WASTE SECTOR INVENTORY

PREPARED UNDER

The Initiative for Climate Action Transparency (ICAT), supported by Austria, Canada, Germany, Italy, the Children's Investment Fund Foundation and the Climate Works Foundation.

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ABBREVIATIONS AND ACRONYMS

BOD	Biochemical Oxygen Demand
CH_4	Methane
CO_2	Carbon dioxide
DEPC	Department of Environmental Protection and Conservation
DOCC	Department of Climate Change
DOC	Degradable Organic Carbon
DWR	Department of Water Resources
FOD	First Order Decay
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
J-PRISM	Japanese Technical Cooperation Project for Promotion of Regional Initiative on Solid Waste Management in Pacific Island Countries
MCF	Methane Correction Factor
MSW	Municipal Solid Waste
N_2O	Nitrous Oxide
NMVOCs	Non-methane volatile organic compounds
OX	Oxidation Factor
PVCC	Port Vila City Council
PWD	Public Works Department
QA/QC	Quality Assurance/Quality Control
RTI	Right to Information
SWD	Solid Waste Disposal

4.1: WASTE OVERVIEW

4.1.1: CATEGORY OVERVIEW

The waste sector in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories provides methodological guidance for estimation of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions from the following waste categories (See Figure A4.1 in Annex):

- Solid Waste Disposal (SWD)
- Biological treatment for solid waste
- Incineration and open burning of waste
- Wastewater treatment and discharge

Usually, CH_4 emissions from Solid Waste Disposal sites (SWDS) are the largest source of greenhouse gas emissions within the waste sector. Incineration and open burning of waste having fossil carbon such as plastics are major sources of CO_2 emissions under the waste sector. In SWDS, wastewater treatment and burning of non-fossil waste, CO_2 is also produced. However, the CO_2 produced is of biogenic origin hence it is not recommended to be reported in this sector[1]. The N_2O oxide is produced in most of the treatments addressed in the waste sector. It is significant in various ways depending mostly on conditions and treatment type.

Non-methane volatile organic compounds (NMVOCs) such as nitrogen oxide (NO_x), carbon monoxide (CO) and ammonia (NH_3) are also products from waste and wastewater treatment and discharge. Nonetheless, the waste volume does not provide specific methodologies for the estimation of emissions from these gases. In general, indirect N_2O produced from NMVOCs within the waste sector is expected to be insignificant (Pipatti & Svardal, 2006).

Solid Waste Disposal on land (excluding burning of waste) and Domestic wastewater treatment and discharge occurs in Vanuatu. Hence, these are the two waste categories that will be covered in this manual.

4.1.2: SOLID WASTE DISPOSAL (SWD) ON LAND AND DOMESTIC WASTEWATER IN VANUATU

The waste sector in Vanuatu encompasses of solid waste and wastewater. The main gases in this sector comprise mainly of methane (CH_4) and nitrous oxide (N_2O) emissions estimated from the two categories, Solid waste Management and Disposal (excluding biological waste) and Domestic and Commercial wastewater (no industrial wastewater generation) (Ministry of Climate Change, 2020).

In solid waste management and disposal, the key source of methane emissions in Vanuatu is mostly from anaerobic decomposition of wastes that are discarded at Bouffa landfill sites in Port Vila,

[1] CO_2 emissions of biogenic origin are either covered by the methodologies and reported as carbon stock change in the AFOLU Sector, or do not need to be accounted for because the corresponding CO_2 uptake by vegetation is not reported in the inventory (e.g., annual crops).

Luganville and Lenakel SWDs. SWD constitutes to a great amount of total greenhouse gas (GHG) emissions in Vanuatu from the waste sector itself. The GHG emission from this sector is a major concern for the country. The common practice in the country of municipal solid waste (MSW) disposal comprises of disposal on land (collected and disposes on landfills), open backyard dumpsite, and disposal on unused land. SWD in urban areas poses many hazards compared to scattered waste in rural areas. The reason being high urban population produces a higher per capita MSW where the generation of organic fraction is relatively high. On the other hand, the shallow waste depths of disposal do not induce anaerobic conditions. These allows for lower emissions of methane in the rural areas in Vanuatu (MOCC, 2021)

The domestic wastewater in Vanuatu is greatly decentralized focusing on privately managed households and commercial septic tanks for collecting human wastes. The by-product of sludge and wastewater are produced from the waste decomposition process. Over time, residual sludge is extracted by private services through tankers and is disposed at allocated waste sites or the sea. The major GHG emissions from domestic wastewater include CH_4 and N_2O emissions. Reports have stated that though GHG emissions from wastewater may not be relevant in Vanuatu, the emissions are posing environmental hazards by increasing in time. Moreover, Tourism sector is a major contributor to the country's economy hence the waste sector may negatively impact the tourism sector in Vanuatu (Ministry of Climate Change, 2020).

4.2: REFERENCE MANUAL

4.2.1: DATA COLLECTION

4.2.1.1: SOLID WASTE DISPOSAL ON LAND

The basic activity data requirements needed for First Order Decay (FOD) for Solid Waste Disposal on Land in Vanuatu comprises of:

- The **total population** and **GDP** for the period of 1950 to 2022 to estimate CH_4. The activity data can be actual or modelled.
- **Waste generation per capita** (kg/cap/year). If not available, use IPCC default value for Caribbean.
- **Waste Composition** (If no country-specific data is available, break the total waste diverted to SWDs into composition with the use of default IPCC default for Oceania). If country-specific data are available, use either the *waste composition* or a *bulk waste* approach. The *waste composition* approach is a great initiative if the waste management practices changes.
- The **types of solid waste management sites** in Vanuatu with the **distribution (%)** of waste among these sites.

Table 1: Key Parameters for Activity Data (AD) in Solid Waste Disposal on Land

Activity Data	Key Parameters	Units
Key Parameters for AD-1		
General Population and Climate Data	❖ The country's population ❖ Total population served by waste management services ❖ The mean average temperature ❖ Climate Zone: Tropical Wet for Vanuatu	In millions In millions In Degree Celsius (◦C)
Characteristics of the solid waste disposal sites in Vanuatu, the fraction of waste managed:	❖ Anaerobically ❖ Semi-aerobically ❖ Deep sites and/or high-water table ❖ Shallow Sites ❖ Uncategorized	
Key Parameters for AD-2		
Information on total waste generation by population	❖ Total MSW (municipal solid waste) generation ❖ Does MSW include industrial waste generated? (Yes, or no?) If *No*, estimate total industrial waste generated ❖ Is sludge deposited in SWDS? If *yes*, how much sludge was deposited?	(tonne/capita/yr.) In kilo tonnes (kt). In kilo tonnes (Kt) In kilo tonnes (kt)

	❖ Total clinical waste (generally not included in MSW) ❖ Total hazardous waste (generally not included in MSW)	In kilo tonnes (kt)
Key Parameters for AD-3		
Waste flows: fraction of total MSW collected (should total to 100%)	❖ % of the amount collected that goes to solid waste disposal sites (SWDS). ❖ % of the amount collected that fraction sent to composting. ❖ % of the amount collected that fraction is open burned. ❖ % of the amount collected that in incinerated ❖ % of the amount collected that sent to recycling.	
Waste flows: fraction of MSW not collected (should total up to 100%)	❖ % of the amount not collected waste that is sent to composting. ❖ % of the amount not collected waste that is open burned ❖ % of the amount not collected waste that is sent to recycling.	
Key Parameters for AD-4		
Composition of waste in Vanuatu (should total to 100%)	❖ % Food ❖ % Garden ❖ % Paper/Cardboard ❖ % Wood ❖ % Textiles ❖ % Rubber/leather, etc If data is not available, use IPCC default values for Caribbean.	
Management practices at Landfills	❖ Are you recovering landfill gas? (Yes/No) If *yes*, amount of landfill gas recovered) ❖ How is landfill gas recovery estimated?	Landfill gas unit in kt

4.2.1.2: DOMESTIC WASTEWATER

4.2.1.2.1: METHANE (CH_4) EMISSIONS IN DOMESTIC WASTEWATER

The activity data for Domestic Wastewater in Vanuatu to estimate methane (CH_4) is the total amount of organically degradable material in wastewater (TOW). To calculate TOW, the required data should be gathered:

- The country's population
- Country-specific per capita Biological Oxygen Demand (BOD), (g/person/day). If unavailable, use default value for region "Latin America", being the closest to Caribbean (*Refer to Annex* Table A4.1*)*.

- 0.001 = To convert from BOD (grams) to BOD (kilograms)
- The correction factor (I) for additional industrial BOD that is discharged into sewers. (Note that for collected the default value is 1.25, for uncollected the default is 1.00).

(See 2006 IPCC Guidelines, Volume 5 Chapter 6, Wastewater treatment and Discharge, Section 6.2.2.3 for the Choice of Activity Data and Equation 6.3).

Table 2: Additional activity data required to estimate methane (CH_4) emissions in domestic water.

ACTIVITY DATA	NOTES	UNITS
Total Organic Component removed as sludge		kg BOD/yr.
Fraction of Population in Income group (i)	Income groups in Vanuatu • High Income Group • Medium Income Group • Low Income Group	In millions
The degree of utilization of treatment/discharge pathway or system, j, for each income group fraction	Vanuatu lacks proper sewage and wastewater treatment systems. Waste is disposed via: • Illegal stormwater connections • Direct discharge to poor designed/maintained septic systems that leach contaminants into coastal and freshwater system	
The Emission factor	Use default for values for B_o and MCF_j to calculate EF from equation. $EFj = Bo \bullet MCFj$ *(See Annex Table A4.2 & Table A4.3)*	kg CH_4 /kg BOD
The amount of CH_4 recovered		kg CH_4 /yr.

(See 2006 IPCC Guidelines, Volume 5 Chapter 6, Wastewater treatment and Discharge, Section 6.2.2.1 for the Domestic wastewater Choice of Method and Equation 6.1).

4.2.1.2.2: INDIRECT NITROUS OXIDE (N_2O) EMISSIONS IN DOMESTIC WASTEWATER

At present, Vanuatu lacks treatment plants. When treatment plants are established in the future, Direct N_2O emissions can be calculated utilizing the following activity data requirements:

- The total amount of nitrogen in wastewater effluent (N/yr.)
- Country's population (millions)
- Protein consumption (annual per capita protein consumption (kg/person/year.)).
- Fraction of nitrogen in protein, default = 0.16 (N/kg protein)
- Default factor for non-consumed protein added to the wastewater. (*See Annex Table A4.4 for* $F_{NON\text{-}CON}$)
- Default factor for industrial and commercial co-discharged protein into the sewer system. (*See Annex Table* A4.4 *for* $F_{IND\text{-}COM}$)
- Nitrogen removed with sludge (default = zero), kg N/yr.

(See 2006 IPCC Guidelines, Volume 5 Chapter 6, Wastewater treatment and Discharge, Section 6.3.1.3 for the Domestic wastewater, Choice of Activity Data and Equation 6.8).

4.2.2. DATA SOURCES (DEPARTMENTS, STAKEHOLDERS)

The country's specific data can be collected from the following departments/stakeholders/organization:

- Department of Environmental Protection and Conservation (DEPC)
- Department of Water Resources (DWR)
- Port Vila City Council (PVCC)
- Environment Unit, Public Health at the Ministry of Health
- Department of Climate Change (DOCC)
- UNELCO Engie
- Public Works Department (PWD)

Once a data set is selected, a more detailed formal specification of data should be created. A clear clarity of data requirements will allow data that is requested from the different departments/organizations to be delivered upon expectation (Goodwin, Woodfield, Ibnoaf, Koch, & Yan, 2006). The specification should include details such as:

- Definition of the data set (e.g., time series, sectors and sub-sector detail, national coverage, requirements for uncertainty data, emission factors and/or activity data units).
- The format (e.g., spreadsheet) and structure (e.g., what different tables are needed and their structure) of the data set,
- Description of any assumptions made regarding national coverage, the sectors included, representative year, technology/management level, and emission factors or uncertainty parameters.

- Identification of the routines and timescales for data collection activities (e.g., how often is the data set updated and what elements are updated).
- Reference to documentation and QA/QC procedures.
- Contact name and department/ organization.
- Date of availability.

Flow chart 4.1: Details of access to data sources by Department of Climate Change (DOCC)

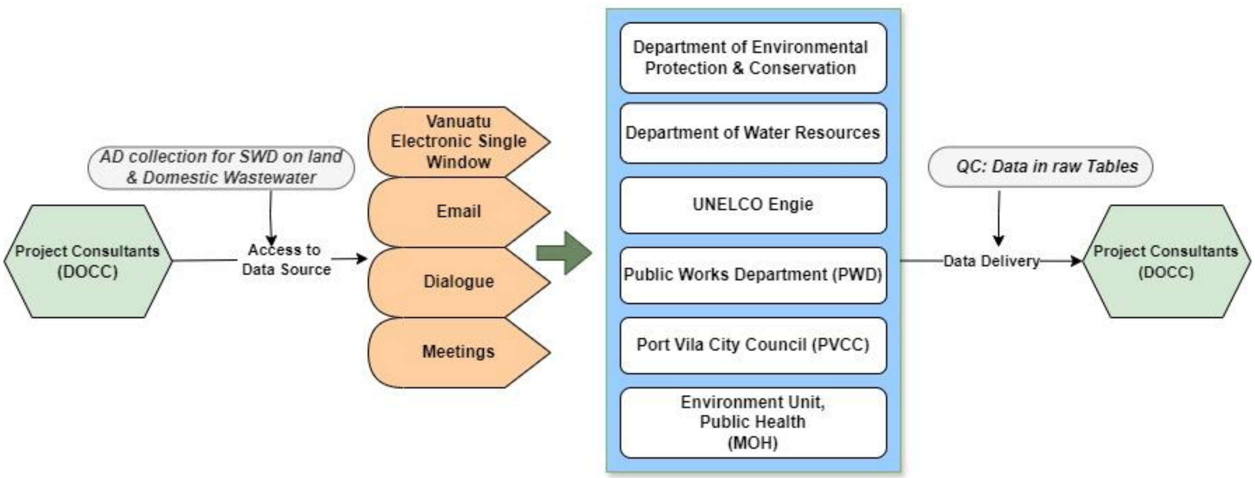


Table 3 Detailed Information of Collecting Data from Sources.

Department/ Organization	Roles and Responsibility	Dates	Relevant Governing Arrangement	Contact Person	Comments
Department of Water Resources (DWR)	To provide information on measurements and analysis of BOD, COD, and activity data on Domestic wastewater operations (collection and disposal of waste) in rural areas in Vanuatu.	First week of April– First week of May every year	A Memorandum of understanding or Right to Information (RTI) can be provided between DWR and DOCC	Department of water resources Tel: (678)22423/33435 Email: esteitoka@vanuatu.gov.vu	For significant information and data collection, DOCC needs to send a prompt letter to DWR two months prior. A follow-up email or call is crucial as well.
Department of Environmental Protection & Conservation (DEPC)	To provide relevant information on activity data and	First week of April– First week of May every year	A Memorandum of understanding or Right to Information (RTI) can be provided	Environment Unit	For significant information and data collection, DOCC needs to

	key parameters on SWD on land.		between DEPC and DOCC	Name: Ionie Bolenga *(Principal Officer on Waste Management and Pollution Control)* Email: ibolenga@vanuatu.gov.vu Name: Annabelle Alilee (Pollution Control Officer) Email: aalilee@vanuatu.gov.vu	send a prompt letter to DEPC two months prior. A follow-up email or call is crucial as well.
Public Works Department (PWD)	To provide relevant information and data on the operation (collection and disposal) of domestic wastewater in Urban and sub-urban areas.	First week of April– First week of May every year	A Memorandum of understanding or Right to Information (RTI) can be provided between PWD and DOCC	Public Works Department Email: pwdheadoffice@vanuatu.gov.vu Tel: 33460 or 22790	For significant information and data collection, DOCC needs to send a prompt letter to PWD two months prior. A follow-up email or call is crucial as well.
UNELCO Engie	To provide relevant information and data on the operation (collection and disposal) of domestic wastewater in Urban and sub-urban areas.	First week of April– First week of May every year	A Memorandum of understanding or Right to Information (RTI) can be provided between UNELCO and DOCC	UNELCO ENGIE Email: unelco@engie.com Tel: 26000	For significant information and data collection, DOCC needs to send a prompt letter to UNELCO two months prior. A follow-up email or call is crucial as well.
Port Vila City Council (PVCC)	To provide relevant information and	First week of April– First	A Memorandum of understanding or Right to		For significant information and data collection,

	data on the operation of SWD on land and domestic wastewater management within its jurisdiction.	week of May every year	Information (RTI) can be provided between PVCC and DOCC		DOCC needs to send a prompt letter to PVCC two months prior. A follow-up email or call is crucial as well.
Department of Climate Change (DOCC)	DOCC is responsible to send a formal letter requesting relevant data and information on SWD on land and Domestic Wastewater to the Environmental Protection and Conservation, The Department of Water Resources, Public Works Department, UNELCO, Port Vila City Council, and the Environment Unit under the Ministry of Climate Change.	February – March every year	Provide a Memorandum of understanding or Right to Information (RTI) to the Environmental Protection and Conservation, The Department of Water Resources, Public Works Department, UNELCO, Port Vila City Council, and the Environment Unit under the Ministry of Climate Change	Name: Nelson Kalo Director of Climate Change Email: nekalo@vanuatu.gov.vu	DOCC is responsible for doing a follow-up to the departments or organization for the required data to be delivered upon schedule.

