.

Productions= Estimated emissions, using these guidelines assuming no capture

Emissionss= Reported emission for the source category or sub-category

4.2 Fugitive Emissions from Fuels

Fugitive emissions associated with coal can be considered in terms of release of greenhouse gases may occur during the extraction, processing, and delivery of fossil fuels to the point of final use.

IPCC 2006 guideline state that methodologies for the estimation of fugitive emissions of CO_2, CH_4 and N_2O from the Energy Sector are very different from those used for fossil fuel combustion. Fugitive emissions tend to be diffuse and may be difficult to monitor directly. In addition, the methods are quite specific to the type of emission release. For example, methods for coal mining are linked to the geological characteristics of the coal seams, whereas methods for fugitive leaks from oil and gas facilities are linked to common types of equipment.

At this stage no methodology to estimate these emissions is available. However, if these emissions can be measured, they should be reported in source category **1.B.3** “Other emissions from energy production”.

Therefore, this guideline follows the IPCC guideline, but few categories are added because they are existing in Lao PDR such as surface mining, and oil and natural gas transportation.

4.2.1 Mining

The mining processes (both underground and surface mining) produce methane (CH4), and carbon dioxide (CO2) may also be present such as in some coal seams. These are known collectively as seam gas and remain trapped in the coal seam until the coal is exposed and broken during mining. CH4 is the major greenhouse gas emitted from coal mining and handling.

In this section(mining) we have a look at surface coal mining production which is CO2 is not significant of greenhouse gas release, so we look at only CH4.

4.2.1.1 Activity Data

The main activity is mass of coal production or other mining production (in tonne)

4.2.1.2 Emission factor

Based on IPCC guideline, the average values of CH4 emission factor is 1.2 m^3/tonne. detault CH4 conversion factor in surface mining is 0.67 x 10^{-6} Gg m^{-3}. The default CO2 conversion factor in surface mining is 1.80 x 10^{-6} Gg m^{-3}.

4.2.1.3 Emission calculation

Based on IPCC guideline, although measurements of methane emissions from surface mining are increasingly available, they are difficult to make and at present no routine widely applicable methods exist. The Tier 1 emission factors are shown together with the estimation method as below.

TIER 1: GLOBAL AVERAGE METHOD – SURFACE MINES

Methane emissions = CH_4 Emission Factor ● Surface Coal Production ● CH_4 Conversion Factor

Where units are:

Methane Emissions (Gg $year^{-1}$)

CH4 Emission Factor (m^3 $tonne^{-1}$)

Surface Coal Production (tonne $year^{-1}$)

Average CH4 Emission Factor= 1.2 m^3 $tonne^{-1}$

To estimate CO2 emission from mining, based on IPCC software it estimates as below

CO2 EMISSION – SURFACE MINES

Methane emissions = CO_2 Emission Factor ● Surface Coal Production ● CO_2 Conversion Factor

Where:

CO_2 Emissions (Gg year^{-1})

*CO_2*Emission Factor (m^3 tonne^{-1})

Surface Coal Production (tonne year^{-1})

Average *CO_2* Emission Factor m^3 tonne^{-1}

4.3 Carbon dioxide transport and storage

Carbon dioxide (CO_2) capture and storage (CCS) is a chain consisting of (1) the capture and compression of CO2 (in big industries), its transport to a storage location and its long-term isolation from the atmosphere.

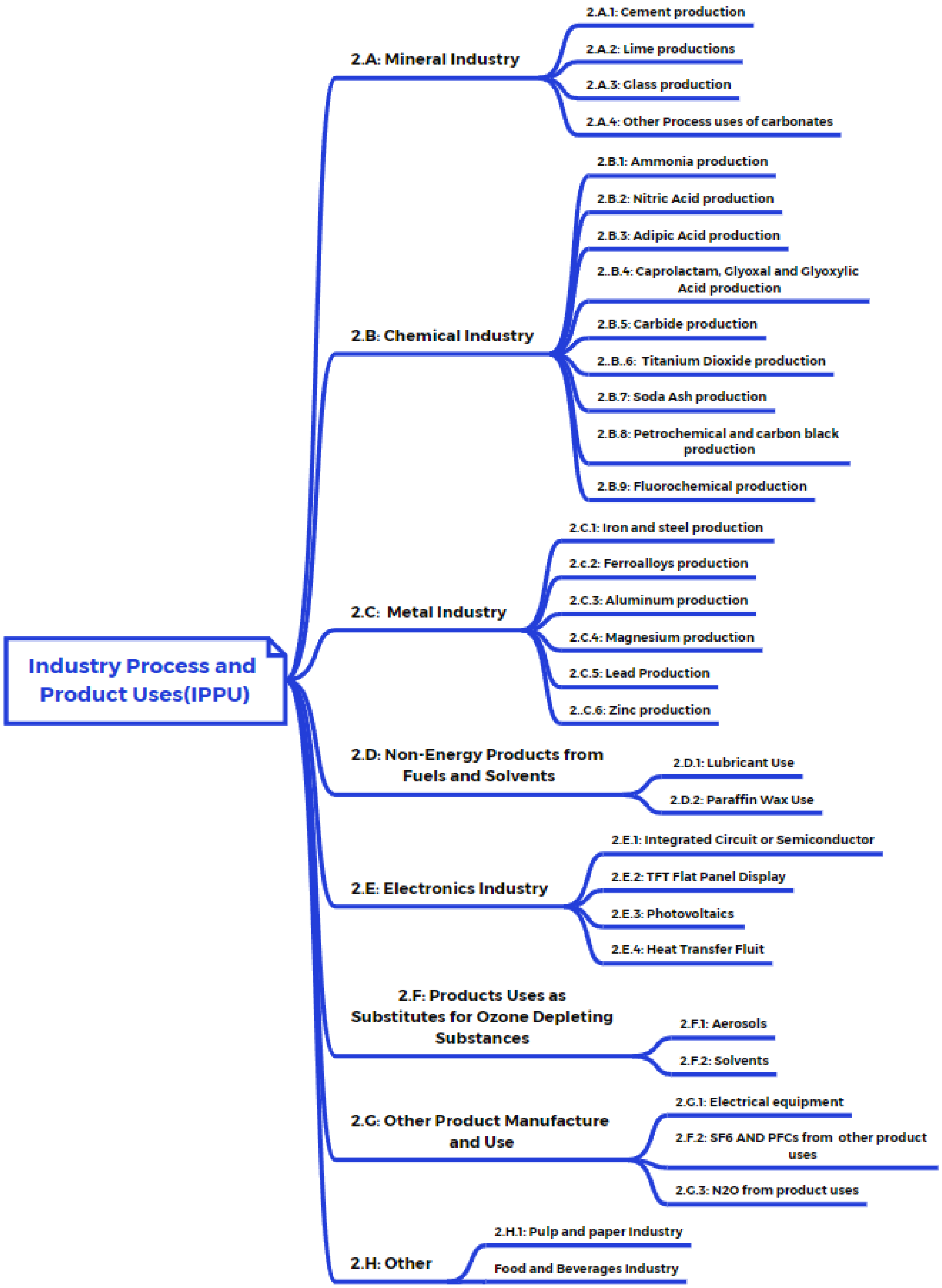
However, for Lao PDR, there is not these activities, but this guideline suggests to have fugitive emission which is measured and treated for intermediate storage facility of the land transport system and is under category 1C1(other).

5. IPPU

According to the IPCC guideline, Industrial Processes and Product Use (IPPU), covers greenhouse gas emissions occurring from industrial processes, from the use of greenhouse gases in products, and from non-energy uses of fossil fuel carbon.

Greenhouse gas emissions are produced from a wide variety of industrial activities. The main emission sources are releases from industrial processes that chemically or physically transform materials (for example, the blast furnace in the iron and steel industry, ammonia and other chemical products manufactured from fossil fuels used as chemical feedstock and the cement industry are notable examples of industrial processes that release a significant amount of CO2). During these processes, many different greenhouse gases, including carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs), can be produced. In addition, greenhouse gases often are used in products such as refrigerators, foams or aerosol cans such as HFCs, SF6 and N_2O.

There are eight (8) main categories in IPPU sector: Mineral Industry, Chemical Industry, Metal Industry, Non-Energy Products from Fuels and Solvent Use, Electronics Industry, Product Uses as Substitutes for Ozone Depleting Substances, Other Product Manufactures and Use and other, as shown below diagram.


Industry Process and Product Uses(IPPU)
2.A: Mineral Industry
2.A.1: Cement production
2.A.2: Lime productions
2.A.3: Glass production
2.A.4: Other Process uses of carbonates
2.B: Chemical Industry
2.B.1: Ammonia production
2.B.2: Nitric Acid production
2.B.3: Adipic Acid production
2..B.4: Caprolactam, Glyoxal and Glyoxylic Acid production
2.B.5: Carbide production
2..B..6: Titanium Dioxide production
2.B.7: Soda Ash production
2.B.8: Petrochemical and carbon black production
2.B.9: Fluorochemical production
2.C: Metal Industry
2.C.1: Iron and steel production
2.c.2: Ferroalloys production
2.C.3: Aluminum production
2.C.4: Magnesium production
2.C.5: Lead Production
2..C.6: Zinc production
2.D: Non-Energy Products from Fuels and Solvents
2.D.1: Lubricant Use
2.D.2: Paraffin Wax Use
2.E: Electronics Industry
2.E.1: Integrated Circuit or Semiconductor
2.E.2: TFT Flat Panel Display
2.E.3: Photovoltaics
2.E.4: Heat Transfer Fluit
2.F: Products Uses as Substitutes for Ozone Depleting Substances
2.F.1: Aerosols
2.F.2: Solvents
2.G: Other Product Manufacture and Use
2.G.1: Electrical equipment
2.F.2: SF6 AND PFCs from other product uses
2.G.3: N2O from product uses
2.H: Other
2.H.1: Pulp and paper Industry
Food and Beverages Industry

5.1 Mineral Industry

This section outlines methodologies for estimating process-related carbon dioxide (CO_2) emissions resulting from the use of carbonate raw materials in the production and use of a variety of mineral industry products. Although methane (CH_4) and nitrous oxide (N_2O) may be emitted from some minerals industry source categories, given current scientific knowledge, these emissions are assumed to be negligible and thus are not addressed in this section. These source categories include cement production, lime production, glass production and other process uses of carbonates.

5.1.1 Cement Production

5.1.1.1 Activity data

In cement manufacture, CO2 is produced during the production of clinker. For Lao PDR, clinker is producing locally and importing from other countries, if imported clinker is considered to have zero process-related CO2 emissions. Because the cement kiln dust (CKD) may be generated during the manufacture of clinker, emission estimates should account for emissions associated with the CKD as well.

Therefore, GHG emissions from cement production are based on clinker which associate with imports and exports of clinker. Therefore, the mass of the cement (activity data) depends on clinker production.

5.1.1.2 Emission factor

Under Tier 1 of IPCC guideline and it is good practice to use default CaO content for clinker of 65%, it means 1 tonne of clinker contains 0.65 tonnes CaO from $CaCO_3$. This carbonate is 56.03 percent CaO and 43.97 percent CO_2 by weight The amount of $CaCO_3$ needed to yield 0.65 tonnes CaO is: 0.65/0.5603 = 1.1601 tonnes $CaCO_3$. The amount of CO_2 released by calcining this $CaCO_3$ = 1.1601 • 0.4397 = 0.5101 tonnes CO_2

Accordingly, IPCC 2006 guideline, the default CKD correction factor (CF_{ckd}) is 1.02(i.e., add 2% to CO_2 calculated for clinker). Therefore, the default emission factor of clinker or EF_{clc} is

$$EF_{clc} = 0.51 \bullet 1.02 \text{ (CKD correction)} = 0.52 \text{ tonnesCO}_2 / \text{tonne clinker}$$

Tier 1 method of IPCC guideline also state the It is good practice to assume an overall clink fraction of 75%(C_{cli} =0.75), but if cement production is all Portland cement, then it is good practice to use default overall clink value of 95%(C_{cli} =0.95).

5.1.1.3 Emission calculation

Based on IPCC guideline, Calculating CO_2 emission associated with import and export of clinker and local cement production. The CO_2 emissions are calculated according to the below formulas.

$$CO_2\ Emissions = \left[\sum_i (M_{ci} \bullet C_{cl\,i}) - Im + Ex \right] \bullet EF_{clc}$$

Where:

CO_2 Emissions = emissions of CO_2 from cement production, tonnes

M_{ci} = weight (mass) of cement produced[3] of type *i*, tonnes

C_{cli} = clinker fraction of cement of type *i*, fraction

Im = imports for consumption of clinker, tonnes

Ex = exports of clinker, tonnes

EF_{clc} = 0.52 tonnes CO_2/tonne clinker

5.1.2 Lime Production

5.1.2.1 Activity Data

In lime manufacture, CO2 is released by heating limestone at high temperature. The GHG emission depends on the mass of lime production and emission effectors of each type of lime production including high calcium lime, dolomitic and hydraulic lime.