4.2.3. DATA ASSUMPTIONS

Solid Waste Disposal

The main considerations and assumptions made are provided for both bulk and waste composition options to estimate methane emissions on Solid waste disposal on land in Vanuatu (See 2006 IPCC Guidelines, Volume 5 Chapter 3 Solid Waste Disposal, Section 3.2.3, Choice for emission factors and parameters under Half-life).

- The default assumption for the time delay is that the reaction starts on the first of January in the year of deposition, which is equivalent to an average delay time of six months before decay to methane commences ("Delay time = 6"). It is best to assume an average delay time of six months. If a value greater than six months is chosen, evidence to support this must be provided.
- Waste composition (especially the organic component) is one of the main factors influencing both the amount and the timing of CH4 production.
- Moisture content of a SWDS is an essential element for anaerobic decomposition and CH4 generation. A simplified method assumes that the moisture content of a SWDS is proportional to the mean annual precipitation (MAP) in the location of the SWDS (Pelt *et al*., 1998; U.S. EPA, 1998; Environment Canada,2003) or to the ratio of MAP and potential evapotranspiration (PET).
- The extent to which ambient air temperatures influence the temperature of the SWDS and gas generation rates depends mainly on the degree of waste management and the depth of SWDS.
- Waste in shallow open dumps generally decomposes aerobically and produces little CH4, and the emissions decline in shorter time than the anaerobic conditions. Managed (and deep unmanaged) SWDS creates anaerobic conditions.

Domestic Wastewater

The emission factor for N_2O emissions is based on limited field especially on specific assumptions considering the occurrence of denitrification and nitrification activities in rivers and estuaries (See 2006 IPCC Guidelines, Volume 5 Chapter 6, Wastewater treatment and Discharge, Section 6.3.1.2, Choice for emission factors and Section 6.3.4, QA/QC, Completeness, Reporting and Documentation). The assumptions provided are:

- All nitrogen is discharged with the effluent.
- N_2O production in rivers and estuaries is directly related to nitrification and denitrification and, thus, to the nitrogen that is discharged into the river. (See Volume 4, Table 11.3 of Section 11.2.2 in Chapter 11, N_2O Emissions from Managed Soils, and CO*2* Emissions from Lime and Urea Application).

- All nitrogen associated with consumption and domestic use, as well as nitrogen from co-discharged industrial wastewater, will eventually enter a waterway. As such, this estimate can be seen as a conservative estimate and covers the entire source associated with domestic wastewater use.

4.3. CALCULATING GREENHOUSE GAS EMMISSIONS FROM WASTE SECTOR

SOLID WASTE DISPOSAL (SWD)

4.3.1 METHODOLOGY CHOICE FOR SOLID WASTE DISPOSAL(SWD)

Figure 1: Decision Tree Utilized for Method Selection in Estimating CH_4 Emissions from Solid Waste Disposal Sites in Vanuatu

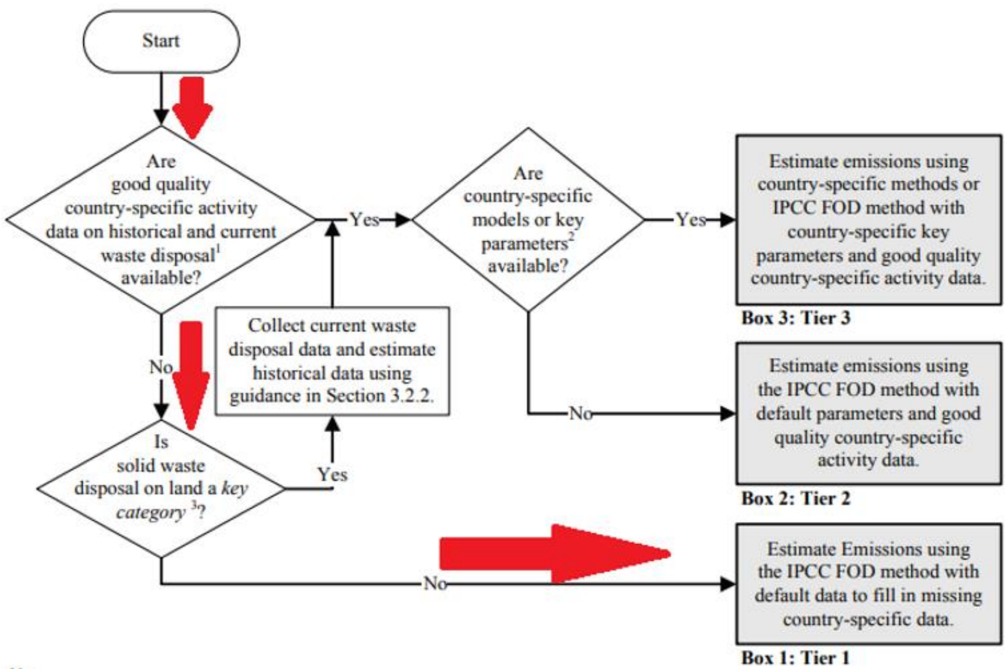


Figure 4.1: (See 2006 IPCC Guidelines, Vol.5, Figure 3.1)

Note: Due to the national circumstances (lack of resources) Vanuatu does not have yet reliable country-specific emission factors and parameters and therefore, and is therefore applying the default parameters and Tier 1 methods to estimate emissions from the category 4A – Solid Waste Disposal and its subcategories 4.A.1 Managed disposal sites, 4.A.2 Unmanaged Disposal Sites and 4.A.3 Uncategorized Waste Disposal.

EQUATIONS USED

1. **Determine the Amount of Decomposed DOC Deposited in the SWDs Each Year**

Step 1: FOD (first-order decay)

*1.1 Estimating the **mass of waste available** for decomposition (DDOCm)*

Equation 1

EQUATION 3.2
DECOMPOSABLE DOC WASTE DISPOSAL
$DDOCm = W \times DOC \times DOC_f \times MCF$

Where:

- **W** = Amount of waste (See 2006 IPCC Guidelines, Vol.5, Pg. 9, EQUATION 3.2)
- **DOC** = Degradable organic carbon in the waste (See 2006 IPCC Guidelines, Vol.5, Pg. 9, EQUATION 3.2).
- **DOC_f** = Fraction of DOC that can decompose anaerobically (See 2006 IPCC Guidelines, Vol.5, Pg. 9, EQUATION 3.2)
- **MCF** = Amount that will decompose anaerobically (See 2006 IPCC Guidelines, Vol.5, Pg. 9, EQUATION 3.2).
- **DOC_f** uses a default value of 0.5 (See IPCC Guidelines, Vol.5 Pg. 27, Table 3.5).

*1.2 Determining **the time series of waste decomposing***

Equation 2

EQUATION 3.4
DDOCm ACCUMULATION IN THE SWDS AT THE END OF THE YEAR T
$DDOC_{maT} = DDOC_{mdT} + (DDOC_{maT-1} \times e^{-k})$

Where:

- **$DDOC_{maT}$** = Mass of decomposable DOC accumulated at the end of the year. (See 2006 IPCC Guidelines, Vol.5, Pg. 9, EQUATION 3.4)

- **$DDOC_{mdT}$** = Amount of DOC deposited in the current year (See 2006 IPCC Guidelines, Vol.5, Pg. 9, EQUATION 3.4)

- **$(DDOC_{maT-1} \times e^{-k})$** = Amount of degradable waste accumulated from the previous year that has not yet decomposed (See 2006 IPCC Guidelines, Vol.5, Pg. 9, EQUATION 3.4)

Equation 3

EQUATION 3.5

$$DDOC_{m\ decompT} = DDOC_{maT-1} \times (1 - e^{-k})$$

Where:

- **T** = Inventory year (See 2006 IPCC Guidelines, Vol.5, Pg. 9, EQUATION 3.5)
- **$DDOC_{maT}$** = DDOCm accumulated in the SWDS at the end of year T, Gg (See 2006 IPCC Guidelines, Vol.5, Pg. 9, EQUATION 3.5)
- **$DDOC_{maT-1}$** = DDOCm accumulated in the SWDS at the end of the year (T-1), Gg (See 2006 IPCC Guidelines, Vol.5, Pg. 9, EQUATION 3.5)
- **DDOCmdT** = DDOCm deposited into the SWDS in year T, Gg (See 2006 IPCC Guidelines, Vol.5, Pg. 9, EQUATION 3.5)
- **DDOCm decompT** = DDOCm decomposed in the SWDS in year T, Gg (See 2006 IPCC Guidelines, Vol.5, Pg. 9, EQUATION 3.5)
- **k** = reaction constant, k = ln (2)/t1/2 (y-1) (See 2006 IPCC Guidelines, Vol.5, Pg. 9, EQUATION 3.5)
- **t1/2** = half-life time (y) (See 2006 IPCC Guidelines, Vol.5, Pg. 9, EQUATION 3.5)

2. Determine Methane Generated as a Result of Decomposition Each Year

Step 2: Converting DDOC to Methane Generated

Equation 4

EQUATION 3.6

CH_4 GENERATED FROM DECAYED DDOCm

$$CH_4 \text{ generated} = DDOCm\ decomp_T \times F \times 16/12,$$

Where:

- **CH_4 generated** = Amount of CH_4 generated from decomposable material (See 2006 IPCC Guidelines, Vol.5, Pg. 10, EQUATION 3.6)
- **DDOCm $decomp_T$** = DDOCm decomposed in year T, Gg (See 2006 IPCC Guidelines, Vol.5, Pg. 10, EQUATION 3.6).
- **F** = Fraction of CH_4, by volume, in generated landfill gas (fraction) (See 2006 IPCC Guidelines, Vol.5, Pg. 10, EQUATION 3.6).
- **16/12** = molecular weight ratio CH_4/C (ratio) (See 2006 IPCC Guidelines, Vol.5, Pg. 10, EQUATION 3.6).

- The **default value of (F)** = 0.5 (See 2006 IPCC Guideline, Vol.5, Pg.27, Table 3.1)

3. Determine Methane Emissions

Step 3: Converting Methane to Methane Emissions

Equation 5

EQUATION 3.1

CH_4 EMISSION FROM SWDS

$$CH_4 \text{ EMISISONS} = \left[\sum CH_4 \text{ GENERATED}_{X,T} - R\right] \times (1 - OX_T)$$

Where:

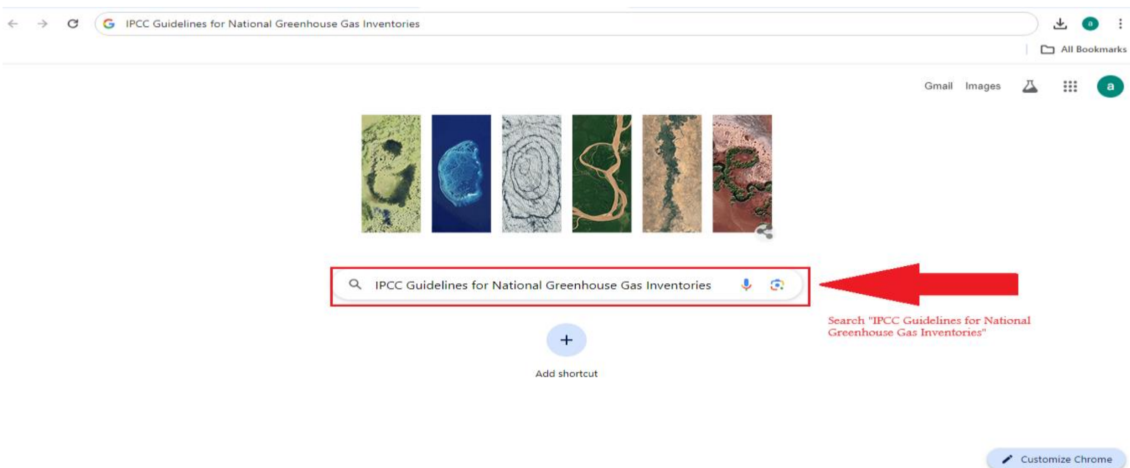
- **CH_4 Emissions** = CH_4 emitted in year T, Gg (See 2006 IPCC Guidelines, Vol.5, Pg. 8, EQUATION 3.1)
- **T** = Inventory year (See 2006 IPCC Guidelines, Vol.5, Pg. 8, EQUATION 3.1)
- **X** = Waste category or type/ material (See 2006 IPCC Guidelines, Vol.5, Pg. 8, EQUATION 3.1)
- **R_T** = Recovered CH_4 in year T, Gg (See 2006 IPCC Guidelines, Vol.5, Pg. 8, EQUATION 3.1)
- **OX_T** = Oxidation factor in year T. (fraction)
- Default **value R** = 0
- Default **OX_T** = 0% (See 2006 IPCC Guideline, Vol 5, pg. 15, Table 3.2)

4.3.2 STEP – BY – STEP CALCULATION, DOCUMENTING RESOURCES USED

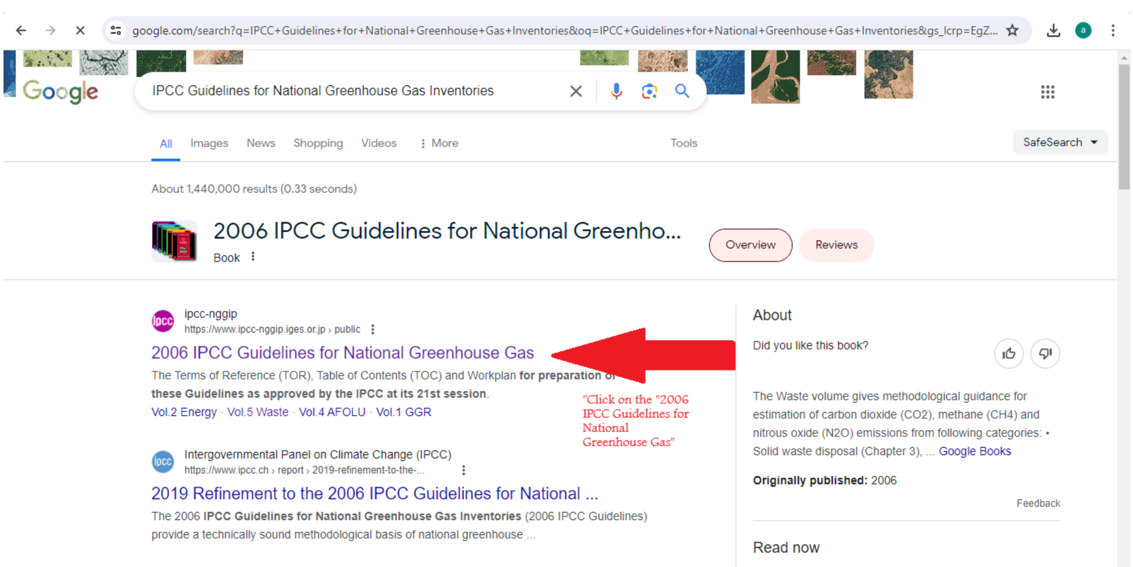
1. USING THE FOD MODEL PARAMETERS:

FILE https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/IPCC_Waste_Model.xls