5.1.2.2 Emission Factor

Based Tier 1 of on IPCC 2006 guideline, emission factor of type lime production can be found in below table.

Lime Type	**Stoichiometric Ratio [tonnes CO_2 per tonne CaO or CaO·MgO]**	**Range of CaO Content [%]**	**Range of MgO Content d [%]**	**Default Value for CaO or CaO·MgO Content [fraction]**	**Default Emission Factor [tonnes CO_2 per tonne lime]**
High-calcium lime	0.785	93-98	0.3-2.5	0.95	0.75
Dolomitic lime	0.913	55-57	38-41	0.85	0.77
Hydraulic lime	0.785	65-92	NA	0.75	0.59

5.1.2.3 Emissions calculation

Based on IPCC software, Calculating CO_2 emission associated with lime production. The CO_2 emissions are calculated according to the below formulas.

$$CO_2\ Emissions = \sum (EF_{lime,i} \bullet M_{l,I})$$

Where:

CO_2 Emissions = emissions of CO_2 from lime production, tonnes.

$EF_{lime,i}$ = emission factor for lime of type *i*, tonnes CO_2/tonne lime.

$M_{l,i}$ = lime production of type *i*, tonnes

5.1.3 Glass Production

5.1.3.1 Activity Data

Many kinds of glass are using for daily life, but the glass industry can be divided into four main categories: containers, flat (window) glass, fibre glass, and specialty glass, but for Lao PDR only two main categories: containers and flat glass.

Based on IPCC guideline, the activity data includes glass production by weight(tonnes) as well an average annual cullet ratio used in grass production(percentage).

5.1.3.2 Emission Factor

Based on Tier 1 of IPCC guideline, the default emission factor for classs production is

$$EF = 0.167 / 0.84 = 0.20 \text{ tonnes } CO_2 \text{ / tonne glass}$$

And a default average annual cullet ratio (CR) is **50% or 0.5**

However, for different glass type, their default factors and cullet ration range are below table.

TABLE 2.6
DEFAULT EMISSION FACTORS AND CULLET RATIOS FOR DIFFERENT GLASS TYPES

Glass Type	CO_2 Emission Factor (kg CO_2/kg glass)	Cullet Ratio (Typical Range)
Float	0.21	10% - 25%
Container (Flint)	0.21	30% - 60%
Container (Amber/Green)	0.21	30% - 80%
Fiberglass (E-glass)	0.19	0% - 15%
Fiberglass (Insulation)	0.25	10% - 50%
Specialty (TV Panel)	0.18	20% - 75%
Specialty (TV Funnel)	0.13	20% - 70%
Specialty (Tableware)	0.10	20% - 60%
Specialty (Lab/Pharma)	0.03	30% - 75%
Specialty (Lighting)	0.20	40% - 70%
Source: Communication with Victor Aume (2004)		

5.1.3.3 Emissions calculation

Based on IPCC software, during glass production the CO2 emissions are released during melting grass raw materials such limestone, CaCO3, dolomite CaMg (CO3)2 and soda ash Na2CO3. The CO_2 emissions are calculated according to the below formulas.

$$CO_2 \ Emissions = M_g \bullet EF \bullet (1 - CR)$$

Where:

CO_2 Emissions = emissions of CO_2 from glass production, tonnes

M_g = mass of glass produced, tonnes

EF = default emission factor for manufacturing of glass, 0.20 tonnes CO_2/tonne glass

CR = cullet ratio for process (either national average or default=0.5)

5.2 Chemical Industry

5.2.1 Ammonia Production

5.2.1.1 Activity Data

The main activity data for entering the system include mass of ammonia production, fuel requirement for production, carbon content of fuel, carbon oxidation factor of fuel and urea production which is organic compound and can be CO_2 recovery. However, based on a good practice of the IPCC guideline, the default values of carbon content of fuel, carbon oxidation factor of fuel can be applied for this ammonia production.

5.2.1.2 Emission Factor

Based on Tier 1 of IPCC guideline, the default emission factor values for ammonia production are below table

Production Process	**Total fuel requirement (GJ(NCV)/tonne NH_3)**	**Carbon content factor [CCF] (kg/GJ)**	**Carbon oxidation factor [COF] (fraction)**	**CO_2 emission factor (tonnes CO_2 /tonne NH_3)**
Average value – partial oxidation	42.5	21.0	1	3.273

5.2.1.3 Emissions calculation

Based on Tear 1 of IPCC guideline, during ammonia production the CO2 emissions are calculated according to the below formulas.

$$E_{CO2} = AP \bullet FR \bullet CCF \bullet COF \bullet 44/12 - R_{CO2}$$

Where:

E_{CO2} = emissions of CO_2, kg

AP = ammonia production, tonnes

FR = fuel requirement per unit of output, GJ/tonne ammonia produced

CCF = carbon content factor of the fuel, kg C/GJ

COF = carbon oxidation factor of the fuel, fraction

R_{CO2} = CO_2 recovered for downstream use (urea production), kg

5.2.2 Soda ash production

5.2.2.1 Activity Data

Soda ash (sodium carbonate, Na2CO3) is a white crystalline solid that is used as a raw material for glass manufacture, soap and detergents, pulp and paper production and water treatment.

The activity data for soda ash production is national consumption of Trona or national production of natural soda ash in tonne.

5.2.2.2 Emission Factor

In this guideline, the default emission factor values are used for soda ash production in Lao PDR as belows:

EF_{Trona} = 0.097 tonnes CO_2/tonne of Trona OR

$EF_{Soda\ Ash}$ = 0.138 tonnes CO_2/tonnes natural soda ash produced.

5.2.2.3 Emissions calculation

Based on IPCC guideline, during soda ash production the CO2 emissions are calculated according to the below formulas.

$$E_{CO2} = AD \bullet EF$$

Where:

E_{CO2} = emissions of CO_2, tonnes

AD = quantity of Trona used or soda ash produced, tonnes

EF = emission factor per unit of Trona input or natural soda ash output, tonnes CO_2/tonne

5.3 Metal Industry

5.3.1 Iron and Steel Production

The production of iron and steel leads to emissions of carbon dioxide (CO_2) and methane (CH_4). In the best practice of IPCC guideline, Lao PDR is suitable to use Tier 1 approach for carbon emission calculate from iron and steel production which combines different types of steelmaking process, calculate emission for each process, and then sum the estimates.

5.3.1.1 Activity Data

Based on IPCC guideline, the activity data of iron and steel production process involve Basic of steelmaking method: Oxygen Furnaces (BOF), Electric Arc Furnaces (EAF), and Open Hearth Furnaces (OHF) in tonne.

5.3.1.2 Emission Factor

The default emission factor values from IPCC guideline are used for iron and steel production in Lao PDR as below.

EF_{BOF} = 1.46 tonnes CO_2/tonne of steel produced.

EF_{EAF} = 0.08 tonnes CO_2/tonnes of steel produced.

EF_{OHF} = 1.72 tonnes CO_2/tonne of steel produced.

5.3.1.3 Emissions calculation

Iron and steel production CO_2 emission shows as below formula.

CO_2 EMISSIONS FROM IRON AND STEEL PRODUCTION (TIER 1)

Iron & Steel: $E_{CO2} = BOF \bullet EF_{BOF} + EAF \bullet EF_{EAF} + OHF \bullet EF_{OHF}$

Where:

E_{CO2}= emissions of CO2 from iron and steel production(tonnes)

BOF= quantity of BOF crude steel produced (tonnes)

EAF = quantity of EAF crude steel produced(tonnes)

OHF = quantity of OHF crude steel produced (tonnes)

5.3.2 Zin Production

Zinc production is not key category of CO_2 emission, so Tier 1 method is used for CO2 emission from Zinc production in Lao PDR.

5.3.2.1 Activity Data

For Tier 1 method, the activity data Zinc production process involve only quantity of zinc production in tonne from national statistics.

5.3.2.2 Emissions Factor

Based on IPCC guideline, it is good practice to use default emission factors for estimating CO2 emission, which is $EF_{default}$ =1.72(tonne of CO2/tonne zinc)

5.3.2.3 Emissions calculation

Based on IPCC guideline, CO2 emissions from zinc production are calculated according to the formula.

CO_2 EMISSIONS FROM ZINC PRODUCTION (TIER 1)

$$E_{CO2} = Zn \bullet EF_{default}$$

Where:

E_{CO2} = CO_2 emissions from zinc production, tonnes

Zn = quantity of zinc produced, tonnes

$EF_{default}$ = default emission factor, tonnes CO_2/tonne zinc produced

5.4 Non-Energy Products from Fuels and Solvents

5.4.1 Lubricant Use

Lubricants are mostly used in industrial and transportation applications such as motor oils and industrial oils, and greases.

5.4.1.1 Activity data

The activity data of Lubricant use is total Lubricant compulsion in TJ from national statistics.

5.4.1.2 Emission Factor

The default values of from IPCC guideline are used for Lubricant use in Lao PDR as below.

- Carbon content of lubricants **($CC_{Lubrican}$)=20 tonne C/TJ**
- ODU factor (based on default composition of oil and grease), fraction (**$ODU_{Lubricant}$)=0.2**

5.4.1.3 Emission Calculation

Based on IPCC guideline Tier 1, CO2 emissions from Lubricant use is calculated according to the formula.

LUBRICANTS – TIER 1 METHOD

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

Where:

CO_2 Emissions = CO_2 emissions from lubricants,

tonne CO_2 LC = total lubricant consumption, TJ

$CC_{Lubricant}$ = carbon content of lubricants (default), tonne C/TJ (= kg C/GJ)

$ODU_{Lubricant}$ = ODU factor (based on default composition of oil and grease), fraction

44/12 = mass ratio of CO_2/C

5.4.2 Paraffin Wax Use

Waxes are used in a number of different applications. Paraffin waxes are used in applications such as: candles, corrugated boxes, paper coating, board sizing, food production, wax polishes, surfactants (as used in detergents) and many others. Emissions from the use of waxes derive primarily when the waxes or derivatives of paraffins are combusted during use (e.g., candles).

5.4.2.1 Activity data

The activity data of Lubricant use is total paraffin wax in TJ from national statistics.

5.4.2.2 Emission Factor

The default values of from IPCC guideline are used for paraffin wax in Lao PDR as below.

- Carbon content of paraffin wax **($CC_{Lubrican}$)=20 tonne C/TJ**
- ODU factor for paraffin wax, fraction (**$ODU_{Lubricant}$)=0.2**

5.4.2.3 Emission Calculation

Based on IPCC guideline Tier 1, CO2 emissions from Lubricant use is calculated according to the formula.

WAXES – TIER 1 METHOD

$$CO_2\ Emissions = PW \bullet CC_{Wax} \bullet ODU_{Wax} \bullet 44/12$$

Where:

CO_2 Emissions = CO_2 emissions from waxes, tonne

CO_2 PW = total wax consumption, TJ

CC_{Wax} = carbon content of paraffin wax (default), tonne C/TJ (= kg C/GJ)

ODU_{Wax} = ODU factor for paraffin wax, fraction

44/12 = mass ratio of CO_2/C

5.5 Electronics Industry

5.5.1 Semiconductors, TFT Flat Panel Display and Photovoltaics

Several advanced electronics manufacturing processes utilize fluorinated compounds (FCs) for plasma etching intricate patterns, cleaning reactor chambers, and temperature control. The specific electronic industry sectors which include semiconductor, thin-film-transistor flat panel display (TFT-FPD), and photovoltaic (PV) manufacturing (collectively termed ‘electronics industry’).

The electronics industry currently emits both FCs that are gases and liquids at room temperature including CF4, C2F6, C3F8, c-C4F8, c-C4F8O, C4F6, C5F8, CHF3, CH2F2, nitrogen trifluoride

(NF3), and sulfur hexafluoride (SF6).

5.5.1.1 Activity data

The activity data of electronic industry can be found from national statistics.

5.5.1.2 Emission Factor

The default EF values of from IPCC guideline are used for electronic industry in Lao PDR as follows.