1.0 Open Google Browser and type in "IPCC Guidelines for National Greenhouse Gas Inventories" (See illustrations below)

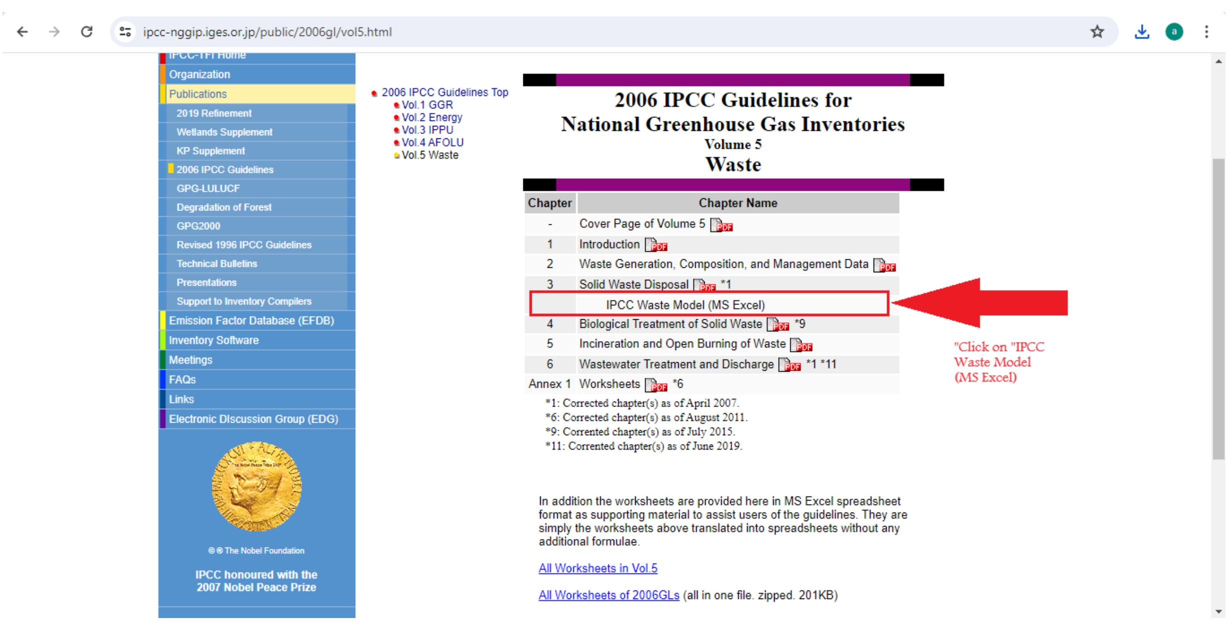


1.1 Click on the website "2006 IPCC Guidelines for National Greenhouse Gas" (See illustration below).



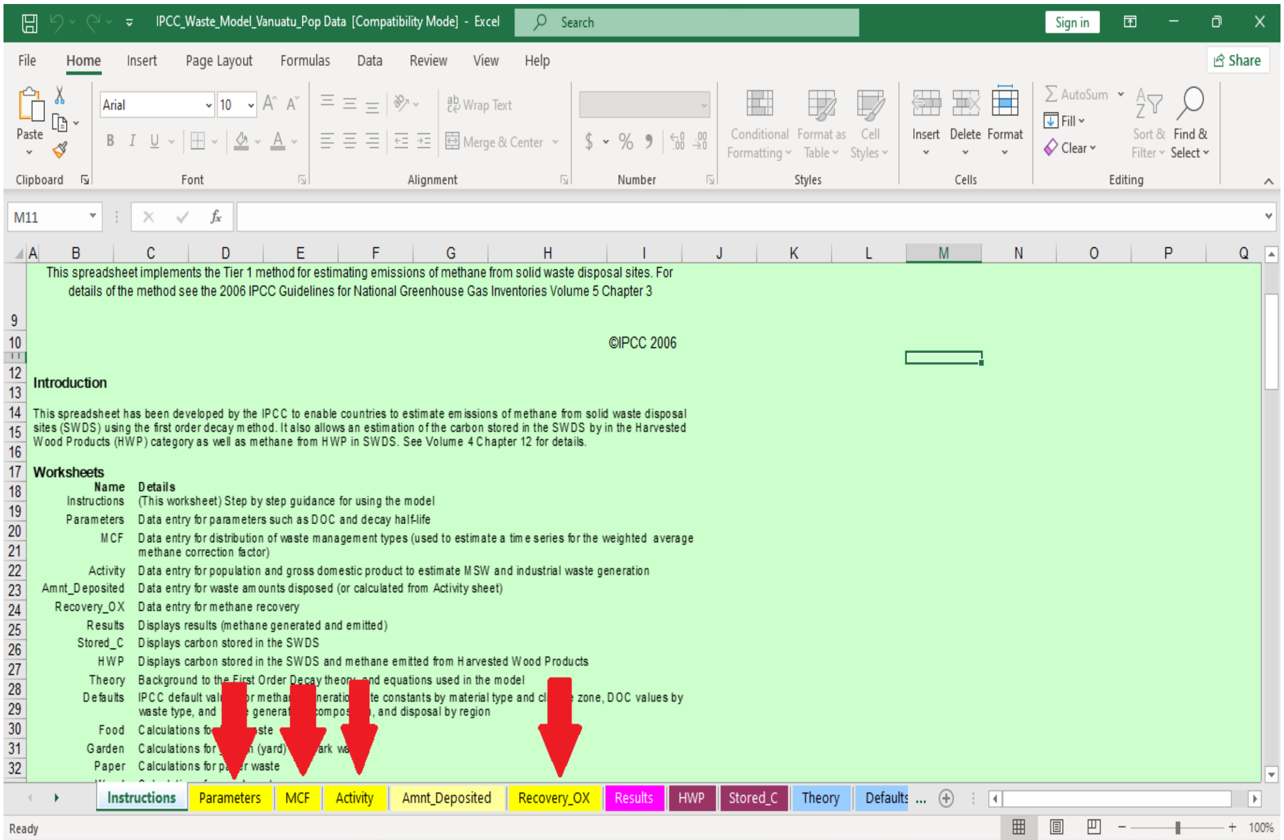
1.2 Click on the "Vol.5 Waste" (See illustration below)

1.3 Click on the "IPCC Waste Model (MS Excel) (See illustration below)

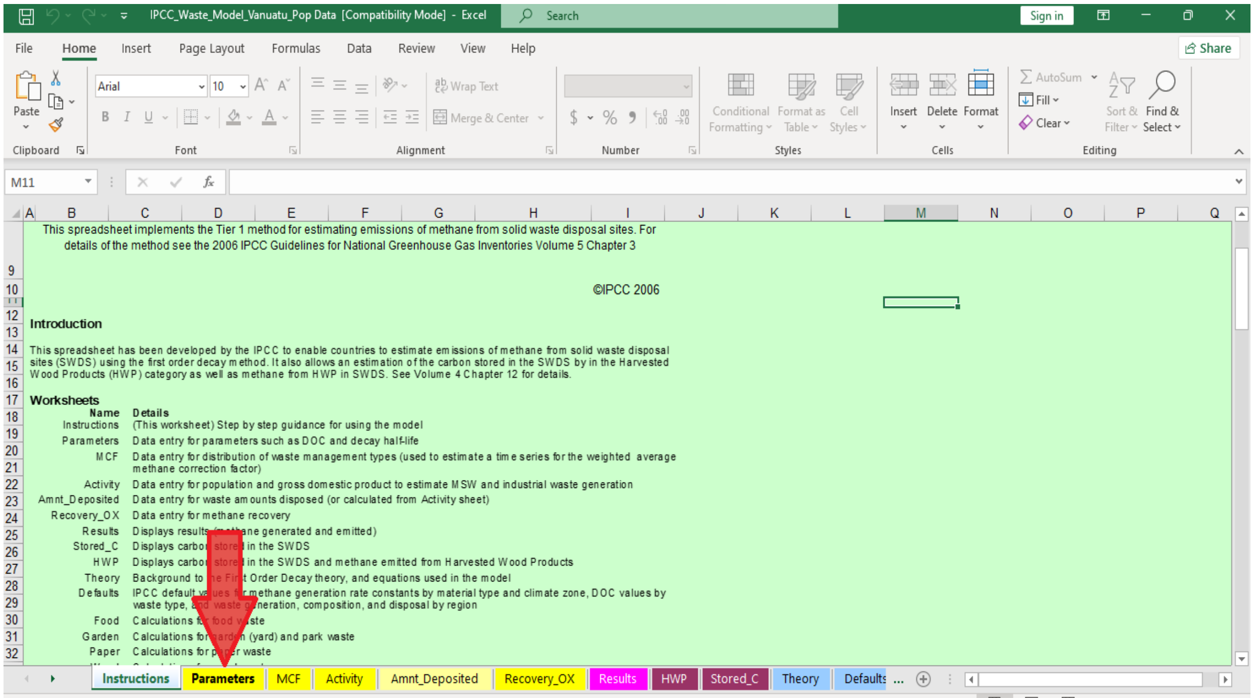


1.4 Open the file, IPCC model https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/IPCC_Waste_Model.xls

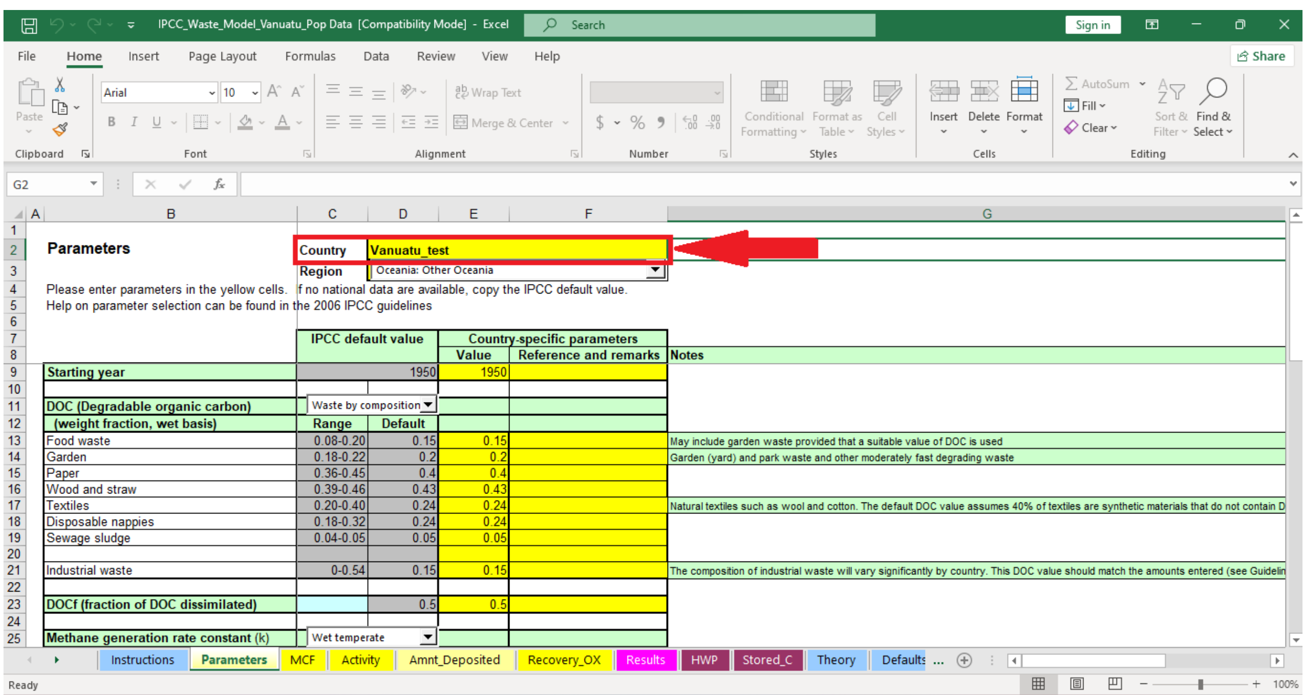
1.5 Note that the possible data entries are in tabs colored yellow (See red arrows below)



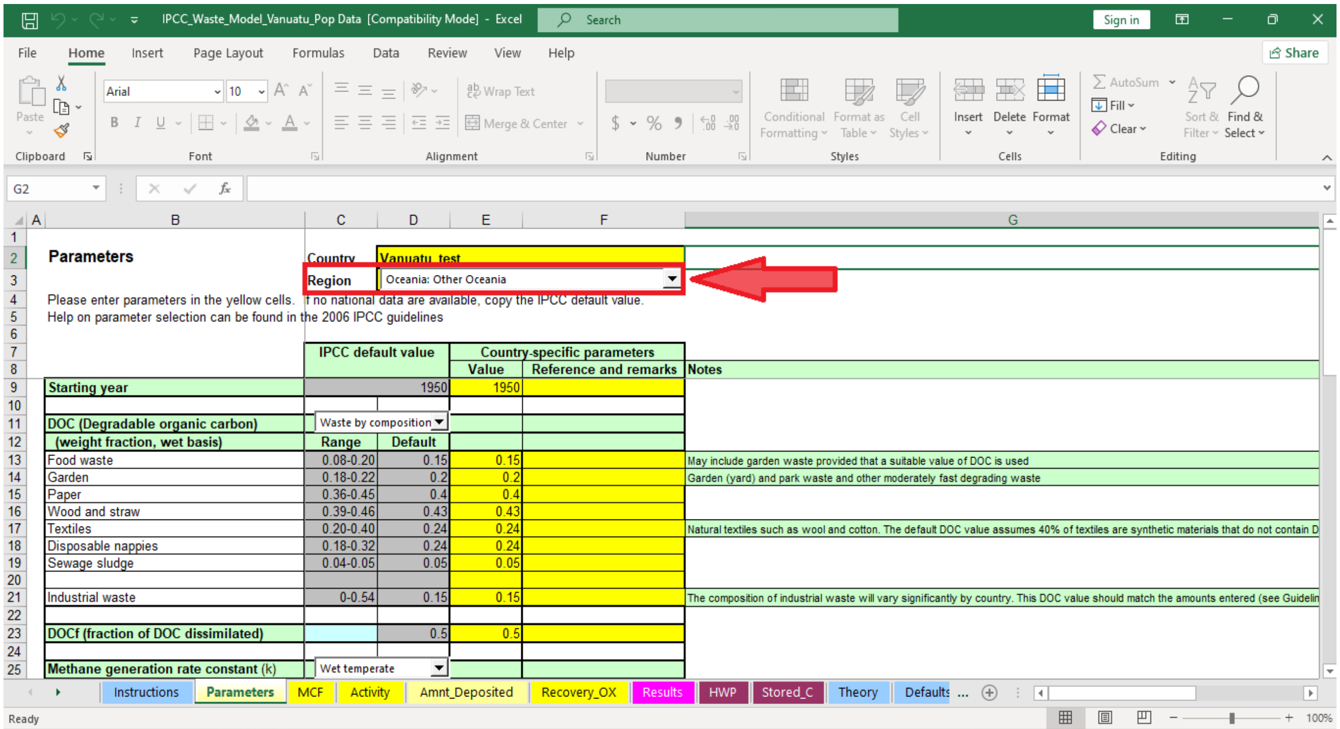
1.6 Click on the tab “Parameters” (See red arrow in illustration below)



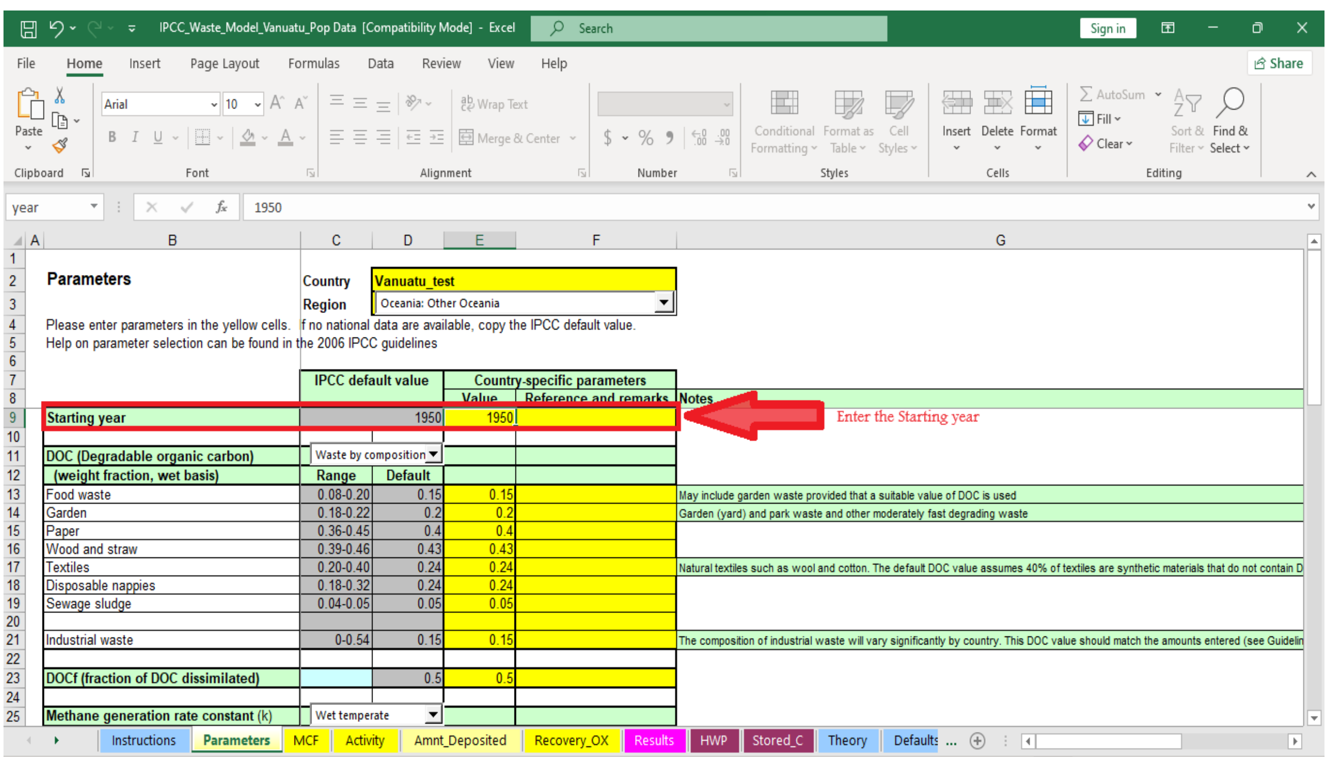
1.7 Click on the cell Country and enter Vanuatu (See red arrow below)



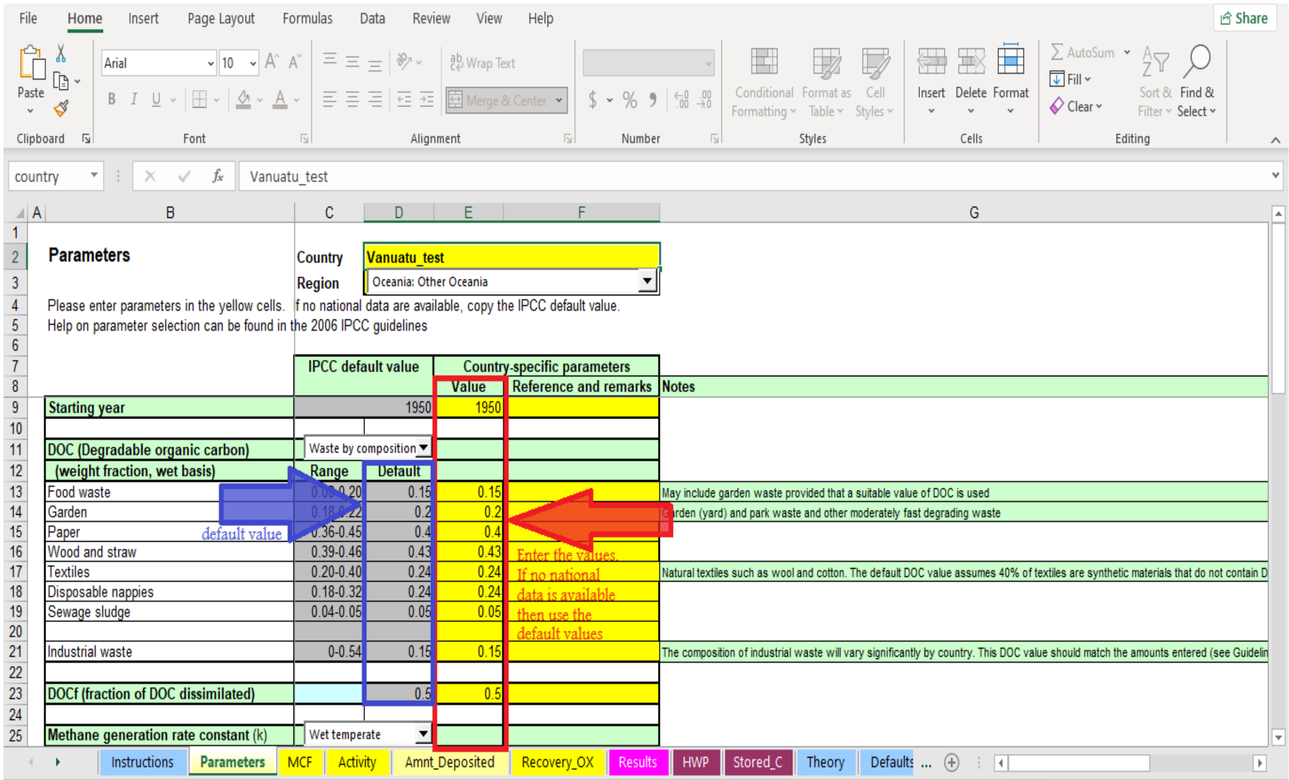
1.8 Click on the “Region” tab and choose “Oceania: other Oceania” (see illustration below).



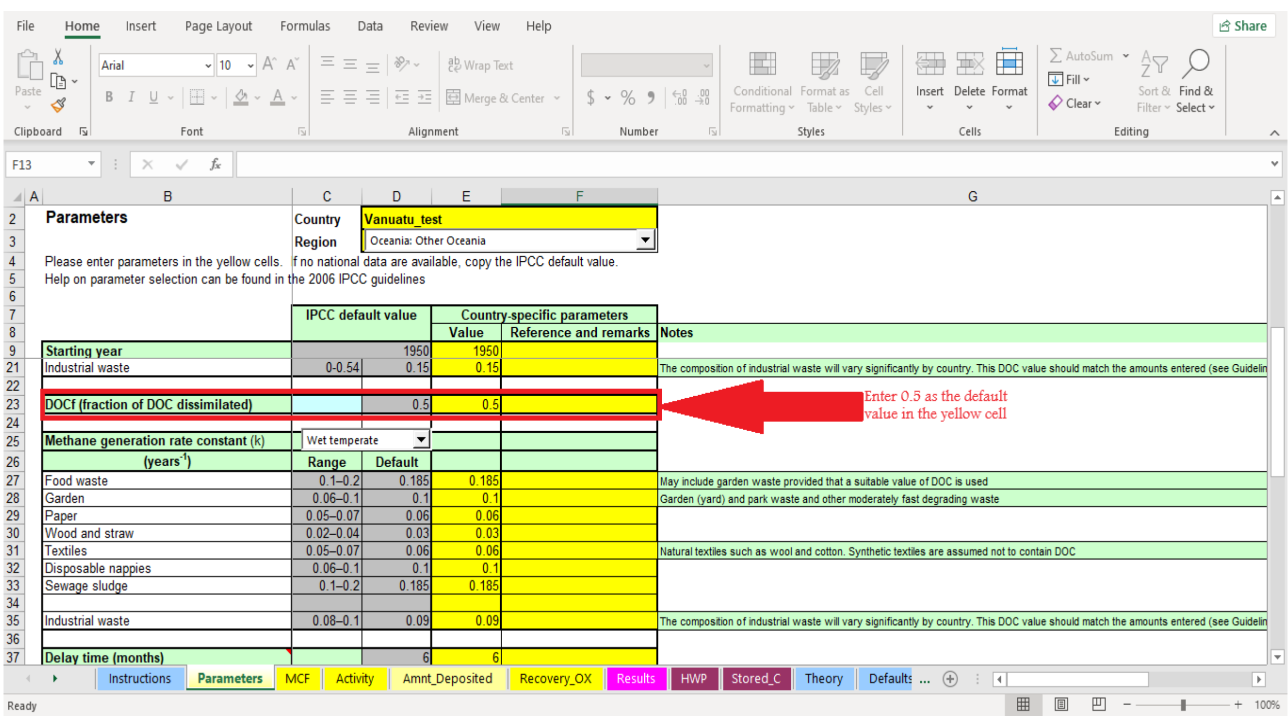
1.9 Enter the default starting year as 1950 in the “Parameters” Worksheet. (See below).



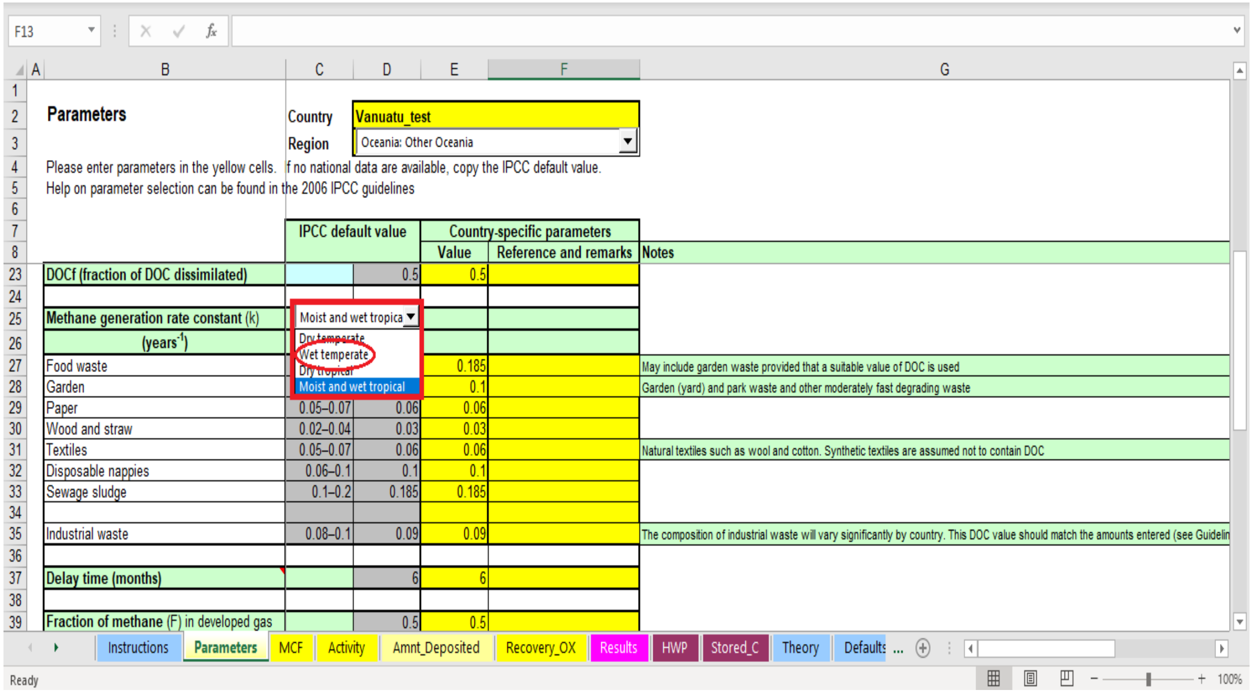
1.10. Fill in the “DOC (Degradable Organic Carbon)” in the “Parameters” Worksheet (See the red arrow pointing to where to fill in the values for DOC and the Blue arrow indicates where the IPCC Default values are if no national data is available.)



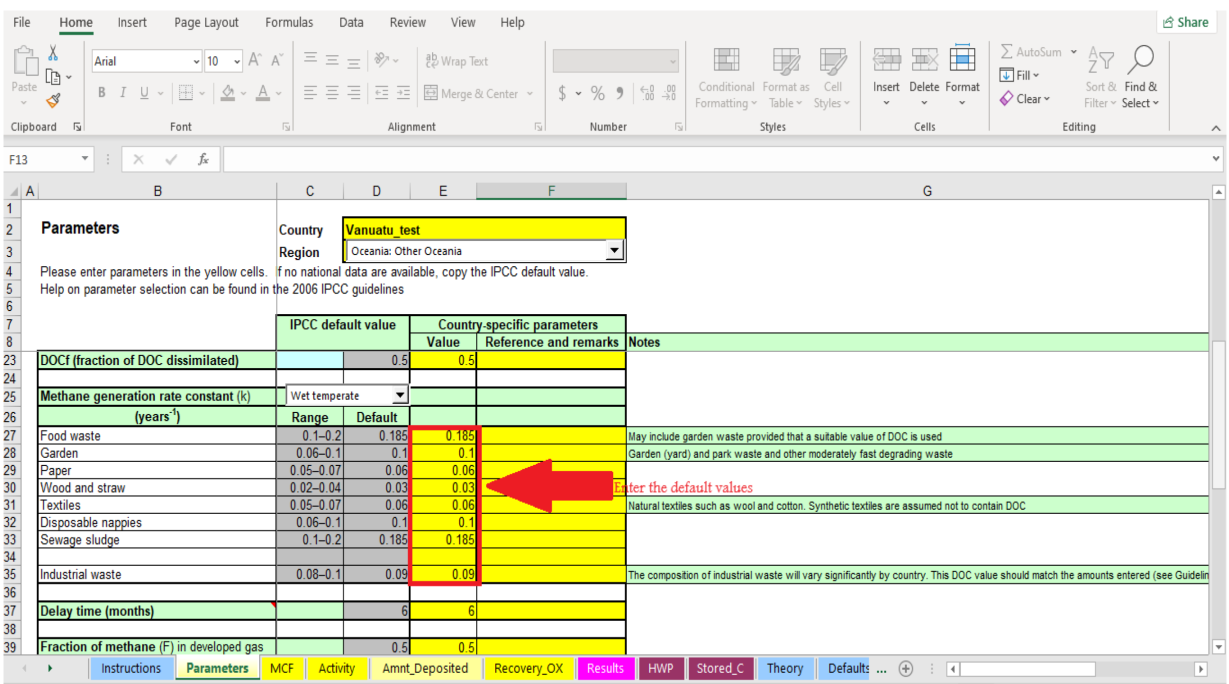
1.11. Enter the DOC default value 0.5 into the yellow cell E23 (See red arrow below)



1.12. Click on the Methane drop-down menu and select Wet temperate (see illustration below)



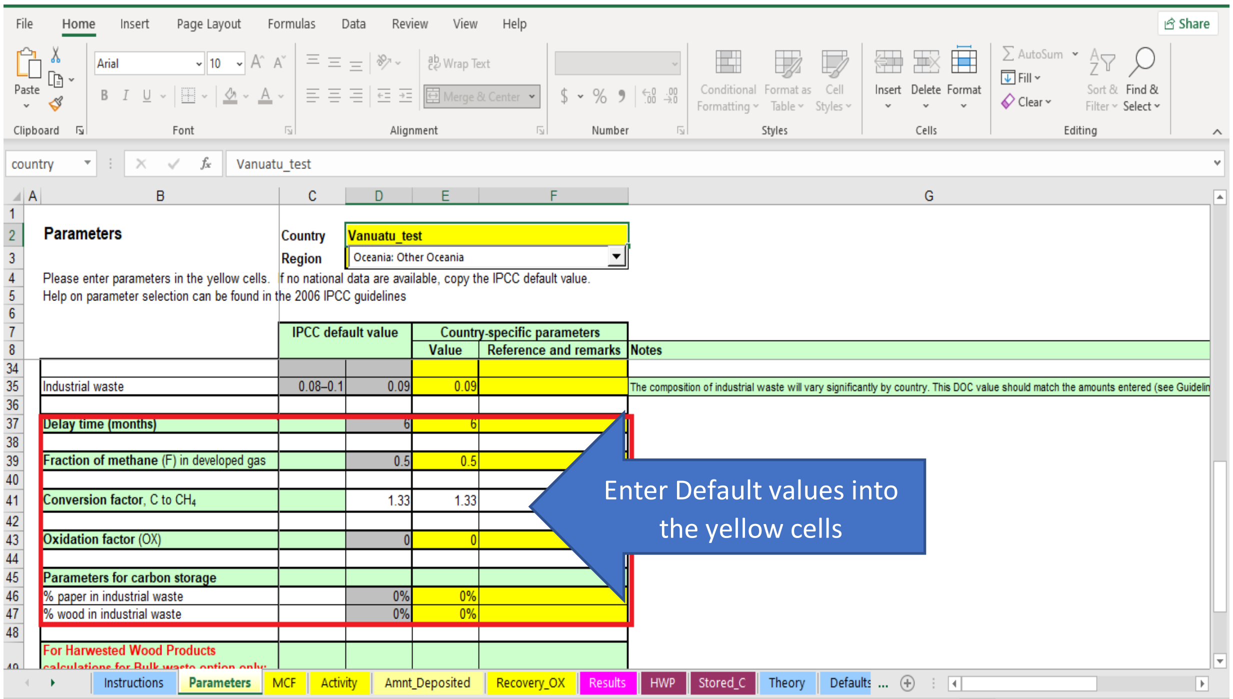
1.13 Enter the default values from the grey cells D27 to D35 into the yellow cells. Vanuatu does not have any Country specific values (See red arrow in the illustration below)