TIER 1 GAS-SPECIFIC EMISSION FACTORS FOR FC EMISSIONS FROM ELECTRONICS MANUFACTURING

Electronics Industry Sector	**Emission Factor (EF) (Mass per Unit Area of Substrate Processed)**						
	CF_4	**C_2F_6**	**CHF_3**	**C_3F_8**	**NF_3**	**SF_6**	**C_6F_{14}**
Semiconductors, kg/m^2	0.9	1.	0.04	0.05	0.04	0.2	NA
TFT-FPDs, g/m^2	0.5	NA	NA	NA	0.9	4.	NA
PV-cells[a], g/m^2	5	0.2	NA	NA	NA	NA	NA
Heat Transfer Fluids[b], kg/m^2	NA	NA	NA	NA	NA	NA	0.3

5.5.1.3 Emissions calculation

Based on IPCC guideline decision tree, Lao PDR is suitable with Tier 1 method to estimate emissions. Therefore, the emission estimation of manufacturing electronic Industry is below:

TIER 1 METHOD FOR ESTIMATION OF THE SET OF FC EMISSIONS

$$\{FC_i\}_n = \{EF_i \bullet C_u \bullet C_d \bullet [C_{PV} \bullet \delta + (1-\delta)]\}_n \qquad (i = 1, \ldots, n)$$

Where:

{FC_i**}ₙ** = emissions of FC gas *i*, mass of gas *i*

> **Note: { }ₙ** denotes the set for each class of products (semiconductors, TFT-FPD or PV-cells) and *n* denotes the number of gases included in each set (six for semiconductors, three for TFT-FPD manufacture and two for PV-cells. See Table 6.2.). The estimates are only valid if made and reported for all members of the set using this Tier 1 methodology.

EF_i = FC emission factor for gas *i* expressed as annual mass of emissions per square meters of substrate surface area for the product class, (mass of gas i)/m^2

C_u = fraction of annual plant production capacity utilization, fraction

C_d = annual manufacturing design capacity, $Gm^2$of substrate processed, except for PV manufacturing which is Mm^2

C_{PV} = fraction of PV manufacture that uses FCs, fraction

δ = 1 when Equation 6.1 is applied to PV industry and zero when Equation 6.1 is applied to either semiconductor or TFT-FPD industries, dimensionless

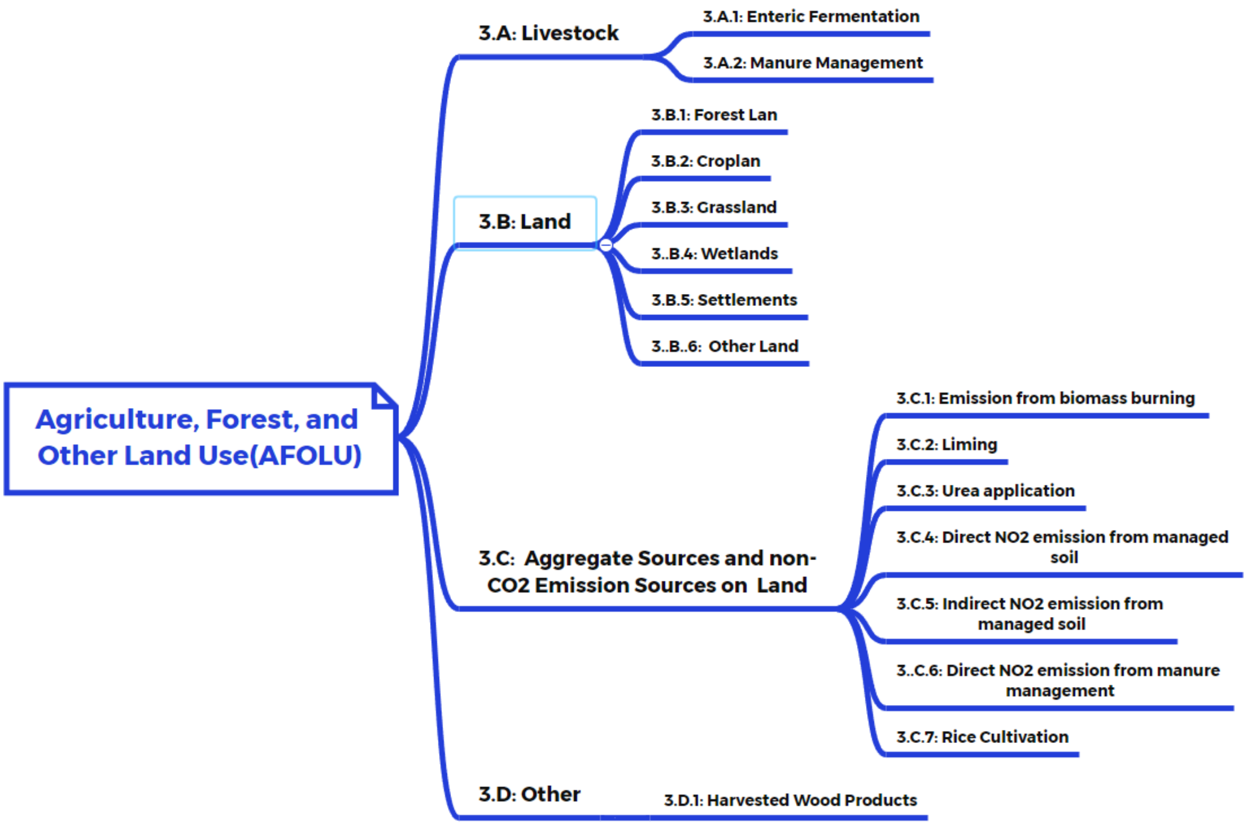
6. AFOLU

The AFOLU Sector has some unique characteristics since many processes leading to emissions and removals of greenhouse gases, which can be widely dispersed in space and highly variable in time. The factors governing emissions and removals can be both natural and anthropogenic (direct and indirect) and it can be difficult to clearly distinguish between causal factors.

Based on 2006 IPCC Guidelines AFOLU Sector greenhouse gas emissions and removals by sinks are defined as all those occurring on 'managed land'. Managed land is land where human interventions and practices have been applied to perform production, ecological or social functions. However, it is good practice for countries to quantify, and track over time, the area of unmanaged land so that consistency in area accounting is maintained as land-use change occurs.

The key greenhouse gases of concern for AFOLU sector are CO2, N2O and CH4. CO2 fluxes between the atmosphere and ecosystems are primarily controlled by uptake through plant photosynthesis and releases via respiration, decomposition and combustion of organic matter. N2O is primarily emitted from ecosystems as a by-product of nitrification and denitrification, while CH4 is emitted through methanogenesis under anaerobic conditions in soils and manure storage, through enteric fermentation, and during incomplete combustion while burning organic matter. Other gases of interest (from combustion and from soils) are NOx, NH3, NMVOC and CO, because they are precursors for the formation of greenhouse gases in the atmosphere.

There are four (4) main categories in AFOLU sector: Livestock, Land, Aggregate Sources and non-CO_2 emission sources on land, and other, as shown below diagram.



6.1 Livestock

6.1.1 Enteric Fermentation

Methane is produced in herbivores as a by-product of enteric fermentation, a digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption into the bloodstream. The amount of methane that is released depends on the type of digestive tract, age, and weight of the animal, and the quality and quantity of the feed consumed, temperature and excretion rate.

6.1.1.1 Activity Data

Based on 2006 IPCC Guideline, to estimated CO2 emission from enteric fermentation, Tier 1 approach is suitable for most animal species and typical moist temperature is applies for Lao PDR.

The required activity data include annual average population, number of animals by category and animal mass.

6.1.1.2 Emission Factor

Because Lao PDR is located in Asia with typical moist temperature, and based on 2006 IPCC guideline, the emission factor can be found in below table.

Livestock	Typical Animal Mass	Excretion Rate per mass per day	Emission Factor of Enteric Fermentation
Dairy Cattle	350	0.47	68
Other cattle	319	0.34	47
Buffalo	380	0.32	47
Sheep	28	1.17	5
Goats	30	1.37	5
Horses	238	0.46	18
Swine	1.8	0.82	1

6.1.1.3 Emissions calculation

To estimate methane emission, it requires to calculate it by each animal category as below formula:

ENTERIC FERMENTATION EMISSIONS FROM A LIVESTOCK CATEGORY

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

Where:

Emissions = methane emissions from Enteric Fermentation, Gg CH4 yr^{-1}

$EF_{(T)}$ = emission factor for the defined livestock population, kg CH4 $head^{-1}$ yr^{-1}

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

T = species/category of livestock

Therefore, the total methane emissions from Enteric Fermentation is

TOTAL EMISSIONS FROM LIVESTOCK ENTERIC FERMENTATION

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

Where:

Total CH4(enteric)= methane emissions from Enteric Fermentation, Gg CH4 yr^{-1}

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

6.1.2 Manure Management

The section describes how to estimate the CH4 and N2O produced, directly and indirectly, during the storage and treatment of animal manure before it is applied to land or otherwise used for feed, fuel, or construction purposes.

Direct N2O emissions occur via combined nitrification and denitrification of nitrogen contained in the manure. The emission of N2O from manure during storage and treatment depends on the nitrogen and carbon content of manure, and on the duration of the storage and type of treatment. Indirect emissions result from volatile nitrogen losses that occur primarily in the forms of ammonia and NOx.

6.1.2.1 Activity Data

According to the 2006 IPCC Guideline, there are two main types of activity data for estimating CH4 and N2O emissions from manure management systems:

- **Livestock population data, N (T):** The animal population data should be obtained using the Tier 1 approach and obtain from annual national statistical data.
- **Manure management system usage data, MS (T, S):** The manure management system usage data used to estimate N2O emissions from Manure Management should be the same as those that are used to estimate CH4 emissions from Manure Management which is collected for each representative livestock category.

Therefore, for Lao PDR we estimate CH4 only because we almost don't store and treatment the livestock manure.

6.1.2.2 Emission Factor

According to 2006 IPCC guideline, CH4 emission factor depends on temperature of the region, Because Lao PDR is in Asia with typical moist temperature of more than 28 in annual overage. Therefore, the CH4emission factor of manure management can be found in below table.

Manure Management CH4 **Emission Factors by Temperature for Livestock (Kg Ch4^{-1-1}) Head Yr.**	
Livestock species	**Ch4 Emission Factors by Average Annual Temperature in Lao PDR is More Than 28 °C**
Dairy Cows	31
Other Cattle	1
Swine	7
Buffalo	2
sheep	0.2
Goats	0.22
horses	2.19
Mules and Asses	1.2
Poultry	0.03

6.1.2.3 Emissions calculation

To estimate methane emission (CH4 emission), it requires to calculate as below formula:

ENTERIC FERMENTATION EMISSIONS FROM A LIVESTOCK CATEGORY

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

Where:

$CH4_{Manure}$ = CH4 emissions from manure management, for a defined population, Gg CH4 yr^{-1}

EF(T) = emission factor for the defined livestock population, kg CH4 $head^{-1}$ yr^{-1}

N(T) = the number of head of livestock species/category T in the country T = species/category of livestock

6.2 Land

To estimate greenhouse gas emission in the types of land use, IPCC guideline uses Generic method for Forest Land, Cropland, Grassland, Wetlands, Settlements and Other Land. For the Lao PDR has specific land types with its subcategories as below. Moreover, each land type characteristics can be found in GHGDMS system user manual.

Forest Land	Cropland	Grassland	Wetlands	Settlements	Other land
• Bamboo • Coniferous forest • Dry dipterocarp forest • Planation forest • Mixed coniferous and broadleaves • Mixed deciduous forest • Regeneration forest	• Agriculture plantation • Other agriculture • Rice paddy • Upland crop	• Grassland • Savannah • Scrub	• River • swamp	• Urban areas	• Barren land and rock • Other land

6.2.1 Forest Land

6.2.1.1 Activity Data

Based on 2006 IPCC Guideline, to estimated CO2 emission from each land type using gain-loss method which is suitable for all land types of Lao PDR.

The required activity data for total CO2 emission estimation include:

- Area of Forest area Remaining Forest(A), ha
- Annual wood removal(H), m3/yr
- Annual volume of fuelwood removal of whole tree (FGtree), m3/yr
- Annual volume of fuelwood removal as tree part (FGpart), m3/yr
- Area effected by disturbances (Adisburb), ha

6.2.1.2 Emission Factor

According to 2006 IPCC guideline, emission factors to estimate CO_2 emission of each land type is shown in below table.