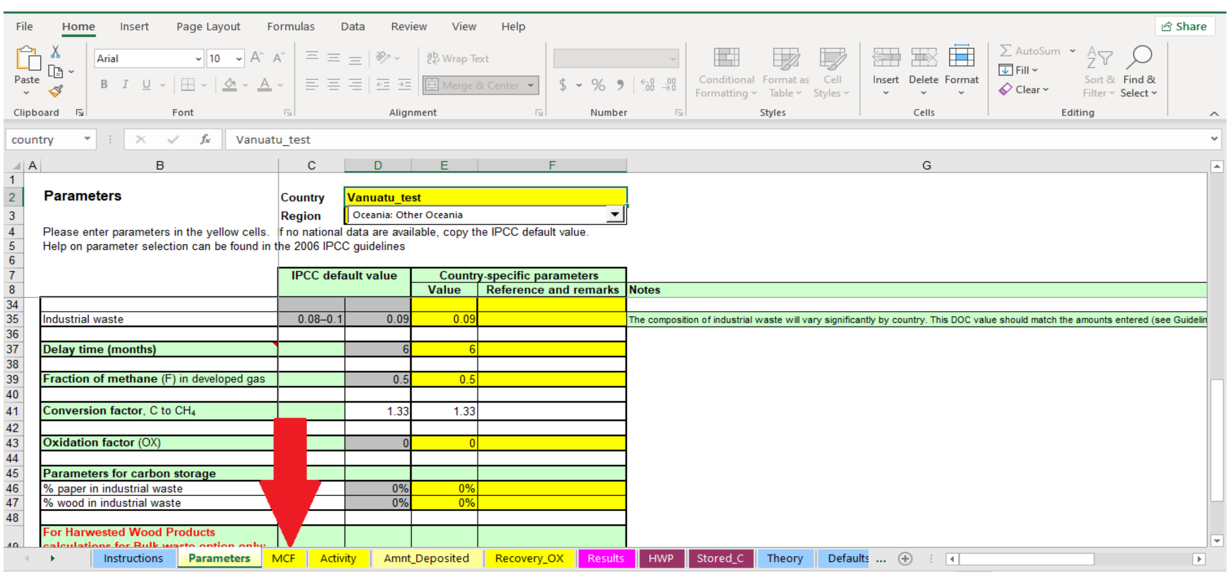
1.14 Enter the default values from the grey cells into the yellow cells:

- Delay time: 6
- Fraction of Methane: 0.5
- Oxidation Factor (OX): 0
- % Paper in industrial waste: 0%
- % Wood in industrial waste: 0%

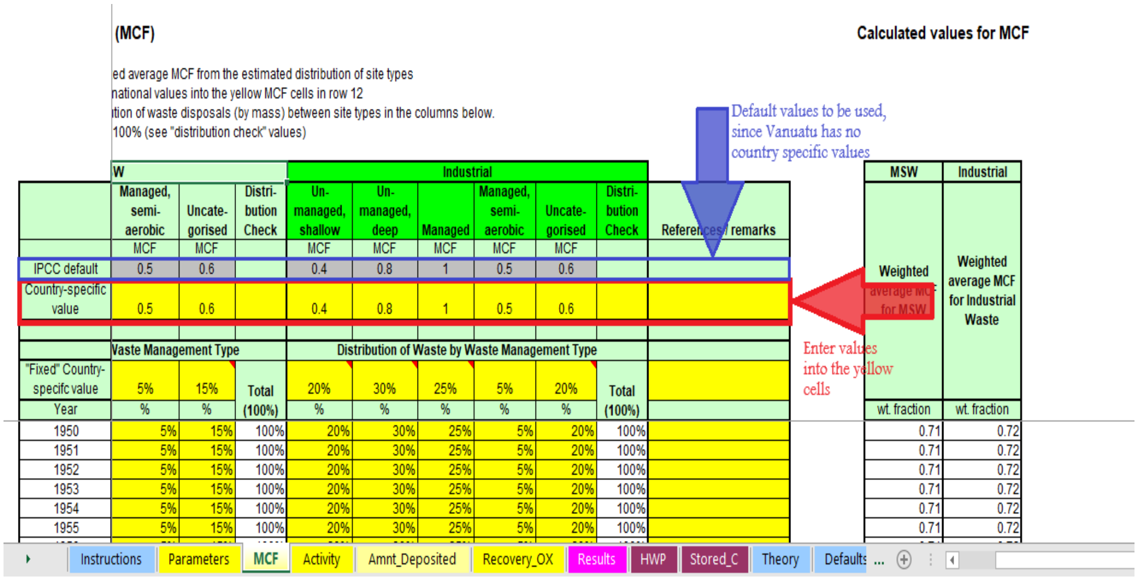
(See the red outline in the figure below)



1.15 Click on the “MFC” tab (see red arrow below)



1.16 Enter the IPCC default values from grey cells 12C to 12M into the yellow cells 13C to 13M. Vanuatu has no country-specific value hence the IPCC default value will be used.


(MCF)

Calculated values for MCF

ed average MCF from the estimated distribution of site types
national values into the yellow MCF cells in row 12
tion of waste disposals (by mass) between site types in the columns below.
100% (see "distribution check" values)

Default values to be used, since Vanuatu has no country specific values

Enter values into the yellow cells

	W			Industrial							MSW	Industrial
	Managed, semi-aerobic	Uncategorised	Distribution Check	Un-managed, shallow	Un-managed, deep	Managed	Managed, semi-aerobic	Uncategorised	Distribution Check	References/ remarks	Weighted average MCF for MSW	Weighted average MCF for Industrial Waste
	MCF	MCF		MCF	MCF	MCF	MCF	MCF				
IPCC default	0.5	0.6		0.4	0.8	1	0.5	0.6				
Country-specific value	0.5	0.6		0.4	0.8	1	0.5	0.6				
	Waste Management Type			Distribution of Waste by Waste Management Type								
"Fixed" Country-specifc value	5%	15%	Total	20%	30%	25%	5%	20%	Total			
Year	%	%	(100%)	%	%	%	%	%	(100%)		wt. fraction	wt. fraction
1950	5%	15%	100%	20%	30%	25%	5%	20%	100%		0.71	0.72
1951	5%	15%	100%	20%	30%	25%	5%	20%	100%		0.71	0.72
1952	5%	15%	100%	20%	30%	25%	5%	20%	100%		0.71	0.72
1953	5%	15%	100%	20%	30%	25%	5%	20%	100%		0.71	0.72
1954	5%	15%	100%	20%	30%	25%	5%	20%	100%		0.71	0.72
1955	5%	15%	100%	20%	30%	25%	5%	20%	100%		0.71	0.72

Instructions | Parameters | MCF | Activity | Amnt_Deposited | Recovery_OX | Results | HWP | Stored_C | Theory | Defaults ...

1.17 Enter the % waste for MSW and Industrial see the tables below for the values. An illustration is also provided after the tables (see figure below, after the tables)

Table 4: Percentage values for each of the different MSW site types

The yellow cells on the excel file where the values are to be entered. These percentages should total to 100%.

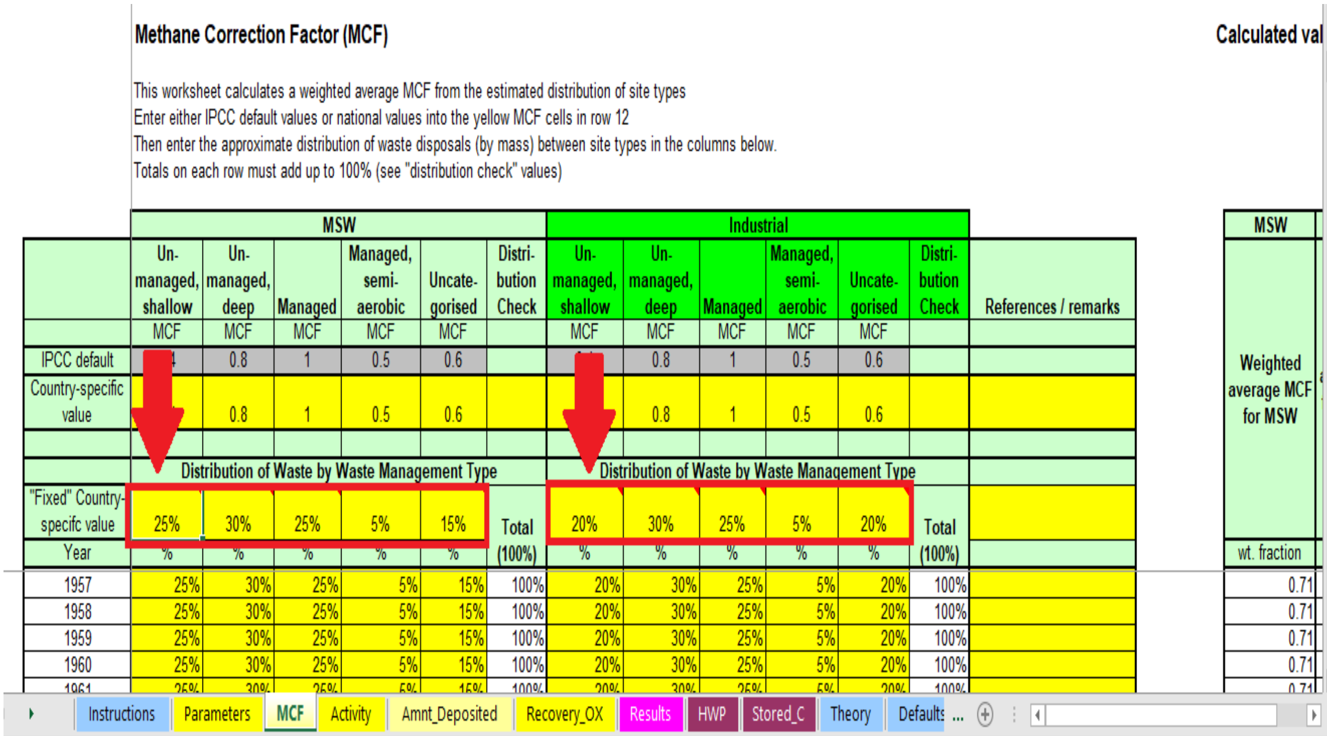
MSW	% of waste	Cell
Unmanaged Shallow	25	C16
Unmanaged Deep	30	D16
Managed	25	E16
Managed Semi-aerobic	5	F16
Uncategorized	15	G16
Total =	**100%**	

Table 5: Percentage values for each of the different Industrial site types

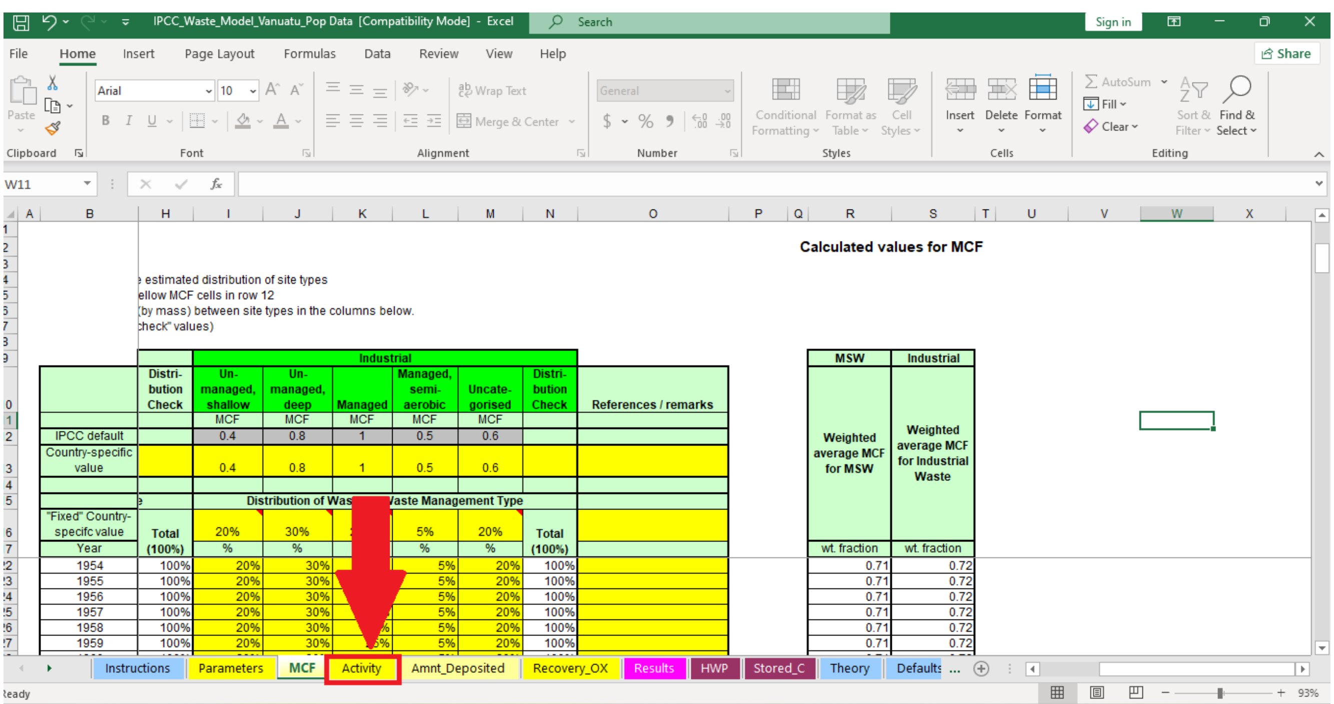
The yellow cells where the values are to be entered. These percentages have to equal to 100%.

Industrial	% of waste	Cell
Unmanaged Shallow	25	I16
Unmanaged Deep	30	J16
Managed	25	K16

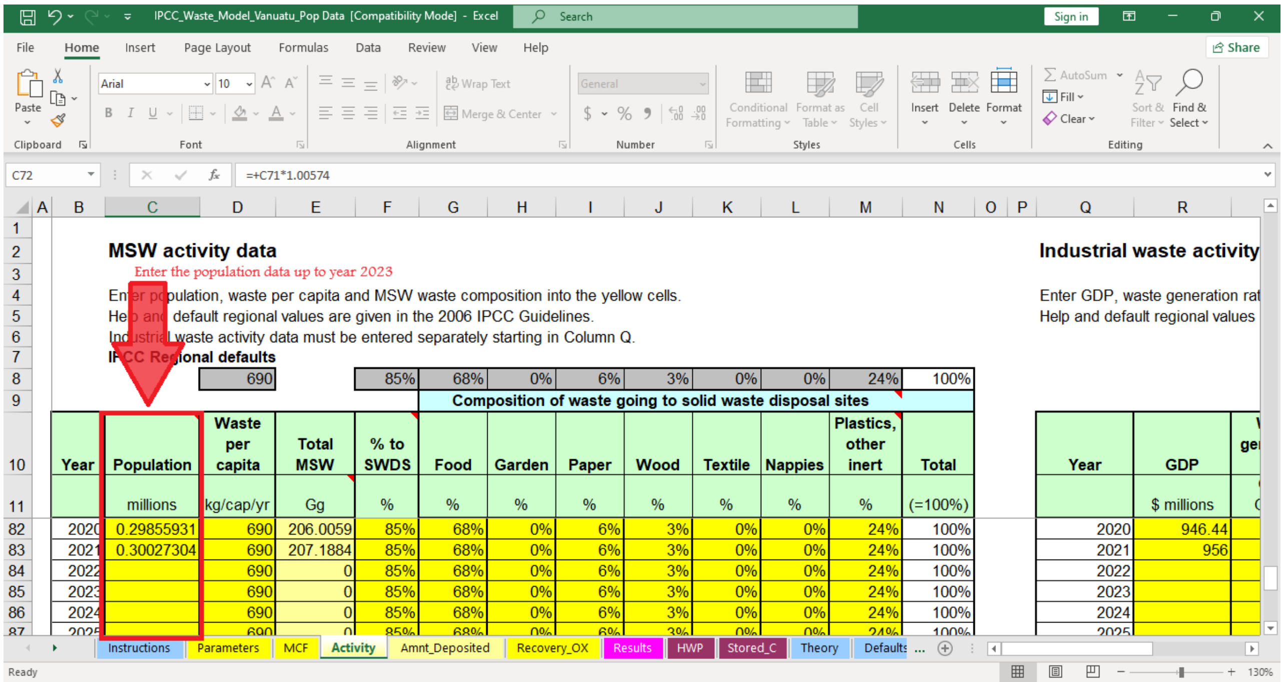
Managed Semi-aerobic	5	L16
Uncategorized	15	M16
Total =	**100%**	