Emission Factors	Bamboo	Coniferous forest	Dry dipterocarp forest	Evergreen forest	Planation forest	Mixed coniferous and broadleaves	Mixed deciduous forest	Regeneration forest
Carbon fraction of above-ground forest biomass (CF), tonne C/tonne d.m	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
Rio of below-ground biomass to above-ground biomass(R), t bg dm/tonne ag dm)	0.2	0.24	0.2	0.24	0.24	0.24	0.2	0.2
Conversion and expansion factor for wood and fuel work removal (BCEFr), t of biomass removal /m3 of removal	10	4.4	10	10	4.4	10	10	4.4
Above-ground biomass of areas effected(Bw), t d.m/ha	180	180	180	180	180	180	180	180
Above-ground biomass growth in plantation/natural forest (GW), t d.m/ha/yr	9	2	2	2	9	2	9	9
Basic wood density(D), tonne/m3								
Fraction of biomass lost in disturbances (fd)	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47

6.2.1.3 *Emissions calculation*

Based on IPCC guideline, to estimate carbon emission of land type is using Gain-Loss method. First it requires to estimate annual biomass gain(ΔC_G) in any forest type, second estimate the annual decrease in carbon stocks(ΔC_L), then estimate the annual change in carbon stocks in biomass (ΔC_B) as below formula, annual carbon stock change in a given pool as function of Gains and Loss method is

$$\Delta C_B = \Delta C_G - \Delta C_L$$

Where:

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

ΔC_G = annual gain of carbon, tonnes C yr^{-1}

ΔC_G =A*Gw*(1+R) *CF

ΔC_L = annual loss of carbon, tonnes C yr^{-1}

Annual carbon loss due to wood removals (Lwood-removals)

Annual carbon loss due to fuelwood removal (Lfuelwood)

Annual carbon loss due to disturbance (Ldisturbance)

ΔCL =(Lwood-removals) +(Lfuelwood)+ (Ldisturbance)

ΔCL =(H*BCEFr*(1+R) *CF) +((FGtrees*BCEFr*(1+R)) +(A*Bw*(1+R)*CF*fd)

ΔCB={A*Gw*(1+R) *CF}-{(H*BCEFr(1+R) *CF) +((FGtrees*BCEFr*(1+R)) +(A*Bw*(1+R)*CF*fd)}

Finally convert C stock change (ΔCB) to CO_2 emission by multiplying by 44/12

Total CO2 emission= ΔCB *44/12, tonnes CO_2 yr-1

6.2.2 Cropland

Cropland includes all annual and perennial crops as well as temporary fallow. Annual crops include cereals, oils seeds, vegetables, root crops and forages. Perennial crops include trees and shrubs, in combination with herbaceous crops (e.g., agroforestry) or as orchards, vineyards and plantations such as coffee, tea, oil palm, coconut, rubber trees, and bananas.

The amount of carbon stored in and emitted or removed from permanent cropland depends on crop type, management practices, and soil and climate variables. To estimate CO2 emission from Cropland, it requires to have data on changes in carbon stocks in biomass in Cropland.

This section provides guidelines on greenhouse gas inventory for croplands that have not undergone any land- “ cropland remaining cropland” of at least for 20 years period.

6.2.2.1 Activity data

Activity data in this section refer to estimates of land areas of growing stock and harvested land with perennial woody crops. The area data are estimated using national methodology/statistic, unit of this Activity data is hectare(ha).

6.2.2.2 Emission factor

To estimate greenhouse gas emission from Cropland, it requires to know biomass stocks, biomass growth rate and biomass losses of above-ground for major climatic regions and agriculture system. The default values from IPCC guideline shows below:

- Default value for above-ground woody biomass

DEFAULT COEFFICIENTS FOR ABOVE-GROUND WOODY BIOMASS AND HARVEST CYCLES IN CROPPING SYSTEMS CONTAINING PERENNIAL SPECIES

Climate region	Above-ground biomass carbon stock at harvest (tonnes C ha^{-1})	Harvest /Maturity cycle (yr)	Biomass accumulation rate (G) (tonnes C ha^{-1} yr^{-1})	Biomass carbon loss (L) (tonnes C ha^{-1} yr^{-1})
Temperate (all moisture regimes)	63	30	2.1	63
Tropical, dry	9	5	1.8	9
Tropical, moist	21	8	2.6	21
Tropical, wet	50	5	10.0	50

- Potential C storage for agroforestry system

POTENTIAL C STORAGE FOR AGROFORESTRY SYSTEMS IN DIFFERENT ECOREGIONS OF THE WORLD

Region	Eco-region	System	Above-ground biomass (tonnes ha^{-1})
SE Asia	Humid tropical	Agrosilvicultural	120.0
SE Asia	Dry lowlands	Agrosilvicultural	75.0
Source: Albrecht and Kandji, 2003			

- Default above-ground biomass for various types for perennial cropland(tonne/ha)

Cropland type	Region	Above-ground biomass
Oil Palm	SE Asia	136.0

Mature rubber	SE Asia	178.0
Young rubber	SE Asia	48.0
Coconut	SE Asia	196.0
Improved fallow		
6-year fallow (average)	SE Asia	16.0
Alley cropping	SE Asia	2.9
Multistorey system		
Jungle rubber	SE Asia	304.0
Gmelina-cacao	SE Asia	116.0

6.2.2.3 Emission calculation

The change in biomass is only estimated for perennial woody crops. For annual crops, increase in biomass stocks in a single year is assumed equal to biomass losses from harvest and mortality in that same year - thus there is no net accumulation of biomass carbon stocks.

The default method is to multiply the area of perennial woody cropland by a net estimate of biomass accumulation from growth and subtract losses associated with harvest or gathering or disturbance. Losses are estimated by multiplying a carbon stock value by the area of cropland on which perennial woody crops are harvested.

ANNUAL CHANGE IN CARBON STOCKS IN BIOMASS IN LAND REMAINING IN A PARTICULAR LAND-USE CATEGORY (GAIN-LOSS METHOD)

$$\Delta C_B = \Delta C_G - \Delta C_L$$

Where:

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

ΔC_G = annual gain of carbon, tonnes C yr^{-1}

ΔC_G =A*Gw*(1+R) *CF

ΔC_L = annual loss of carbon, tonnes C yr^{-1}

Annual carbon loss due to wood removals (Lwood-removals)

Annual carbon loss due to fuelwood removal (Lfuelwood)

Annual carbon loss due to disturbance (Ldisturbance)

ΔCL =(Lwood-removals) +(Lfuelwood)+ (Ldisturbance)

ΔCL =(H*BCEFr*(1+R) *CF) +((FGtrees*BCEFr*(1+R)) +(A*Bw*(1+R)*CF*fd)

ΔCB={A*Gw*(1+R) *CF}-{(H*BCEFr(1+R) *CF) +((FGtrees*BCEFr*(1+R)) +(A*Bw*(1+R)*CF*fd)}

Finally convert C stock change (ΔCB) to CO_2 emission by multiplying by 44/12

Total CO2 emission= ΔCB *44/12, tonnes CO_2 yr-1

6.3 Aggregate Sources and non-CO2 Emission Sources on Land

6.3.1 Emission from biomass burning.

Biomass burning in Lao PDR include slash and burn for cultivation and wildfire caused by farmers activities. The biomass burning mainly can be happened with forestland, cropland and grassland. During biomass burning, some emissions type release such as Methane (CH4), carbon monoxide (CO2), Nitrous oxide(N_2O), and Nitrogen Oxide.

6.3.1.1 Activity data

Based on 2006 IPCC Guideline, to estimated CO2 emission from each land type of biomass is only areas burnt(A) in hectare(ha). the burnt areas have different type of vegetation.

6.3.1.2 Emission factor

According to 2006 IPCC guideline, to estimate CO2 emission from biomass burning of each land type are below.

- **Emission factor of dry matter (G_{ef}):** is emission factor of dry matte for different biomass burning which produce different GHG gas emission (CO_2,CO, CH_4, N_2O, NO_X)

EMISSION FACTORS (g kg^{-1} DRY MATTER BURNT) FOR VARIOUS TYPES OF BURNING.

Category	CO_2	CO	CH_4	N_2O	NO_X
Savanna and grassland	1613	65	2.3	0.21	3.9
Agricultural residues	1515	92	2.7	0.07	2.5
Tropical forest	1580	104	6.8	0.20	1.6
Extra tropical forest	1569	107	4.7	0.26	3.0
Biofuel burning	1550	78	6.1	0.06	1.1

Biomass consumption value (Mb): is mass of fuel biomass include dead organic matter plus live biomass in tonne per hectare(tonne/ha). The value is varied depending on vegetation type of biomass.

FUEL (DEAD ORGANIC MATTER PLUS LIVE BIOMASS) BIOMASS CONSUMPTION VALUES (TONNES DRY MATTER HA^{-1}) FOR FIRES IN A RANGE OF VEGETATION TYPES	
Vegetation type	**Mean(tonne/ha)**
All primary tropical forests	119.6
All secondary tropical forests	42.2
All Tertiary tropical forest	54.1
All boreal forest	41.0
All Eucalypt forests	69.4
All Shrublands	14.3
All savanna woodlands	2.6
All savanna grasslands	2.1

Combustion factor (Cf): based on IPCC guideline**,** combustion factor value depends on vegetation

COMBUSTION FACTOR VALUES (PROPORTION OF PREFIRE FUEL BIOMASS CONSUMED) FOR FIRES IN A RANGE OF VEGETATION TYPES	
Vegetation type	**Mean**
All primary tropical forests	0.36
All secondary tropical forests	0.55
All Tertiary tropical forest	0.59
All boreal forest	0.34
All Eucalypt forests	0.63
All Shrublands	0.72
All savanna woodlands	0.40
All savanna grasslands	0.74

6.3.1.3 Emission calculation

ESTIMATION OF GREENHOUSE GAS EMISSIONS FROM FIRE

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

Where:

L_{fire} = amount of greenhouse gas emissions from fire, tonnes of each GHG e.g., CH_4, N_2O, etc. A = area burnt, ha

M_B = mass of fuel available for combustion, tonnes ha^{-1}. This includes biomass, ground litter and dead wood.

C_f = combustion factor, dimensionless

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

6.3.2 Liming

Liming is used to reduce soil acidity and improve plant growth in managed systems, particularly agricultural lands and managed forests. Adding carbonates to soils in the form of lime (e.g., calcic limestone (CaCO3), or dolomite (CaMg(CO3)2) leads to CO2 emissions as the carbonate limes dissolve and release bicarbonate ($2HCO_3$)$_2$, which evolves into CO_2 and water (H_2O).

6.3.2.1 Activity data

In lime process, annual amount of the carbonates(tonne) such as limestone (CaCO3), or dolomite (CaMg(CO3)2) are key activity data which can come from national statistics. Alternatively, annual sales of carbonate lime may be used to infer the amount that is applied to soils, under the assumption that all lime sold to farmers, ranchers, foresters, etc.

6.3.2.2 Emission factor

Based on IPCC guideline, the default emission factors (EF) are 0.12 for limestone and 0.13 for dolomite use to estimate CO_2 emission from liming application.

6.3.2.3 Emission calculation

In order to estimate the CO2 emission from liming, first to find annual C emissions from liming (CO2-C Emission), then multiply by 44/12 to convert CO_2–C emissions into CO_2 as below formula.

ANNUAL CO_2 EMISSIONS FROM LIME APPLICATION

$$CO_2\!-\!C\,Emission = \left(M_{Limestone} \bullet EF_{Limestone}\right) + \left(M_{Dolomite} \bullet EF_{Dolomite}\right)$$

Where:

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

M = annual amount of calcic limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$), tonnes yr^{-1}

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

Therefore, annual CO_2 emissions from liming (tonne CO_2) = CO_2–C emissions*44/12

6.3.3 Urea application

Similar to the lime application, bicarbonate that is formed evolves into CO2 and water during urea fertilization.

6.3.3.1 Activity data

Domestic production records and import/export data on urea can be used to obtain an approximate estimate of the amount of urea applied to soils on an annual basis (M). It can be assumed that all urea fertilizer produced or imported annually minus annual exports is applied to soils.

6.3.3.2 Emission factor

Based on IPCC guideline using Tier 1 approach, the default emission factor (EF) is 0.20 for carbon emissions from urea applications.

6.3.3.3 Emission calculation

In order to estimate the CO2 emission from urea application, first to find annual C emissions from urea application (CO_2-C Emission), then multiply by 44/12 to convert CO_2–C emissions into CO2 emission as below formula.

ANNUAL CO_2 EMISSIONS FROM UREA APPLICATION

$$CO_2\text{–}C\ Emission = M \bullet EF$$

Where:

CO2–C Emission = annual C emissions from urea application, tonnes C yr^{-1}

M = annual amount of urea fertilisation, tonnes urea yr-1

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

Therefore, annual CO2 emissions from liming (tonne CO2) = CO2–C emissions*44/12

7. WASTE

7.1 Biological Treatment of Solid Waste

7.1.1 Biological treatment of solid waste

Biological treatment of solid waste is Composting and anaerobic digestion of organic waste, such as food waste, garden (yard) and park waste and sludge, it involves CH4 and N2O emission.

7.1.1.1 Activity data

Activity data on biological treatment is mass of solid waste in Gg to be treated and can be based on national statistics.