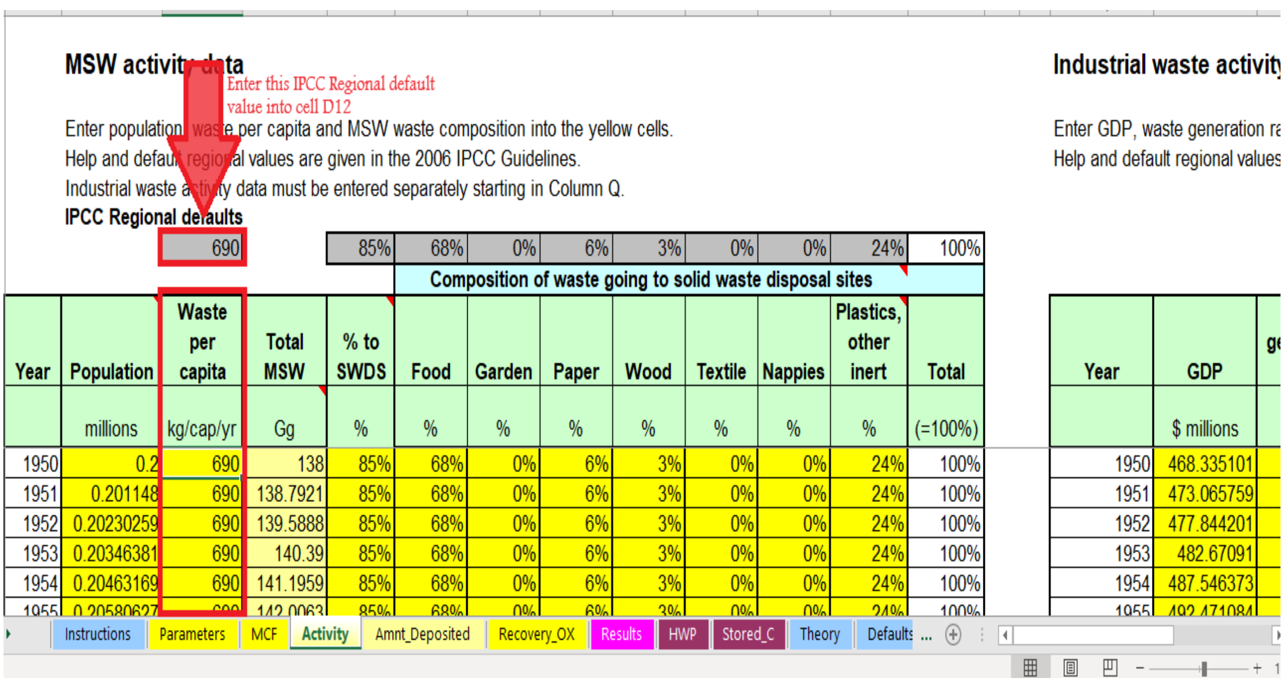
1.18 Click on the "Activity" tab at the bottom of the page (see red arrow in illustration)



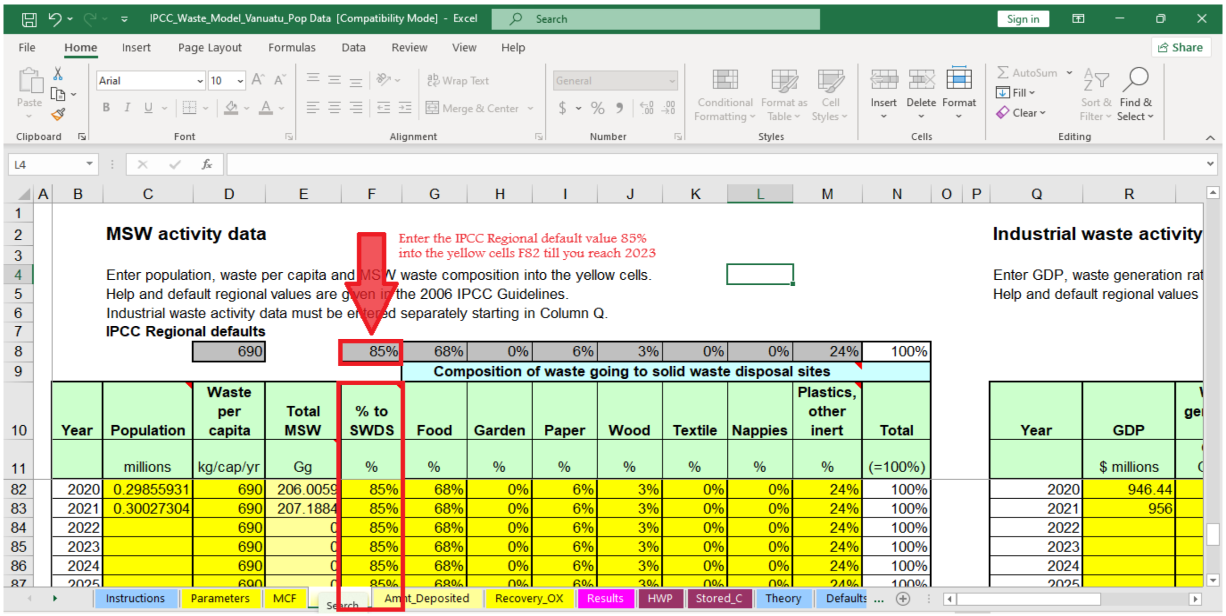
1.19 Enter population data in yellow cell C12 to Yellow cell C84 (See red figure below).



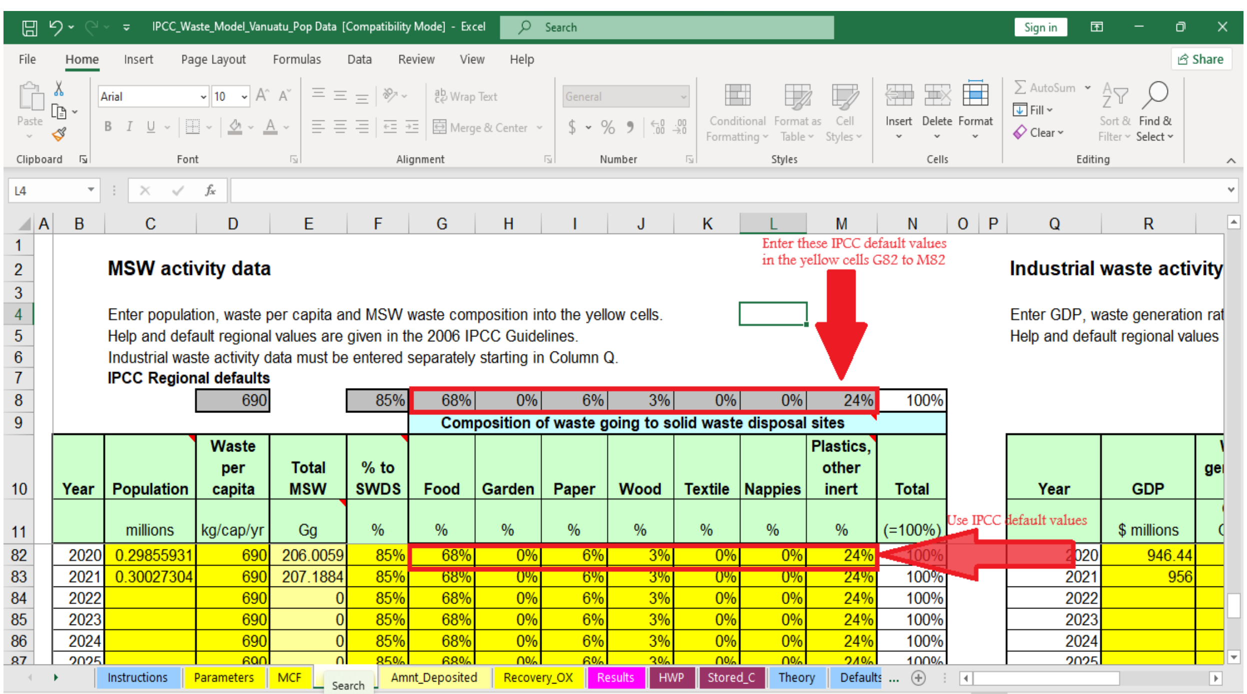
1.20 Enter in the IPCC Regional default value of 690 for waste per capita in yellow cell D12 (See illustration below)



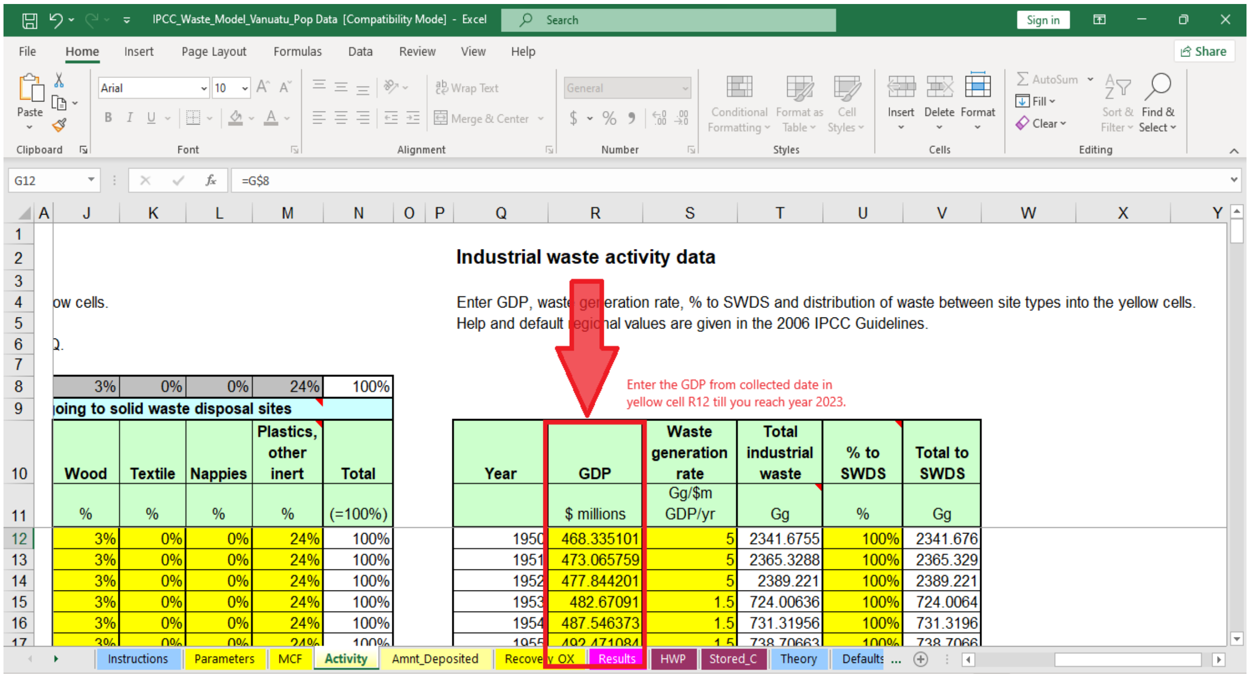
1.21 Enter in yellow Cell F12 Enter the default value of 85% from the grey cell F8.



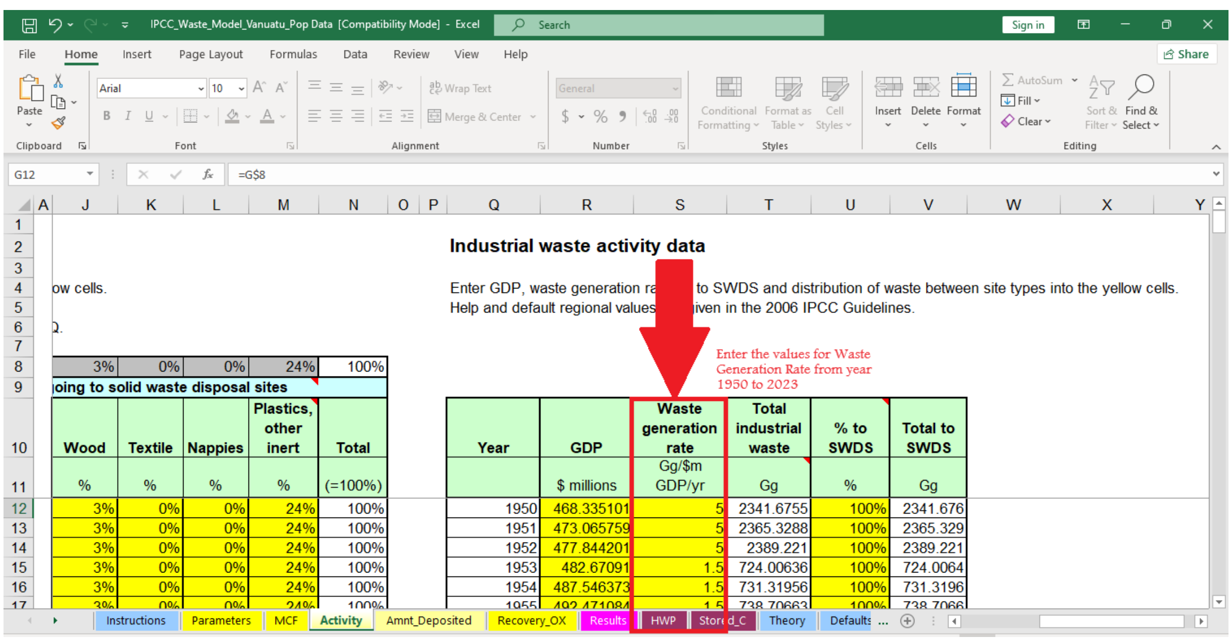
1.22 Enter the IPCC Regional default values for the Different Compositions of waste going to the Solid Waste Disposal Site (SWDS) into yellow cells G12 to M12 using the values from the grey cells in G8 to M8 (See figure below). Note that the total percentage should add up to 100%.



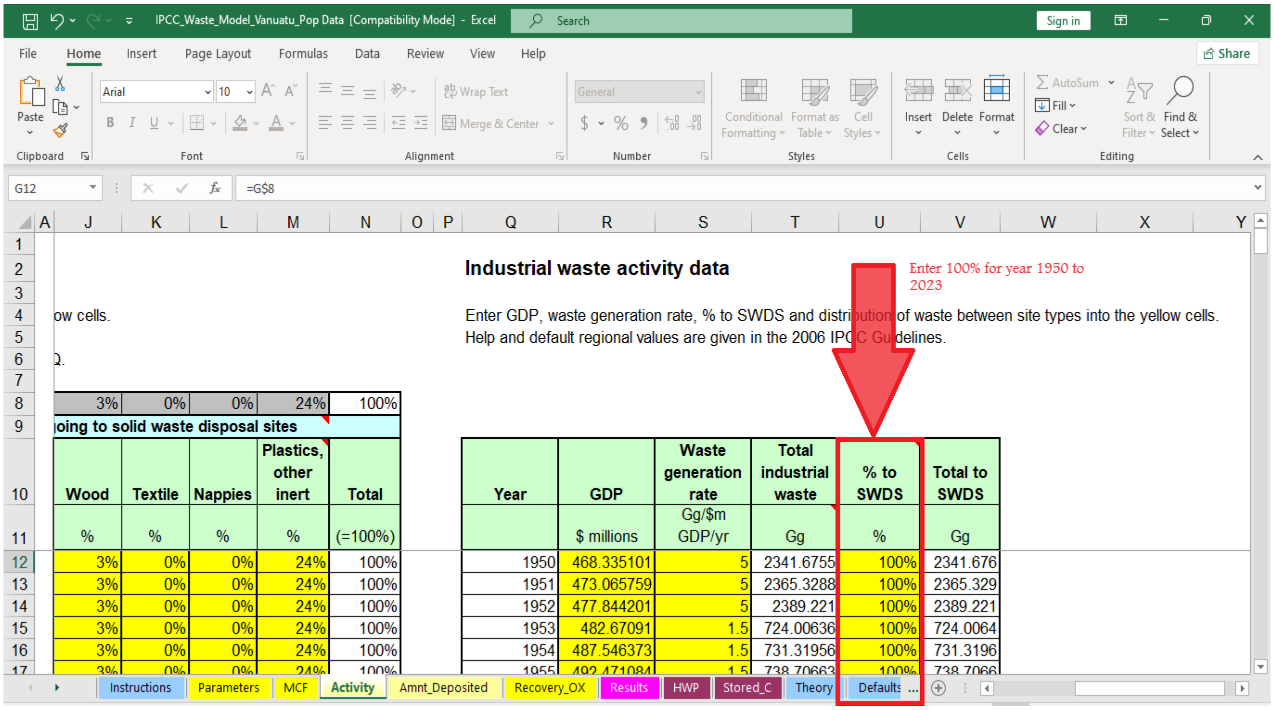
1.23 Enter the collected data on GDP for years 1950 to 2023 into the yellow cell R12 to R85 (See figure below).



1.24 Enter the data for waste generation rate for the years 1950 to 2023 into yellow cells S12 to S85 (see figure below)

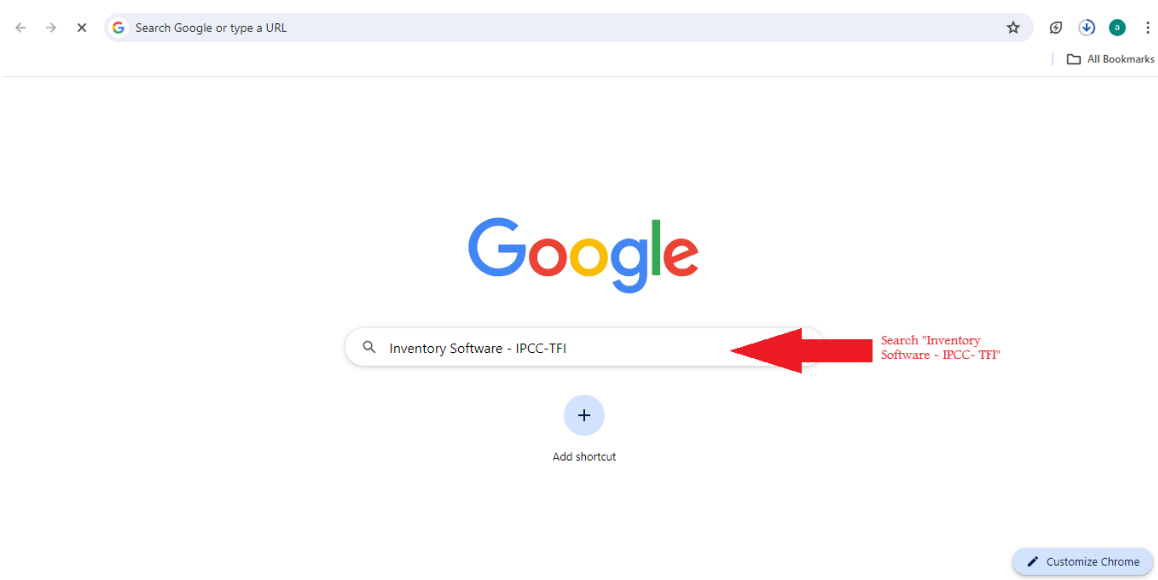


1.25 Enter 100% for all of the years in yellow cells U12 to U85 under the “% to SWDS” column.

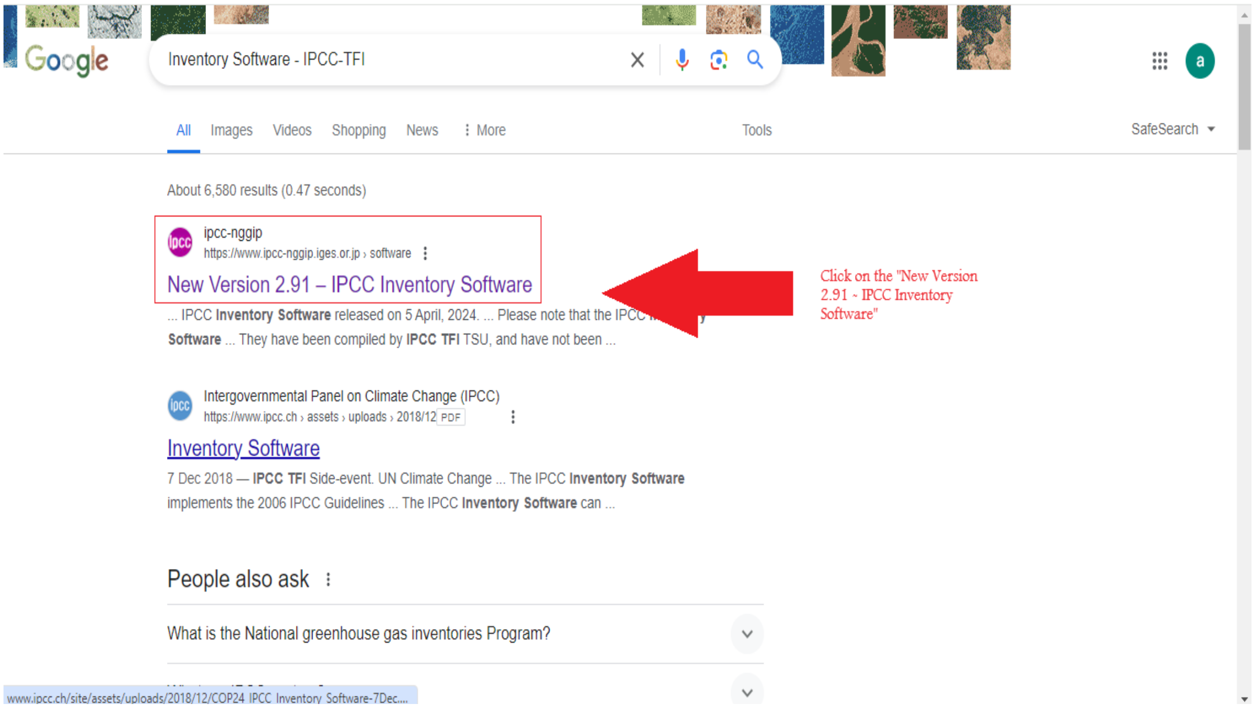


2. ALTERNATIVE METHOD TO CALCULATING CH_4 EMISSIONS FROM THE SWDS USING THE IPCC SOFTWARE.

1.0 Open Google chrome and search “Inventory Software – IPCC-TFI” (See illustration below)



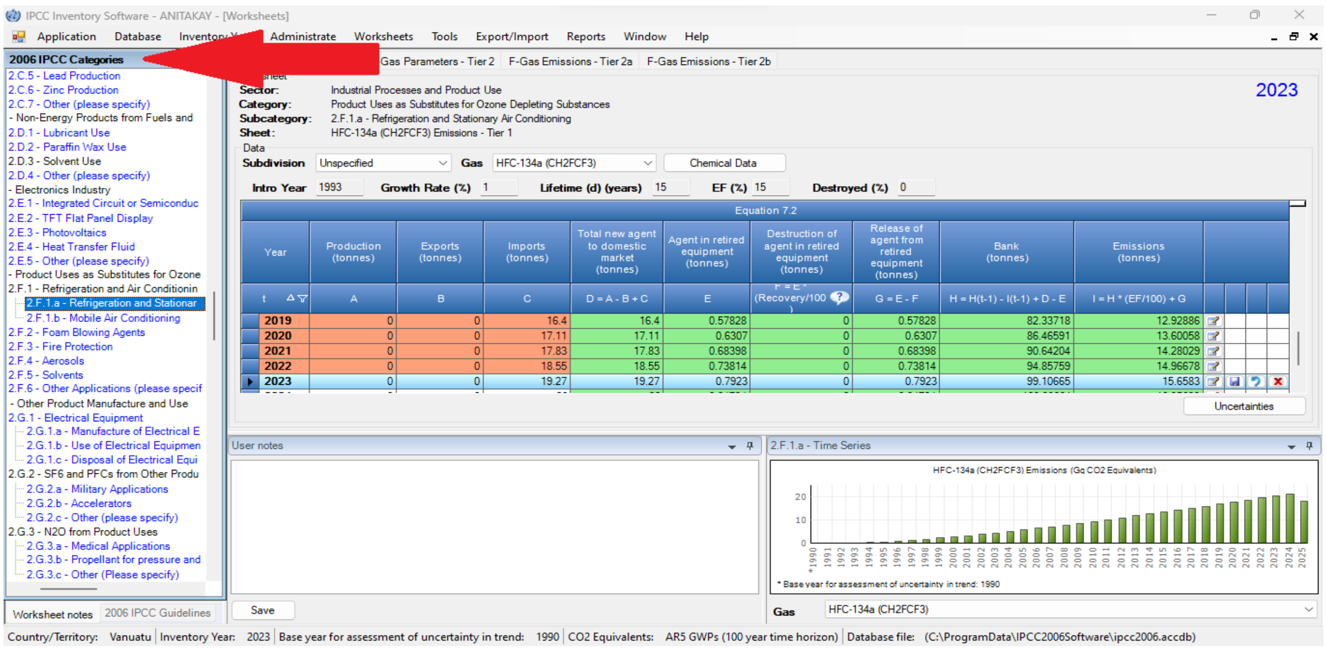
1.2 Click on the "New Version 2.91 – IPCC Inventory Software (See illustration below)



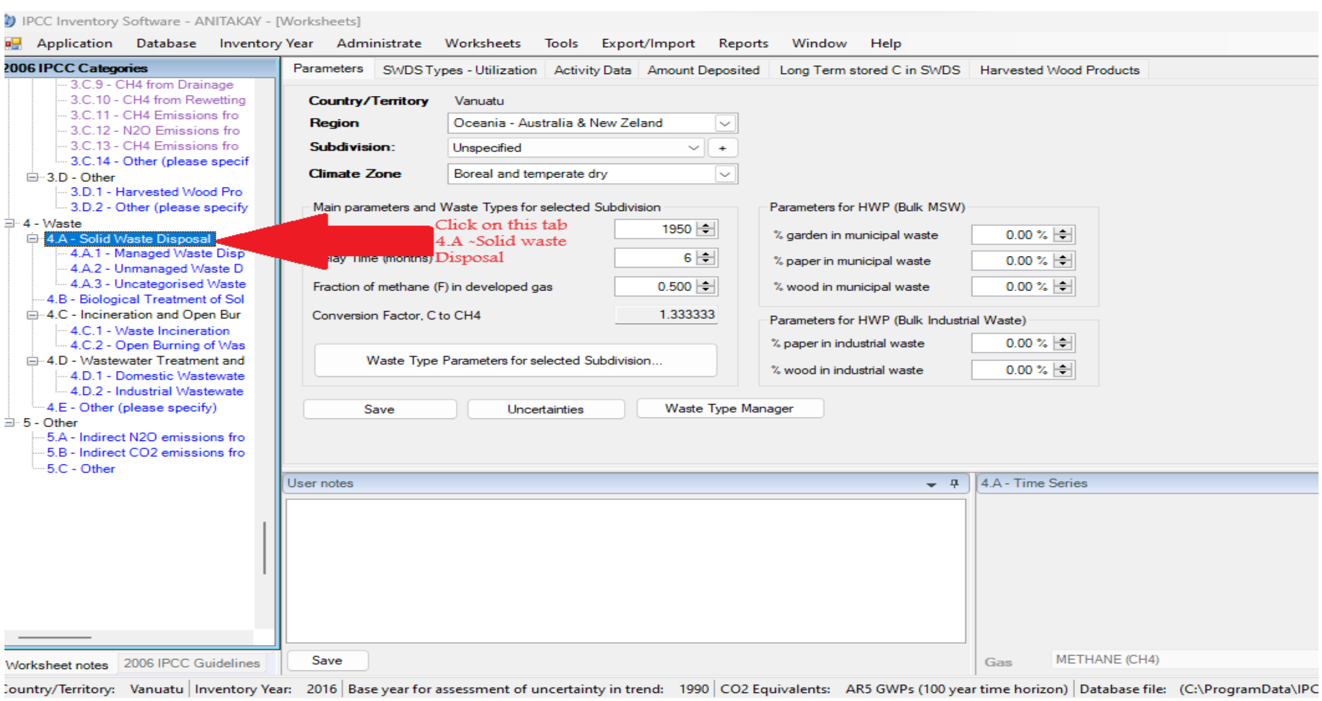
1.3 Click on the "ver 2.91 IPCC inventory Software – 32bit" (See illustration below).

1.4 Launch the Ver. 2.901 IPCC Inventory Software - **32bit** and install to your PC.
1.5 Create your password and username.
1.6 Type in the year of your choosing or the current inventory year.

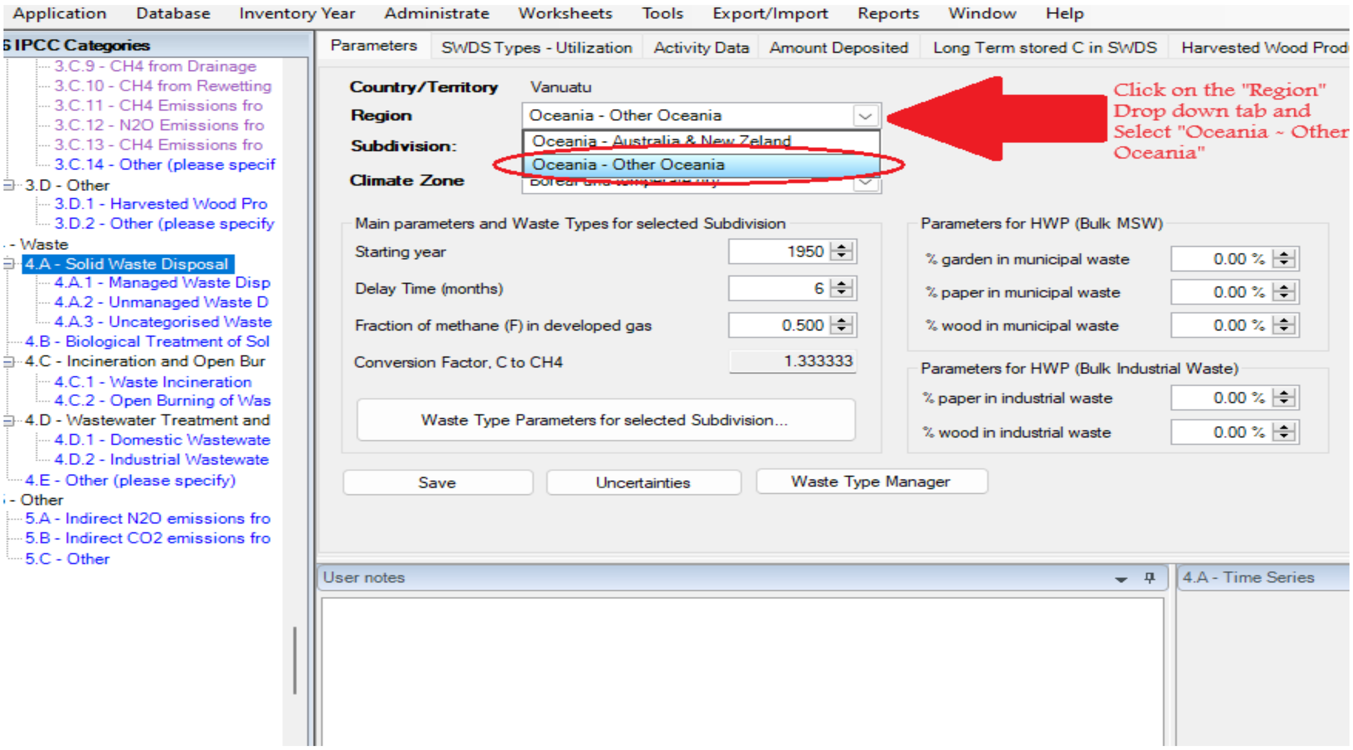
1.7 Locate the bar labeled "IPCC categories" on the left side of the page (See Illustration below)



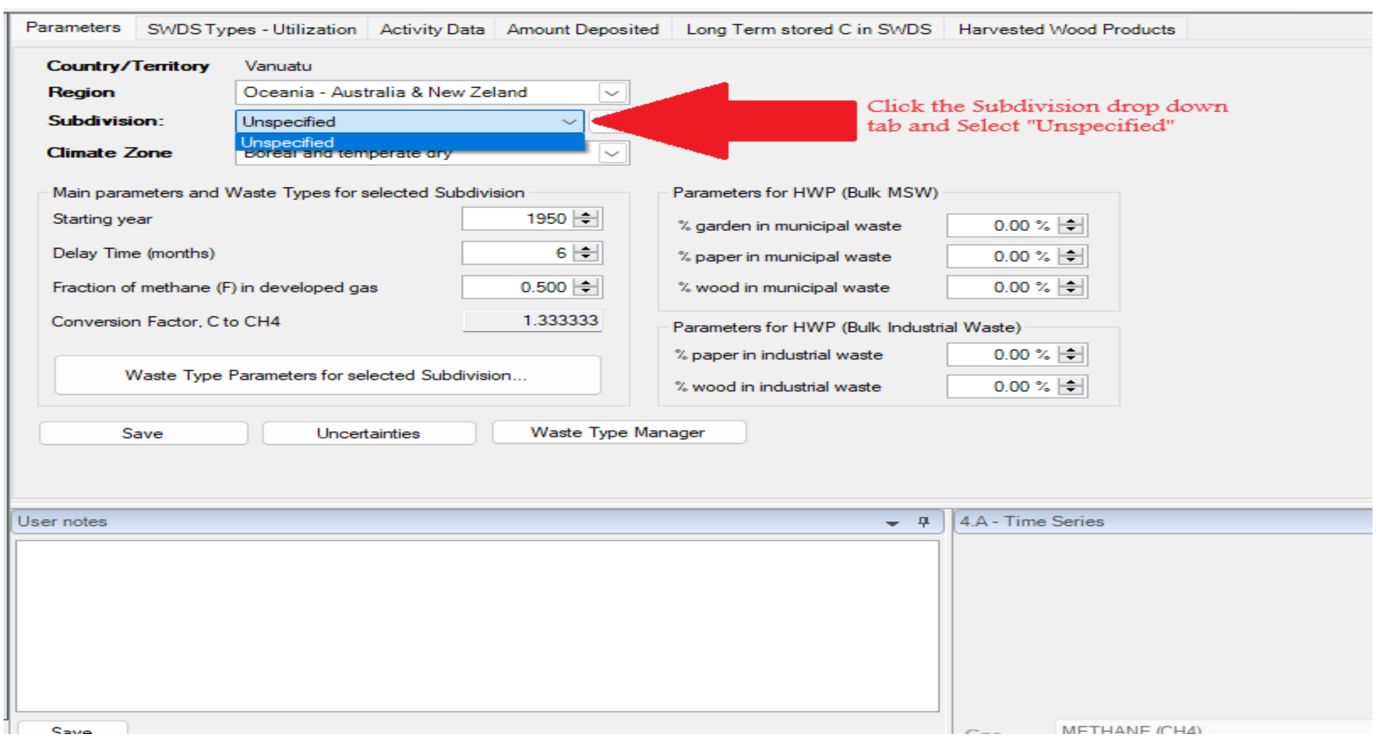
1.8 Scroll Down the category list till you get to 4 – Waste, then select 4 A – Solid Waste Disposal (See red arrow in figure below)