7.1.1.2 Emission factor

Based on IPCC guideline, the emission factors of CH_4 and N_2O are below

DEFAULT EMISSION FACTORS FOR CH_4 AND N_2O EMISSIONS FROM BIOLOGICAL TREATMENT OF WASTE					
Type of biological treatment	**CH_4 Emission Factors (g CH_4/kg waste treated)**		**N_2O Emission Factors (g N_2O/kg waste treated)**		**Remarks**
	on a dry weight basis	**on a wet weight basis**	**on a dry weight basis**	**on a wet weight basis**	
Composting	10 (0.08 - 20)	4 (0.03 - 8)	0.6 (0.2 - 1.6)	0.24 (0.06 - 0.6)	Assumptions on the waste treated: 25-50% DOC in dry matter, 2% N in dry matter, moisture content 60%. The emission factors for dry waste are estimated from those for wet waste assuming a moisture content of 60% in wet waste.
Anaerobic digestion at biogas facilities	2 (0 - 20)	0.8 (0 - 8)	Assumed negligible	Assumed negligible	

7.1.1.3 Emission calculation

The CH_4 and N_2O emissions of biological treatment can be estimated using the default method as shown below:

CH_4 EMISSIONS FROM BIOLOGICAL TREATMENT

$$CH_4\ Emissions = \sum_i (M_i \bullet EF_i) \bullet 10^{-3} - R$$

Where:

CH4 Emissions = total CH4 emissions in inventory year, Gg CH4

Mi = mass of organic waste treated by biological treatment type i, Gg

EF = emission factor for treatment i, g CH4/kg waste treated

i = composting or anaerobic digestion

R = total amount of CH4 recovered in inventory year, Gg CH4

However, based on IPCC guideline, the emissions from combustion of the recovered gas are however not significant, as the CO_2 emissions are of biogenic origin, and the CH_4 and N_2O emissions are very small so *good practice* in the Waste Sector does not require their estimation, R=0.

N_2O EMISSIONS FROM BIOLOGICAL TREATMENT

$$N_2O\ Emissions = \sum (M_i \bullet EF_i) \bullet 10^{-3}$$

Where:

N2O Emissions = total N2O emissions in inventory year, Gg N2O

Mi = mass of organic waste treated by biological treatment type i, Gg

EF	=	emission factor for treatment i, g N2O/kg waste treated
i	=	composting or anaerobic digestion

7.2 Incineration and Open Burning of Waste

Incineration waste is a waste treatment process that involves the combustion of substances contained in waste materials. In other word, Waste incineration is defined as the combustion of solid and liquid waste in controlled incineration facilities. Types of waste incinerated include municipal solid waste (MSW), industrial waste, hazardous waste, clinical waste and sewage sludge. The practice of MSW incineration is currently more common in developed countries, while it is common for both developed and developing countries to incinerate clinical waste. For Lao PDR, waste incineration will be implemented in the near future, this process will be operated by private sector which converts waste into energy method.

Open burning of waste can be defined as the combustion of unwanted combustible materials such as paper, wood, plastics, textiles, rubber, waste oils and other debris in nature (open-air) or in open dumps, where smoke and other emissions are released directly into the air without passing through a chimney or stack. Open burning can also include incineration devices that do not control the combustion air to maintain an adequate temperature and do not provide sufficient residence time for complete combustion. This waste management practice is used in many developing including in Lao PDR.

7.2.1 Waste incineration and open burning

Incineration and open burning of waste are sources of greenhouse gas emissions, like other types of combustion. Relevant gases emitted include CO2, methane (CH4) and nitrous oxide (N2O). based on IPCC decision tree for CO2 emission from incineration and open burning of waste, Lao PDR is still suitable to use Tier 1 method to estimate CO2 emission.

7.2.1.1 Activity data

For Lao PDR, the amount of waste open-burned is the most important activity data required for estimating emissions from open burning of waste since waste incineration is not yet in place here. Based on IPCC guideline, below formula is to estimate total amount of MSW open-burned.

TOTAL AMOUNT OF MUNICIPAL SOLID WASTE OPEN-BURNED

$$MSWB = P.\ P_{frac}.\ MSW_{P}.\ B_{frac}.\ 365.\ 10^{-6}$$

Where:

MSW_B	=	Total amount of municipal solid waste open-burned, Gg/yr
P	=	population (capita)
P_{frac}	=	fraction of population burning waste, (fraction)

MSW_P = per capita waste generation, kg waste/capita/day

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

365 = number of days by year

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

Based on IPCC guideline for Southeast Asia Region), Lao PDR will use default value of MSWP = 270kg waste /capital/year; P_{frac} = 0.09; B_{frac} could be considered equal to 1(when all the amount of waste is burned). The details of MSW generation by region as below.

MSW GENERATION AND TREATMENT DATA - REGIONAL DEFAULTS					
Region	**MSW Generation Rate (tonnes/cap/yr)**	**Fraction of MSW disposed to SWDS**	**Fraction of MSW incinerated**	**Fraction of MSW composted**	**Fraction of other MSW management, unspecified[4]**
Asia					
Eastern Asia	0.37	0.55	0.26	0.01	0.18
South-Central Asia	0.21	0.74	-	0.05	0.21
South-East Asia	0.27	0.59	0.09	0.05	0.27

7.2.1.2 Emission factor

Based on IPCC guideline, the emission factors to estimate CO2, CH4 and N2O for open-burning waste process include

Gas	Emission factor[3](tonne/Gg)
CO_2	1.453
CH_4	6.5
N_2O	5.5

- **Default Dry matter content of MSW**

DEFAULT DRY MATTER CONTENT, DOC CONTENT, TOTAL CARBON CONTENT AND FOSSIL CARBON FRACTION OF DIFFERENT MSW COMPONENTS					
MSW component	**Dry matter content in % of wet weight**	**degradable organic carbon (DOC) content in % of wet waste**	**DOC content in % of dry waste**	**Total carbon content in % of dry weight**	**Fossil carbon fraction in % of total carbon**

[3] https://www.unep.org/resources/report/atmospheric-brown-clouds-emission-inventory-manual

	Default	Default	Default	Default	Default
Paper/cardboard	90	40	44	46	1
Textiles	80	24	30	50	20
Food waste	40	15	38	38	-
Wood	85	43	50	50	-
Garden and Park waste	40	20	49	49	0
Nappies	40	24	60	70	10
Rubber and Leather	84	(39)	(47)	67	20
Plastics	100	-	-	75	100
Metal	100	-	-	NA	NA
Glass	100	-	-	NA	NA
Other, inert waste	90	-	-	3	100

- **Default data for CO2 emission factors for open-burning waste**

TABLE 5.2
DEFAULT DATA FOR CO_2 EMISSION FACTORS FOR INCINERATION AND OPEN BURNING OF WASTE

Parameters	Management practice	MSW	Industrial Waste (%)	Clinical Waste (%)	Sewage Sludge (%) Note 4	Fossil liquid waste (%) Note 5
Dry matter content in % of wet weight		see Above	NA	NA	NA	NA
Total carbon content in % of dry weight		see Above	50	60	40 – 50	80
Fossil carbon fraction in % of total carbon content		see Above	90	40	0	100
Oxidation factor in % of carbon input	incineration	100	100	100	100	100
	Open- burning (see Note 3)	58	NO	NO	NO	NO
NA: Not Available, NO: Not Occurring						

7.2.1.3 Emission calculation

The Tier 1 method is the method uses to estimated CO2, CH4, and N2O emissions from incineration/open burning.

CO_2 EMISSION ESTIMATE BASED ON THE MSW COMPOSITION

$$CO_2\ Emissions = MSW \bullet \sum_j \left(WF_j \bullet dm_j \bullet CF_j \bullet FCF_j \bullet OF_j\right) \bullet 44/12$$

Where:

CO_2 Emissions = CO2 emissions in inventory year, Gg/yr

MSW = total amount of municipal solid waste as wet weight incinerated or open-burned, Gg/yr

WFj = fraction of waste type/material of component j in the MSW (as wet weight incinerated or open-burned)

Dmj = dry matter content in the component j of the MSW incinerated or open-burned, (fraction)

CFj=fraction of carbon in the dry matter (i.e., carbon content) of component j

j= component of the MSW incinerated/open-burned such as paper/cardboard, textiles, food waste, wood, garden (yard) and park waste, disposable nappies, rubber and leather, plastics, metal, glass, other inert waste.

The calculation of CH4 emissions is based on the amount of waste incinerated/open-burned and on the related emission factor as shown below.

CH_4 EMISSION ESTIMATE BASED ON THE TOTAL AMOUNT OF WASTE COMBUSTED

$$CH_4 \ Emissions = \sum_i (IW_i \bullet EF_i) \bullet 10^{-6}$$

Where:

CH_4 Emissions = CH_4 emissions in inventory year, Gg/yr

IW_i = amount of solid waste of type *i* incinerated or open-burned, Gg/yr

EF_i = aggregate CH_4 emission factor, kg CH_4/Gg of waste

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

I = category or type of waste incinerated/open-burned, specified as follows:

MSW: municipal solid waste, ISW: industrial solid waste, HW: hazardous waste, CW: clinical waste, SS: sewage sludge, others (that must be specified)

The calculation of N2O emissions is based on the waste input to the incinerators or the amount of waste open-burned and a default emission factor.

N_2O EMISSION ESTIMATE BASED ON THE TOTAL AMOUNT OF WASTE COMBUSTED

$$N_2O \ Emissions = \sum (IW_i \bullet EF_i) \bullet 10^{-6}$$

Where:

N_2O Emissions = N_2O emissions in inventory year, Gg/yr

IW_i = amount of solid waste of type *i* incinerated or open-burned, Gg/yr

EF_i = aggregate N_2O emission factor, kg N_2O /Gg of waste

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

I = category or type of waste incinerated/open-burned, specified as follows:

MSW: municipal solid waste, ISW: industrial solid waste, HW: hazardous waste, CW: clinical waste, SS: sewage sludge, others (that must be specified)

7.3 Wastewater Treatment and Discharge

Wastewater can be a source of methane (CH_4) when treated or disposed anaerobically. It can also be a source of nitrous oxide (N_2O) emissions. Carbon dioxide (CO_2) emissions from wastewater are not considered in this Guidelines because based on IPCC guideline these are of biogenic origin and should not be included in national total emissions.

Wastewater originates from a variety of domestic, commercial and industrial sources and may be treated on site (uncollected), sewered to a centralized plant (collected). Domestic wastewater is defined as wastewater from household water use, while industrial wastewater is from industrial practices only (such as from factories, mining and etc.).

7.3.1 Domestic wastewater treatment and discharge

In Lao PDR Domestic wastewater is treated in centralized plants, and disposed to ground, waterways, via open or closed sewers.

7.3.1.1 Activity data

The activity data for this source category is the total amount of organically degradable material in the wastewater (TOW). This parameter is a function of human population and BOD generation per person. It is expressed in terms of biochemical oxygen demand (kg BOD/year).

TOTAL ORGANICALLY DEGRADABLE MATERIAL IN DOMESTIC WASTEWATER

$$TOW = P \bullet BOD \bullet 0.001 \bullet I \bullet 365$$

Where:

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

P = country population in inventory year, (person)

BOD = country-specific per capita BOD in inventory year, g/person/day, (based on IPCC guideline Lao PDR uses default Asian regional value which is 40g/person/day)

0.001 = conversion from grams BOD to kg BOD

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

7.3.1.2 Emission factor

The emission factor for a wastewater treatment and discharge pathway and system is a function of the maximum CH_4 producing potential (Bo) and the methane correction factor (MCF) for the wastewater treatment and discharge system. The Bo is the maximum amount of CH_4 that can be produced from a given quantity of organics (as expressed in BOD or COD) in the wastewater. The MCF indicates the extent to which the CH4 producing capacity (Bo) is realized in each type of treatment and discharge pathway and system.

CH_4 EMISSION FACTOR FOR
EACH DOMESTIC WASTEWATER TREATMENT/DISCHARGE PATHWAY OR SYSTEM

$$EF_j = B_o \bullet MCF_j$$

Where:

EF_j = emission factor, kg CH_4/kg BOD

J = each treatment/discharge pathway or system

B_o = maximum CH_4 producing capacity, default value is 0.6 kg CH_4/kg BOD

MCF_j = methane correction factor (fraction)

The default MCF value for domestic wastewater is below.

Type of treatment and discharge pathway or system	**Comments**	**MCF**
Untreated system		
Sea, river and lake discharge	Rivers with high organics loadings can turn anaerobic.	0.1
Stagnant sewer	Open and warm	0.5
Flowing sewer (open or closed)	Fast moving, clean. (Insignificant amounts of CH_4 from pump stations, etc)	0
Treated system		
Centralized, aerobic treatment plant	Must be well managed. Some CH_4 can be emitted from settling basins and other pockets.	0
Centralized, aerobic treatment plant	Not well managed. Overloaded.	0.3
Anaerobic digester for sludge	CH_4 recovery is not considered here.	0.8
Anaerobic reactor	CH_4 recovery is not considered here.	0.8
Anaerobic shallow lagoon	Depth less than 2 metres, use expert judgment.	0.2
Anaerobic deep lagoon	Depth more than 2 metres	0.8
Septic system	Half of BOD settles in anaerobic tank.	0.5
Latrine	Dry climate, ground water table lower than latrine, small family (3-5 persons)	0.1
Latrine	Dry climate, ground water table lower than latrine, communal (many users)	0.5

Latrine	Wet climate/flush water use, ground water table higher than latrine	0.7
Latrine	Regular sediment removal for fertilizer	0.1

7.3.1.3 Emission calculation

To estimate CH_4 emissions from domestic wastewater is as follows.

TOTAL CH_4 EMISSIONS FROM DOMESTIC WASTEWATER

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

Where:

CH4 Emissions = CH4 emissions in inventory year, kg CH4/yr

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

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

U_i = fraction of population in income group *i* in inventory year, See Table 6.5.

$T_{i,j}$ = degree of utilization of treatment/discharge pathway or system, *j*, for each income group fraction *i* in inventory year, See Table 6.5.

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

= each treatment/discharge pathway or system

EF_j = emission factor, kg CH4 / kg BOD

R = amount of CH4 recovered in inventory year, kg CH4/yr

7.3.2 Industrial Wastewater Treatment and Discharge

Wastewater can be a source of methane (CH4) when treated or disposed anaerobically. Nitrous oxide (N2O) emissions and Carbon dioxide (CO2) emissions from wastewater are not considered in this Guidelines because based on IPCC guideline these are of biogenic origin should not be included in national total emissions.

Wastewater originates from a variety of domestic, commercial and industrial sources and may be treated on site (uncollected), sewered to a centralized plant (collected). Domestic wastewater is defined as wastewater from household water use, while industrial wastewater is from industrial practices only (such as from factories, mining and etc.).

In Lao PDR industrial wastewater while major industrial facilities have comprehensive in-plant treatment, but some of them are discharged directly into bodies of water such as unmanaged lake, flowing sewers or ponds.

7.3.2.1 Activity data

The activity data for this source category is the amount of organically degradable material in the wastewater (TOW). This parameter is a function of industrial output (product) P (tons/yr), wastewater generation W (m^3/ton of product), and degradable organics concentration in the wastewater COD (kg COD/m^3) as below equation.

ORGANICALLY DEGRADABLE MATERIAL IN INDUSTRIAL WASTEWATER

$$TOW_i = P_i \bullet W_i \bullet COD_i$$

Where:

TOW_i = total organically degradable material in wastewater for industry *i*, kg COD/yr

i = industrial sector

P_i = total industrial product for industrial sector *i*, t/yr

W_i = wastewater generated, $m^3/t_{product}$

COD_i = chemical oxygen demand (industrial degradable organic component in wastewater), kg COD/m^3

Using the IPCC guideline, below table shows the default value of waste generated (W_i) and Chemical oxygen demand(COD_i)

Industry Type	Wastewater Generation W (m^3/ton)	Range for W (m^3/ton)	COD (kg/m^3)	COD Range (kg/m^3)
Alcohol Refining	24	16 – 32	11	5 – 22
Beer & Malt	6.3	5.0 – 9.0	2.9	2 – 7
Coffee	NA	NA –	9	3 – 15
Dairy Products	7	3 – 10	2.7	1.5 – 5.2
Fish Processing	NA	8 – 18	2.5	
Meat & Poultry	13	8 – 18	4.1	2 – 7
Organic Chemicals	67	0 – 400	3	0.8 – 5
Petroleum Refineries	0.6	0.3 – 1.2	1.0	0.4 – 1.6
Plastics & Resins	0.6	0.3 – 1.2	3.7	0.8 – 5
Pulp & Paper (combined)	162	85 – 240	9	1 – 15
Soap & Detergents	NA	1.0 – 5.0	NA	0.5 – 1.2
Starch Production	9	4 – 18	10	1.5 – 42
Sugar Refining	NA	4 – 18	3.2	1 – 6
Vegetable Oils	3.1	1.0 – 5.0	NA	0.5 – 1.2
Vegetables, Fruits & Juices	20	7 – 35	5.0	2 – 10
Wine & Vinegar	23	11 – 46	1.5	0.7 – 3.0

Notes: NA = Not Available. Source: Doorn *et al*. (1997).

7.3.2.2 Emission factor

The emission factor for a wastewater treatment and discharge pathway and system is a function of the maximum CH4 producing potential (Bo) and the methane correction factor (MCF) for the wastewater treatment and discharge system. The Bo is the maximum amount of CH4 that can be produced from a given quantity of organics (as expressed in BOD or COD) in the wastewater. The MCF indicates the extent to which the CH4 producing capacity (Bo) is realized in each type of treatment and discharge pathway and system.

CH_4 EMISSION FACTOR FOR
EACH DOMESTIC WASTEWATER TREATMENT/DISCHARGE PATHWAY OR SYSTEM

$$EF_j = B_o \bullet MCF_j$$

Where:

EF_j =emission factor, kg CH4/kg BOD

J = each treatment/discharge pathway or system

B_o = maximum CH4 producing capacity, using IPCC COD-default factor value is 0.25 kg CH4/kg BOD

MCF_j = methane correction factor (fraction)

The default MCF value for Industrial wastewater is below.

Type of treatment and discharge pathway or system	Comments	MCF
Sea, river and lake discharge	Rivers with high organics loadings may turn anaerobic, however this is not considered here.	0.1
Aerobic treatment plant	Must be well managed. Some CH_4 can be emitted from settling basins and other pockets.	0
Aerobic treatment plant	Not well managed. Overloaded	0.3
Anaerobic digester for sludge	CH_4 recovery not considered here	0.8
Anaerobic reactor (e.g., UASB, Fixed Film Reactor)	CH_4 recovery not considered here	0.8

Anaerobic shallow lagoon	Depth less than 2 metres, use expert judgment	0.2
Anaerobic deep lagoon	Depth more than 2 metres	0.8

7.3.2.3 Emission calculation

To estimate CH_4 emissions from industrial wastewater is as follows.

TOTAL CH_4 EMISSIONS FROM INDUSTRIAL WASTEWATER

$$CH_4\ Emissions = \sum_i \left[\left(TOW_i - S_i \right) EF_i - R_i \right]$$

Where:

CH_4 Emissions = CH_4 emissions in inventory year, kg CH_4/yr

TOW_i = total organically degradable material in wastewater from industry *i* in inventory year, kg COD/yr

i = industrial sector

S_i = organic component removed as sludge in inventory year, kg COD/yr

EF_i = emission factor for industry *i*, kg CH_4/kg COD for treatment/discharge pathway or system(s) used in inventory year

If more than one treatment practice is used in an industry this factor would need to be a weighted average.

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

8. OTHER

9. REFERENCES

- 2006 IPCC Guideline for National Greenhouse Gas Inventories
  https://www.ipcc-nggip.iges.or.jp/public/2006gl/
- IPCC software emission factor database
  https://www.ipcc-nggip.iges.or.jp/EFDB/main.php
- 2019 Refinement to 2006 IPCC Guideline
  https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html
- 2010 ABC emission inventory manual

https://www.unep.org/resources/report/atmospheric-brown-clouds-emission-inventory-manual

10. ANNEX

4.6 Annex 1: GHG Default Value

- Fraction of carbon stored for reference approach.

Bitumen – 1
Coal oils and tars (from coking coal – 0.75
Ethane – 0.8
Gas/Diesel oil – 0.5
LPG – 0.8
Lubricants – 0.5
Naphtha – 0.8
Natural gas – 0.33

- **Conversion factors**

CH_4 volume → CH_4 Gg = 0.67

Conversion factors for energy

From	To	Multiply by
J	TJ	10^{-12}
KJ	TJ	10^{-9}
MJ	TJ	10^{-6}
GJ	TJ	10^{-3}
TJ	TJ	1
cal	TJ	4.1868×10^{-12}
kcal	TJ	4.1868×10^{-9}
Mcal	TJ	4.1868×10^{-6}
Gcal	TJ	4.1868×10^{-3}
Tcal	TJ	4.1868
kWh	TJ	3.6×10^{-6}
MWh	TJ	3.6×10^{-3}
GWh	TJ	3.6
Btu	TJ	1.0551×10^{-9}

kBtu	TJ	1.0551×10^{-6}
MBtu	TJ	1.0551×10^{-3}
GBtu	TJ	1.0551
toe	TJ	41.868×10^{-3}
ktoe	TJ	41.868
Mtoe	TJ	4.1868×10^{4}
TJ	J	10^{12}
TJ	KJ	10^{9}
TJ	MJ	10^{6}
TJ	GJ	10^{3}
TJ	cal	238.8×10^{9}
TJ	kcal	238.8×10^{6}
TJ	Mcal	238.8×10^{3}
TJ	Gcal	238.8
TJ	Tcal	238.8×10^{-3}
TJ	kWh	277.8×10^{3}
TJ	MWh	277.8
TJ	GWh	277.8×10^{-3}
TJ	Btu	947.8×10^{6}
TJ	kBtu	947.8×10^{3}
TJ	MBtu	947.8
TJ	GBtu	947.8×10^{-3}
TJ	toe	23.88
TJ	ktoe	$23.88 \times x \times 10^{-3}$
TJ	Mtoe	23.88×10^{-6}

- **Emission factors**

*Ozone precursors and SO_2 from oil refining – **Crude oil throughput***

NOx = 0.06

CO = 0.09

NMVOC = 0.62

SO_2 = 0.93

*Ozone precursors and SO2 from oil refining – **Catalytic cracker throughput***

NOx = 0.2

CO = 42.6

NMVOC = 0.6

SO_2 = 1.5

*NMVOC emissions from storage and handling – **Crude oil throughput***

Secondary seals = 0.2

Primary seals = 0.7

Fixed Roof = 4.9

SO_2 from Sulphur Recovery Plants – **139 kg/t**

- **CKD correction factor** = 1.02

- **Methane Correction Factor (MCF)**

Managed — 1.0

Unmanaged – deep (>= 5m) — 0.8

Unmanaged – shallow (< 5m) — 0.4

Methane Correction Factor — 0.6

- **Inventory time period** *(for Cropland remaining Cropland – Carbon stock change – Mineral soils)* = **20 years**

4.7 Annex 2: Global Warming Potentials (GWP)

Greenhouse gas	Chemical formula	1995 IPCC GWP
Carbon dioxide	CO2	1
Methane	CH4	21
Nitrous oxide	N2O	310
HFC-23	CHF3	11,700
HFC-32	CH2F2	650
HFC-41	CH3F	150
HFC-43-10mee	C5H2F10	1,300
HFC-125	C2HF5	2,800
HFC-134	C2H2F4	1,000
HFC-134a	CH2FCF3	1,300
HFC-152a	C2H4F2	140
HFC-143	C2H3F3	300
HFC-143a	CF3CH3	3,800
HFC-227ea	C3HF7	2,900
HFC-236fa	C3H2F6	6,300
HFC-254ca	C3H3F5	560
Perfluoro methane	CF4	6,500
Perfluoro ethane	C2F6	9,200

Perfluoropropape	C3F8	7,000
Perfluoro butane	C2F10	7,000
Perfluorocyclobutane	c-c4F8	8,700
Perfluoro pentane	C5F12	7,500
Perfluoro hexane	C6F14	7,400
Sulphur hexafluoride	SF6	23,900

4.8 Annex 3: Default Calorific Values

DEFAULT NET CALORIFIC VALUES (NCVS) AND LOWER AND UPPER LIMITS OF THE 95% CONFIDENCE INTERVALS				
Fuel type English description		**Net calorific value (TJ/Gg)**	**Lower**	**Upper**
Crude Oil		42.3	40.1	44.8
Orimulsion		27.5	27.5	28.3
Natural Gas Liquids		44.2	40.9	46.9
Gasoline	Motor Gasoline	44.3	42.5	44.8
	Aviation Gasoline	44.3	42.5	44.8
	Jet Gasoline	44.3	42.5	44.8
Jet Kerosene		44.1	42.0	45.0
Other Kerosene		43.8	42.4	45.2
Shale Oil		38.1	32.1	45.2
Gas/Diesel Oil		43.0	41.4	43.3
Residual Fuel Oil		40.4	39.8	41.7
Liquefied Petroleum Gases		47.3	44.8	52.2
Ethane		46.4	44.9	48.8
Naphtha		44.5	41.8	46.5
Bitumen		40.2	33.5	41.2
Lubricants		40.2	33.5	42.3
Petroleum Coke		32.5	29.7	41.9
Refinery Feedstocks		43.0	36.3	46.4
Other Oil	Refinery Gas	49.5	47.5	50.6
	Paraffin Waxes	40.2	33.7	48.2
	White Spirit and SBP	40.2	33.7	48.2
	Other Petroleum Products	40.2	33.7	48.2
Anthracite		26.7	21.6	32.2
Coking Coal		28.2	24.0	31.0

Other Bituminous Coal		25.8	19.9	30.5
Sub-Bituminous Coal		18.9	11.5	26.0
Lignite		11.9	5.50	21.6
Oil Shale and Tar Sands		8.9	7.1	11.1
Brown Coal Briquettes		20.7	15.1	32.0
Patent Fuel		20.7	15.1	32.0
Coke	Coke Oven Coke and	28.2	25.1	30.2
	Gas Coke	28.2	25.1	30.2
Coal Tar [3]		28.0	14.1	55.0
Derived	Gas Works Gas	38.7	19.6	77.0
	Coke Oven Gas	38.7	19.6	77.0
	Blast Furnace Gas	2.47	1.20	5.00
	Oxygen Steel Furnace	7.06	3.80	15.0
Natural Gas		48.0	46.5	50.4
Municipal Wastes (non-biomass		10	7	18
Industrial Wastes		NA	NA	NA
Waste Oil [8]		40.2	20.3	80.0
Peat		9.76	7.80	12.5
Solid Biofuels	Wood/Wood Waste	15.6	7.90	31.0
	Sulphite lyes (black	11.8	5.90	23.0
	Other Primary Solid	11.6	5.90	23.0
	Charcoal	29.5	14.9	58.0
Liquid Bi	Biogasoline	27.0	13.6	54.0
	Biodiesels	27.0	13.6	54.0
	Other Liquid Biofuels	27.4	13.8	54.0
Gas Bi	Landfill Gas	50.4	25.4	100
	Sludge Gas	50.4	25.4	100
	Other Biogas	50.4	25.4	100
Other	Municipal Wastes (biomass fraction)	11.6	6.80	18.0

4.9 Annex 4: Default Emission Factors of Stationary Combustion

DEFAULT EMISSION FACTORS FOR STATIONARY COMBUSTION IN THE ENERGY INDUSTRIES (kg of greenhouse gas per TJ on a Net Calorific Basis)			
	CO_2	CH_4	N_2O

Fuel		Defaul t Emissi	Lower	Upper	Default Emissio n	Lower	Upper	Defaul t Emissi	Lower	Upper
Crude Oil		73 300	71 100	75 500	3	1	10	0.6	0.2	2
Orimulsion		77 000	69 300	85 400	3	1	10	0.6	0.2	2
Natural Gas Liquids		64 200	58 300	70 400	3	1	10	0.6	0.2	2
Gasoline	Motor Gasoline	69 300	67 500	3	3	1	10	0.6	0.2	2
	Aviation Gasoline	70 000	67 500	3	3	1	10	0.6	0.2	2
	Jet Gasoline	70 000	67 500	3	3	1	10	0.6	0.2	2
Jet Kerosene		71 500	69 700	74 400	3	3	10	0.6	0.2	2
Other Kerosene		71 900	70 800	73 700	3	3	10	0.6	0.2	2
Shale Oil		73 300	67 800	79 200	3	3	10	0.6	0.2	2
Gas/Diesel Oil		74 100	72 600	74 800	3	3	10	0.6	0.2	2
Residual Fuel Oil		77 400	75 500	78 800	3	3	10	0.6	0.2	2
Liquefied Petroleum Gases		63 100	61 600	65 600	1	0.3	3	0.1	0.03	0.3
Ethane		61 600	56 500	68 600	1	0.3	3	0.1	0.03	0.3
Naphtha		73 300	69 300	76 300	3	1	10	0.6	0.2	2
Bitumen		80 700	73 000	89 900	3	1	10	0.6	0.2	2
Lubricants		73 300	71 900	75 200	3	1	10	0.6	0.2	2
Petroleum Coke		97 500	82 900	115 000	3	1	10	0.6	0.2	2
Refinery Feedstocks		73 300	68 900	76 600	3	1	10	0.6	0.2	2
Other Oil	Refinery Gas	57 600	48 200	69 000	1	0.3	3	0.1	0.03	0.3
	Paraffin Waxes	73 300	72 200	74 400	3	1	10	0.6	0.2	2
	White Spirit and SBP	73 300	72 200	74 400	3	1	10	0.6	0.2	2
	Other Petroleum	73 300	72 200	74 400	3	1	10	0.6	0.2	2
Anthracite		98 300	94 600	101 000	1	0.3	3	1.5	0.5	5
Coking Coal		94 600	87 300	101 000	1	0.3	3	1.5	0.5	5
Other Bituminous Coal		94 600	89 500	99 700	1	0.3	3	1.5	0.5	5
Sub-Bituminous Coal		96 100	92 800	100 000	1	0.3	3	1.5	0.5	5
Lignite		101 000	90 900	115 000	1	0.3	3	1.5	0.5	5
Oil Shale and Tar Sands		107 000	90 200	125 000	1	0.3	3	1.5	0.5	5
Brown Coal Briquettes		97 500	87 300	109 000	1	0.3	3	1.5	0.5	5
Patent Fuel		97 500	87 300	109 000	1	0.3	3	1.5	0.5	5
Coke	Coke Oven Coke and	107 000	95 700	119 000	1	0.3	1.5	1. 5	0.5	5
	Gas Coke	107 000	95 700	119 000	1	0.3	3	0.1	0.03	0.3
Coal Tar		80 700	68 200	95 300	1	0.3	3	1. 5	0.5	5
Derived Gases	Gas Works Gas	44 400	37 300	54 100	1	0.3	3	0.1	0.03	0.3
	Coke Oven Gas	44 400	37 300	54 100	1	0.3	3	0.1	0.03	0.3

	Blast Furnace Gas	260 000	219	308 000	1	0.3	3	0.1	0.03	0.3
	Oxygen Steel Furnace	182 000	145	202 000	1	0.3	3	0.1	0.03	0.3
Natural Gas		56 100	54 300	58 300	1	0.3	3	0.1	0.03	0.3

(CONTINUED)
DEFAULT EMISSION FACTORS FOR STATIONARY COMBUSTION IN THE <u>ENERGY INDUSTRIES</u>
(kg of greenhouse gas per TJ on a Net Calorific Basis)

Fuel		CO_2			CH_4			N_2O		
		Defau lt Emiss	**Lower**	**Upper**	**Defaul t Emissi**	**Lower**	**Upper**	**Defaul t Emissi**	**Lowe r**	**Upper**
Municipal Wastes (non-biomass fraction)		91 700	73 300	121 000	30	10	100	4	1.5	15
Industrial Wastes		143 000	110	183 000	30	10	100	4	1.5	15
Waste Oils		73 300	72 200	74 400	30	10	100	4	1.5	15
Peat		106	100 000	108 000	1	0.3	3	1.5	0.5	5
Solid Biofuels	Wood / Wood	112 000	95 000	132 000	30	10	100	4	1.5	15
	Sulphite lyes	95 300	80 700	110 000	3	1	18	2	1	21
	Other Primary	100 000	84 700	117 000	30	10	100	4	1.5	15
	Charcoal	112 000	95 000	132 000	200	70	600	4	1.5	15
Liquid Biofuels	Biogasoline	70 800	59 800	84 300	3	1	10	0.6	0.2	2
	Biodiesels	70 800	59 800	84 300	3	1	10	0.6	0.2	2
	Other Liquid	79 600	67 100	95 300	3	1	10	0.6	0.2	2
Gas Biomass	Landfill Gas	54 600	46 200	66 000	1	0.3	3	0.1	0.03	0.3
	Sludge Gas	54 600	46 200	66 000	1	0.3	3	0.1	0.03	0.3
	Other Biogas	54 600	46 200	66 000	1	0.3	3	0.1	0.03	0.3
Other non- fossil fuels	Municipal Wastes	100 000	84 700	117 000	30	10	100	4	1.5	15

DEFAULT EMISSION FACTORS FOR STATIONARY COMBUSTION IN MANUFACTURING INDUSTRIES AND CONSTRUCTION
(kg of greenhouse gas per TJ on a Net Calorific Basis)

Fuel		CO_2			CH_4			N_2O		
		Default Emiss	Lower	Upper	Default Emiss	Lower	Upper	Default Emiss	Lower	Upper
Crude Oil		73 300	71 100	75 500	3	1	10	0.6	0.2	2
Orimulsion		77 000	69 300	85 400	3	1	10	0.6	0.2	2
Natural Gas Liquids		64 200	58 300	70 400	3	1	10	0.6	0.2	2
Gasoline	Motor Gasoline	69 300	67 500	73 000	3	1	10	0.6	0.2	2
	Aviation Gasoline	70 000	67 500	73 000	3	1	10	0.6	0.2	2
	Jet Gasoline	70 000	67 500	73 000	3	1	10	0.6	0.2	2
Jet Kerosene		71 500	69 700	74 400	3	1	10	0.6	0.2	2
Other Kerosene		71 900	70 800	73 700	3	1	10	0.6	0.2	2
Shale Oil		73 300	67 800	79 200	3	1	10	0.6	0.2	2
Gas/Diesel Oil		74 100	72 600	74 800	3	1	10	0.6	0.2	2
Residual Fuel Oil		77 400	75 500	78 800	3	1	10	0.6	0.2	2
Liquefied Petroleum Gases		63 100	61 600	65 600	1	0.3	3	0.1	0.03	0.3
Ethane		61 600	56 500	68 600	1	0.3	3	0.1	0.03	0.3
Naphtha		73 300	69 300	76 300	3	1	10	0.6	0.2	2
Bitumen		80 700	73 000	89 900	3	1	10	0.6	0.2	2
Lubricants		73 300	71 900	75 200	3	1	10	0.6	0.2	2
Petroleum Coke		97 500	82 900	115 000	3	1	10	0.6	0.2	2
Refinery Feedstocks		73 300	68 900	76 600	3	1	10	0.6	0.2	2
Other Oil	Refinery Gas	57 600	48 200	69 000	1	0.3	3	0.1	0.03	0.3
	Paraffin Waxes	73 300	72 200	74 400	3	1	10	0.6	0.2	2
	White Spirit and SBP	73 300	72 200	74 400	3	1	10	0.6	0.2	2
	Other Petroleum	73 300	72 200	74 400	3	1	10	0.6	0.2	2
Anthracite		98 300	94 600	101 000	10	3	30	1.5	0.5	5
Coking Coal		94 600	87 300	101 000	10	3	30	1.5	0.5	5
Other Bituminous Coal		94 600	89 500	99 700	10	3	30	1.5	0.5	5
Sub-Bituminous Coal		96 100	92 800	100 000	10	3	30	1.5	0.5	5
Lignite		101 000	90 900	115 000	10	3	30	1.5	0.5	5
Oil Shale and Tar Sands		107 000	90 200	125 000	10	3	30	1.5	0.5	5
Brown Coal Briquettes		97 500	87 300	109 000	10	3	30	1.5	0.5	5
Patent Fuel		97 500	87 300	109 000	10	3	30	1.5	0.5	5

Coke	Coke Oven Coke and Lignite Coke	107 000	95 700	119 000	10	3	30	1.5	0.5	5
	Gas Coke	107 000	95 700	119 000	1	0.	3	0.1	0.03	0.3
Coal Tar		80 700	68 200	95 300	10	3	30	1.5	0.5	5
Derived Gases	Gas Works Gas	44 400	37 300	54 100	1	0.	3	0.1	0.03	0.3
	Coke Oven Gas	44 400	37 300	54 100	1	0.	3	0.1	0.03	0.3
	Blast Furnace Gas	260 000	219 000	308 000	1	0.	3	0.1	0.03	0.3
	Oxygen Steel Furnace	182 000	145 000	202 000	1	0.	3	0.1	0.03	0.3
Natural Gas		56 100	54 300	58 300	1	0.	3	0.1	0.03	0.3

(CONTINUED)
DEFAULT EMISSION FACTORS FOR STATIONARY COMBUSTION IN MANUFACTURING INDUSTRIES AND CONSTRUCTION
(kg of greenhouse gas per TJ on a Net Calorific Basis)

Fuel		CO_2			CH_4			N_2O		
		Defau lt Emiss	Lower	Upper	Defau lt Emiss	Lowe r	Uppe r	Defau lt Emiss	Lowe r	Upper
Municipal Wastes (non-biomass		91 700	73 300	121 000	30	10	100	4	1.5	15
Industrial Wastes		143 000	110	183 000	30	10	100	4	1.5	15
Waste Oils		73 300	72 200	74 400	30	10	100	4	1.5	15
Peat		106 000	100	108 000	2	0.6	6	1.5	0.5	5
Solid Biofuels	Wood / Wood Waste	112 000	95 000	132 000	30	10	100	4	1.5	15
	Sulphite lyes (Black	95 300	80 700	110 000	3	1	18	2	1	21
	Other Primary Solid	100 000	84 700	117 000	30	10	100	4	1.5	15
	Charcoal	112 000	95 000	132 000	200	70	600	4	1.5	15
Liqui d	Biogasoline	70 800	59 800	84 300	3	1	10	0.6	0.2	2
	Biodiesels	70 800	59 800	84 300	3	1	10	0.6	0.2	2
	Other Liquid Biofuels	79 600	67 100	95 300	3	1	10	0.6	0.2	2
Gas Biom	Landfill Gas	54 600	46 200	66 000	1	0.3	3	0.1	0.03	0.3
	Sludge Gas	54 600	46 200	66 000	1	0.3	3	0.1	0.03	0.3
	Other Biogas	54 600	46 200	66 000	1	0.3	3	0.1	0.03	0.3
Other non-	Municipal Wastes (biomass fraction)	100 000	84 700	117 000	30	10	100	4	1.5	15

DEFAULT EMISSION FACTORS FOR STATIONARY COMBUSTION IN THE COMMERCIAL/INSTITUTIONAL CATEGORY
(kg of greenhouse gas per TJ on a Net Calorific Basis)

Fuel	CO_2			CH_4			N_2O		
	Defau lt Emissi	Lower	Upper	Defaul t Emissi	Lower	Upper	Defaul t Emissi	Lowe r	Upper

Crude Oil		73 300	71 100	75 500	10	3	30	0.6	0.2	2
Orimulsion		77 000	69 300	85 400	10	3	30	0.6	0.2	2
Natural Gas Liquids		64 200	58 300	70 400	10	3	30	0.6	0.2	2
Gasoline	Motor Gasoline	69 300	67 500	73 000	10	3	30	0.6	0.2	2
	Aviation Gasoline	70 000	67 500	73 000	10	3	30	0.6	0.2	2
	Jet Gasoline	70 000	67 500	73 000	10	3	30	0.6	0.2	2
Jet Kerosene		71 500	69 700	74 400	10	3	30	0.6	0.2	2
Other Kerosene		71 900	70 800	73 700	10	3	30	0.6	0.2	2
Shale Oil		73 300	67 800	79 200	10	3	30	0.6	0.2	2
Gas/Diesel Oil		74 100	72 600	74 800	10	3	30	0.6	0.2	2
Residual Fuel Oil		77 400	75 500	78 800	10	3	30	0.6	0.2	2
Liquefied Petroleum		63 100	61 600	65 600	5	1.5	15	0.1	0.03	0.3
Ethane		61 600	56 500	68 600	5	1.5	15	0.1	0.03	0.3
Naphtha		73 300	69 300	76 300	10	3	30	0.6	0.2	2
Bitumen		80 700	73 000	89 900	10	3	30	0.6	0.2	2
Lubricants		73 300	71 900	75 200	10	3	30	0.6	0.2	2
Petroleum Coke		97 500	82 900	115 000	10	3	30	0.6	0.2	2
Refinery Feedstocks		73 300	68 900	76 600	10	3	30	0.6	0.2	2
Other Oil	Refinery Gas	57 600	48 200	69 000	5	1.5	15	0.1	0.03	0.3
	Paraffin Waxes	73 300	72 200	74 400	10	3	30	0.6	0.2	2
	White Spirit and	73 300	72 200	74 400	10	3	30	0.6	0.2	2
	Other Petroleum	73 300	72 200	74 400	10	3	30	0.6	0.2	2
Anthracite		98 300	94 600	101 000	10	3	30	1.5	0.5	5
Coking Coal		94 600	87 300	101 000	10	3	30	1.5	0.5	5
Other Bituminous Coal		94 600	89 500	99 700	10	3	30	1.5	0.5	5
Sub-Bituminous Coal		96 100	92 800	100 000	10	3	30	1.5	0.5	5
Lignite		101 000	90 900	115 000	10	3	30	1.5	0.5	5
Oil Shale and Tar Sands		107 000	90 200	125 000	10	3	30	1.5	0.5	5
Brown Coal Briquettes		97 500	87 300	109 000	10	3	30	1.5	0.5	5

(CONTINUED)
DEFAULT EMISSION FACTORS FOR STATIONARY COMBUSTION IN THE COMMERCIAL/INSTITUTIONAL CATEGORY
(kg of greenhouse gas per TJ on a Net Calorific Basis)

Fuel	CO_2			CH_4			N_2O		
	Defaul t Emissi	Lower	Upper	Default Emissio n	Lower	Upper	Default Emissio n	Lower	U p p

Coal Tar		80 700	68 200	95 300	10	30	30	1.5	0.5	5
Derived Gases	Gas Works Gas	44 400	37 300	54 100	5	1.5	15	0.1	0.03	0.3
	Coke Oven Gas	44 400	37 300	54 100	5	1.5	15	0.1	0.03	0.3
	Blast Furnace Gas	260 000	219 000	308 000	5	1.5	15	0.1	0.03	0.3
	Oxygen Steel Furnace Gas	182 000	145 000	202 000	5	1.5	15	0.1	0.03	0.3
Natural Gas		56 100	54 300	58 300	5	1.5	15	0.1	0.03	0.3
Municipal Wastes (non- biomass		91 700	73 300	121 000	300	100	900	4	1.5	15
Industrial Wastes		143 000	110 000	183 000	300	100	900	4	1.5	15
Waste Oils		73 300	72 200	74 400	300	100	900	4	1.5	15
Peat		106 000	100 000	108 000	10	3	30	1.4	0.5	5
Solid Biofuels	Wood / Wood	112 000	95 000	132 000	300	100	900	4	1.5	15
	Sulphite lyes (Black Liquor)	95 300	80 700	110 000	3	1	18	2	1	21
	Other Primary Solid Biomass	100 000	84 700	117 000	300	100	900	4	1.5	15
	Charcoal	112 000	95 000	132 000	200	70	600	1	0.3	3
Liquid Biofuel	Biogasoline	70 800	59 800	84 300	10	3	30	0.6	0.2	2
	Biodiesels	0 800	59 800	84 300	10	3	30	0.6	0.2	2
	Other Liquid	79 600	67 100	95 300	10	3	30	0.6	0.2	2
Gas Biomas	Landfill Gas	54 600	46 200	66 000	5	1.5	15	0.1	0.03	0.3
	Sludge Gas	54 600	46 200	66 000	5	1.5	15	0.1	0.03	0.3
	Other Biogas	54 600	46 200	66 000	5	1.5	15	0.1	0.03	0.3
Othe r	Municipal Wastes (biomass	100 000	84 700	117 000	300	100	900	4	1..5	15

DEFAULT EMISSION FACTORS FOR STATIONARY COMBUSTION IN THE RESIDENTIAL AND AGRICULTURE/FORESTRY/FISHING/FISHING FARMS CATEGORIES (kg of greenhouse gas per TJ on a Net Calorific Basis)

Fuel		CO_2			CH_4			N_2O		
		Default Emissi	Lower	Upper	Default Emission	Lower	Upper	Default Emission	Lower	Up
Crude Oil		73 300	71 100	75 500	10	3	30	0.6	0.2	2
Orimulsion		77 000	69 300	85 400	10	3	30	0.6	0.2	2
Natural Gas Liquids		64 200	58 300	70 400	10	3	30	0.6	0.2	2
Gasoline	Motor Gasoline	69 300	67 500	73 000	10	3	30	0.6	0.2	2
	Aviation Gasoline	70 000	67 500	73 000	10	3	30	0.6	0.2	2
	Jet Gasoline	70 000	67 500	73 000	10	3	30	0.6	0.2	2

	Jet Kerosene	71 500	69 700	74 400	10	3	30	0.6	0.2	2
	Other Kerosene	71 900	70 800	73 700	10	3	30	0.6	0.2	2
	Shale Oil	73 300	67 800	79 200	10	3	30	0.6	0.2	2
	Gas/Diesel Oil	74 100	72 600	74 800	10	3	30	0.6	0.2	2
	Residual Fuel Oil	77 400	75 500	78 800	10	3	30	0.6	0.2	2
	Liquefied Petroleum Gases	63 100	61 600	65 600	5	1.5	15	0.1	0.03	0.3
	Ethane	61 600	56 500	68 600	5	1.5	15	0.1	0.03	0.3
	Naphtha	73 300	69 300	76 300	10	3	30	0.6	0.2	2
	Bitumen	80 700	73 000	89 900	10	3	30	0.6	0.2	2
	Lubricants	73 300	71 900	75 200	10	3	30	0.6	0.2	2
	Petroleum Coke	97 500	82 900	115 000	10	3	30	0.6	0.2	2
	Refinery Feedstocks	73 300	68 900	76 600	10	3	30	0.6	0.2	2
Other Oil	Refinery Gas	57 600	48 200	69 000	5	1.5	15	0.1	0.03	0.3
	Paraffin Waxes	73 300	72 200	74 400	10	3	30	0.6	0.2	2
	White Spirit and	73 300	72 200	74 400	10	3	30	0.6	0.2	3
	Other Petroleum	73 300	72 200	74 400	10	3	30	0.6	0.2	2
	Anthracite	98 300	94 600	101 000	300	100	900	1.5	0.5	5
	Coking Coal	94 600	87 300	101 000	300	100	900	1.5	0.5	5
	Other Bituminous Coal	94 600	89 500	99 700	300	100	900	1.5	0.5	5
	Sub-Bituminous Coal	96 100	92 800	100 000	300	100	900	1.5	0.5	5
	Lignite	101 000	90 900	115 000	300	100	900	1.5	0.5	5
	Oil Shale and Tar Sands	107 000	90 200	125 000	300	100	900	1.5	0.5	5
	Brown Coal Briquettes	97 500	87 300	109 000	300	100	900	1.5	0.5	5
	Patent Fuel	97 500	87 300	109 000	300	100	900	1.5	0.5	5
Coke	Coke Oven Coke and Lignite Coke	107 000	95 700	119 000	300	100	900	1.5	0.5	5
	Gas Coke	107 000	95 700	119 000	5	1.5	15	0.1	0.03	0.3
	Coal Tar	80 700	68 200	95 300	300	100	900	1.5	0.5	5
Derived Gases	Gas Works Gas	44 400	37 300	54 100	5	1.5	15	0.1	0.03	0.3
	Coke Oven Gas	44 400	37 300	54 100	5	1.5	15	0.1	0.03	0.3
	Blast Furnace Gas	260 000	219 000	308 000	5	1.5	15	0.1	0.03	0.3
	Oxygen Steel	182 000	145 000	202 000	5	1.5	15	0.1	0.03	0.3

(CONTINUED)

DEFAULT EMISSION FACTORS FOR STATIONARY COMBUSTION IN THE RESIDENTIAL AND AGRICULTURE/FORESTRY/FISHING/FISHING FARMS CATEGORIES (kg of greenhouse gas per TJ on a Net Calorific Basis)

	Fuel	CO_2			CH_4			N_2O		
		Defaul t Emissi	Lower	Upper	Default Emissio n	Lower	Upper	Default Emissio n	Lower	Uppe r
	Natural Gas	56 100	54 300	58 300	5	1.5	15	0.1	0.03	0.3
	Municipal Wastes (non-	91 700	73 300	121 000	300	100	900	4	1.5	15
	Industrial Wastes	143 000	110 000	183 000	300	100	900	4	1.5	15
	Waste Oils	73 300	72 200	74 400	300	100	900	4	1.5	15
	Peat	106 000	100 000	108 000	300	100	900	1.4	0.5	5
Solid Biofuels	Wood / Wood	112 000	95 000	132 000	300	100	900	4	1.5	15
	Sulphite lyes (Black Liquor)	95 300	80 700	110 000	3	1	18	2	1	21
	Other Primary Solid Biomass	100 000	84 700	117 000	300	100	900	4	1.5	15
	Charcoal	112 000	95 000	132 000	200	70	600	1	0.3	3
Liquid	Biogasoline	70 800	59 800	84 300	10	3	30	0.6	0.2	2
	Biodiesels	70 800	59 800	84 300	10	3	30	0.6	0.2	2
	Other Liquid	79 600	67 100	95 300	10	3	30	0.6	0.2	2
Gas Biomass	Landfill Gas	54 600	46 200	66 000	5	1.5	15	0.1	0.03	0.3
	Sludge Gas	54 600	46 200	66 000	5	1.5	15	0.1	0.03	0.3
	Other Biogas	54 600	46 200	66 000	5	1.5	15	0.1	0.03	0.3
Other	Municipal Wastes (biomass	100 000	84 700	117 000	300	100	900	4	1.5	15