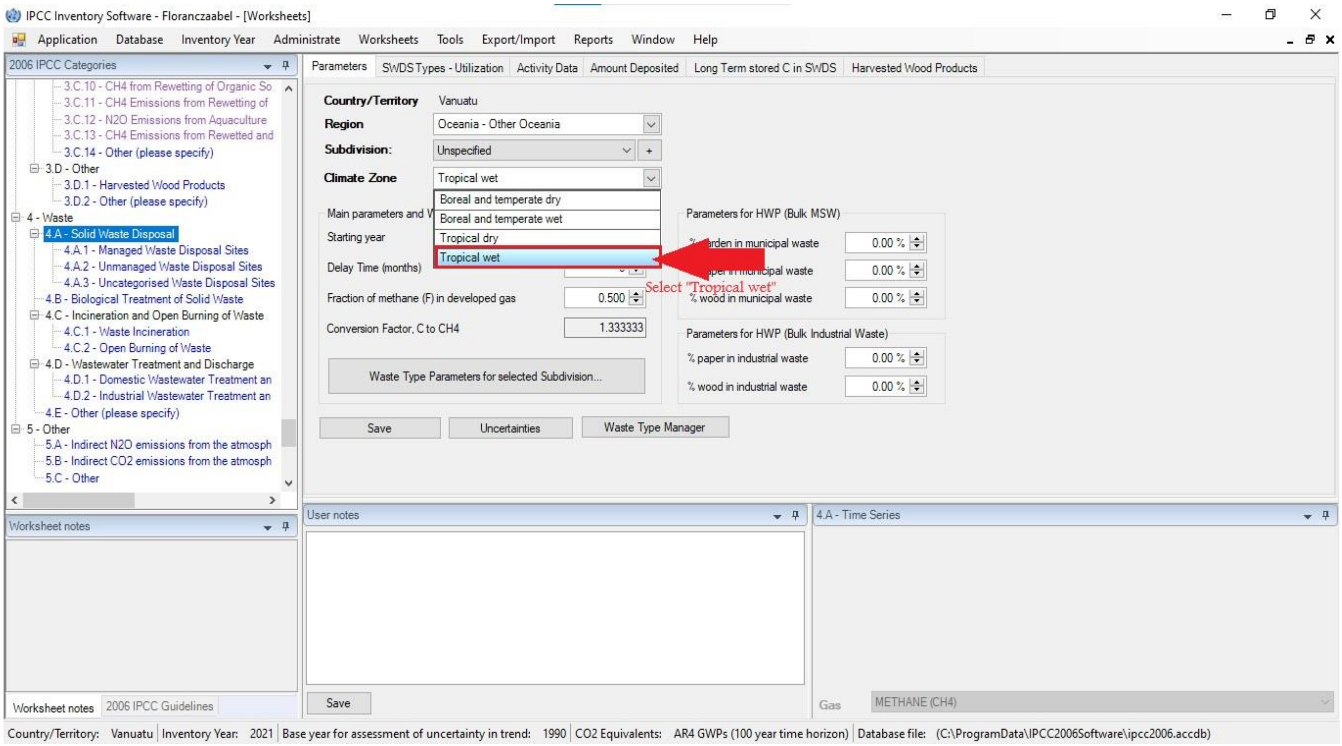
1.9 Click on the "Region" drop-down tab and select "Oceania – Other Oceania (See illustration below)



1.10 Click the Subdivision drop-down tab and select "Unspecified" (see illustration below)



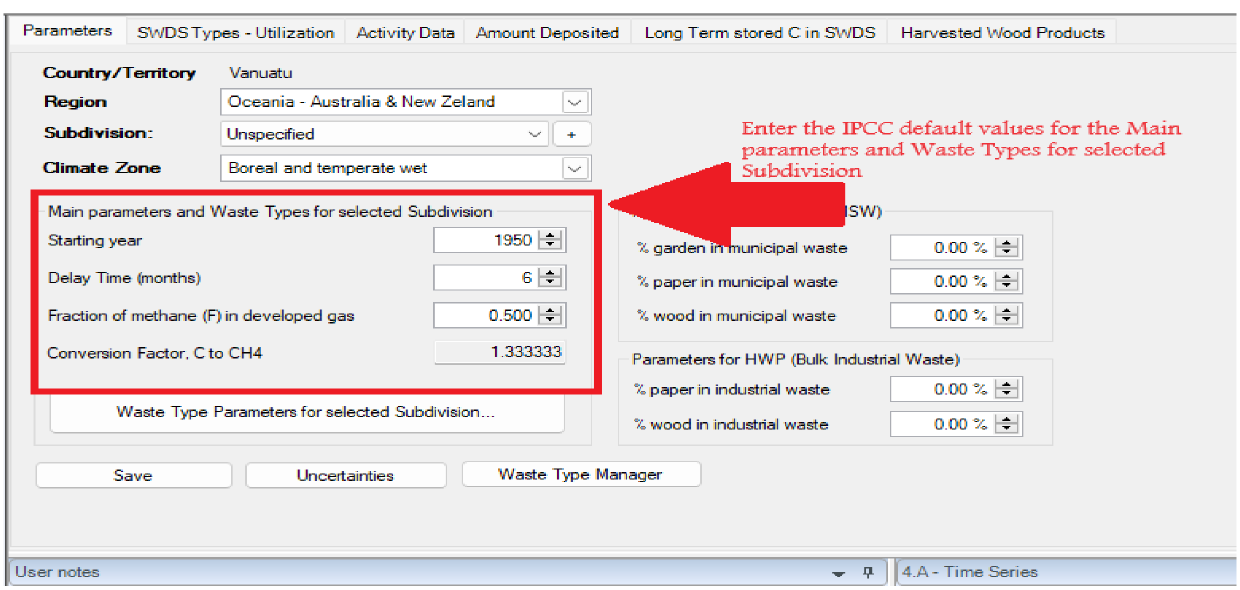
1.11 Select the “Climate zone” drop-down bar and Select “Tropical Wet”



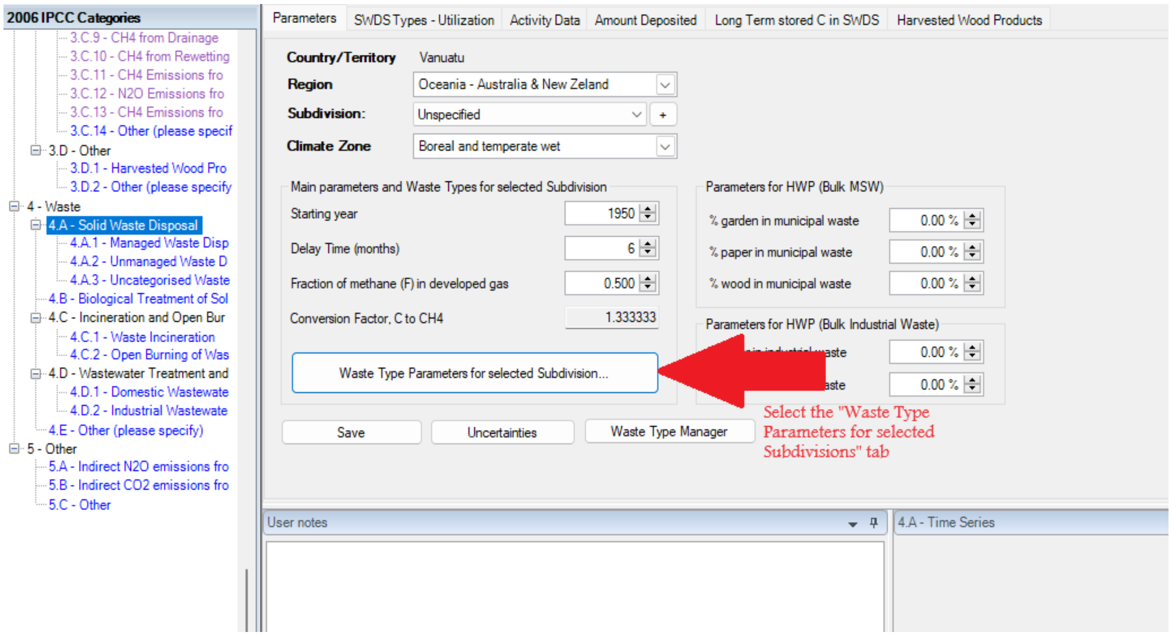
1.12 Enter the following default values into the “Main Parameters and waste types for Selected Subdivision (See illustration below)

Default Value:

- Starting year:1950
- Delay Time (months): 6
  Fraction of methane (F) in developed gas: 0.5



1.13 Click the "Waste Type Parameters for Selected Subdivision" tab (See illustration below)



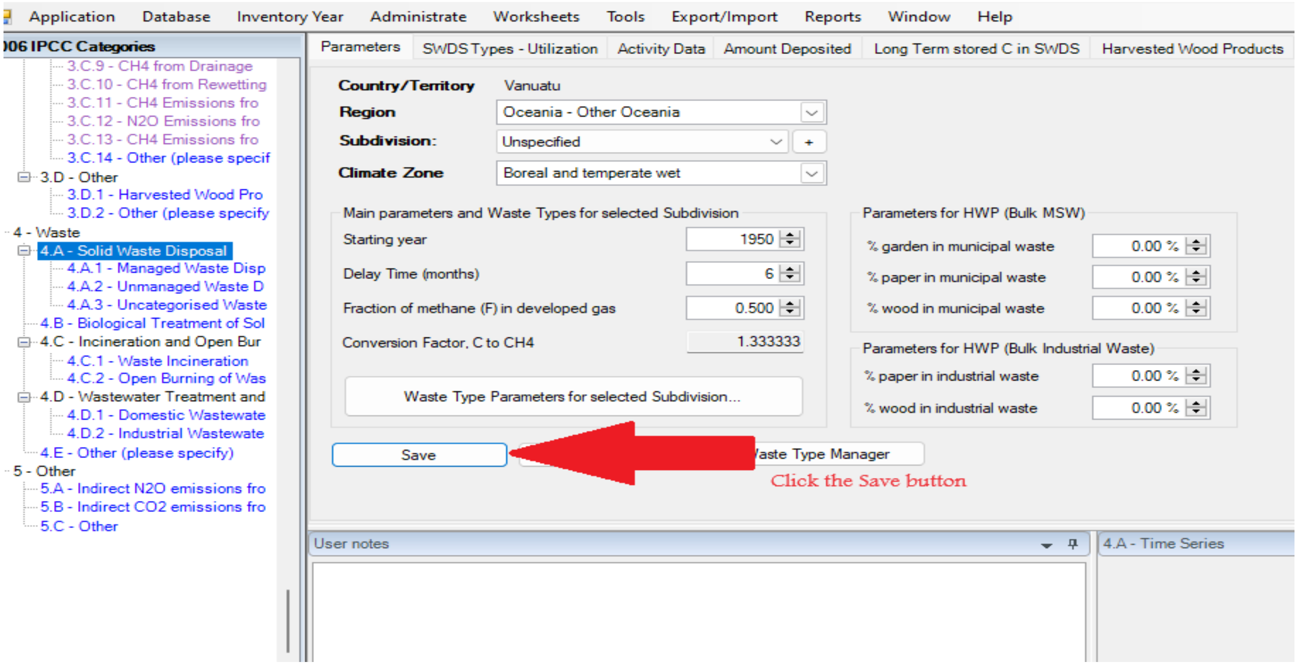
1.14 and click on the "methane generation rate constant" drop-down tab to select the default values as illustrated below. Click OK.

Waste Type Parameters

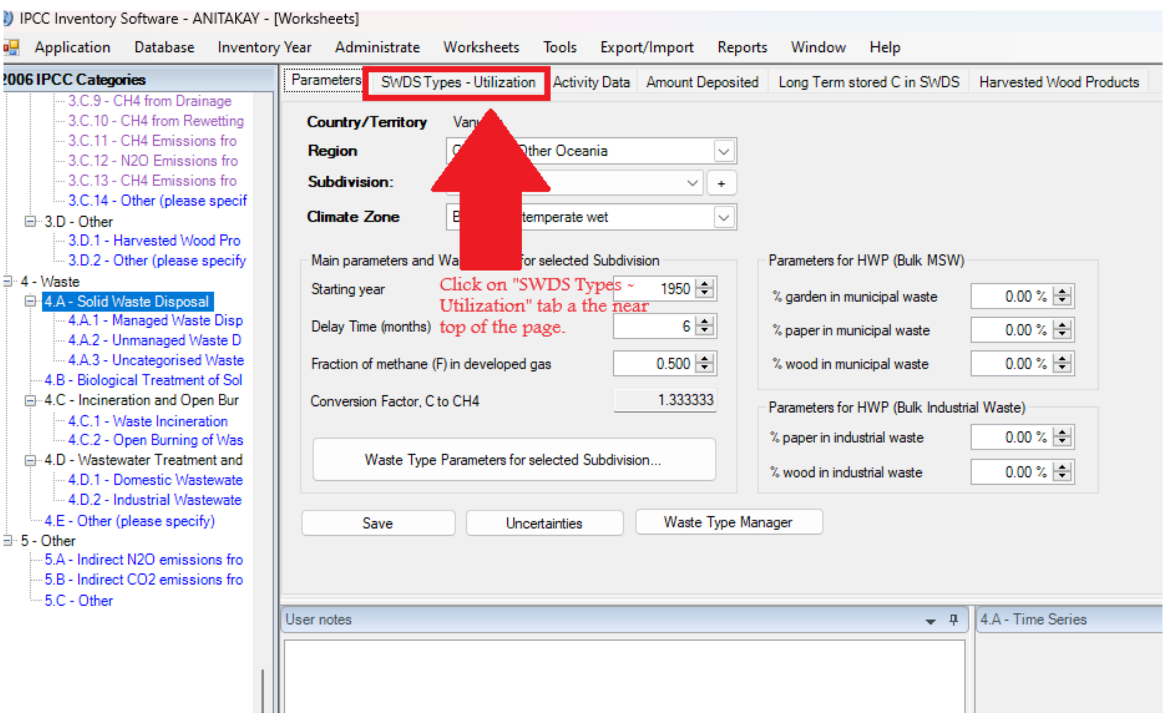
Waste Category	Class of decomposability	Type	Use in calculations	DOC (Fraction of wet weight)	DOCf (Fraction)	k
Industrial Waste	Bulk waste	Bulk Industrial Waste	☑	0.15	0.5	0.17
	Highly decomposable waste	Food, beverages and tobacco	☑	0.15	0.7	
	Less decomposable waste	Construction and demolition	☑	0.04	0.5	
		Wood and wood products	☑	0.43	0.5	
	Moderately decomposable w...	Pulp and paper	☑	0.4	0.5	
		Textile	☑	0.24	0.5	
Municipal Waste	Bulk waste	Bulk Municipal Waste	☑	0.18	0.5	0.17
	Highly decomposable waste	Food waste	☑	0.15	0.7	0.4
		Garden and park	☑	0.2	0.7	0.17
	Less decomposable waste	Wood	☑	0.43	0.5	0.035
	Moderately decomposable w...	Disposable nappies	☑	0.24	0.5	0.17
		Paper and cardboard	☑	0.4	0.5	0.07
		Textile	☑	0.24	0.5	0.07
Other waste	Bulk waste	Clinical waste	☑	0.15	0.5	
		Hazardous waste	☑		0.5	
Sludge	Highly decomposable waste	Industrial sewage sludge	☑	0.09	0.5	
		Municipal sewage sludge	☑	0.05	0.5	0.4

Cancel OK

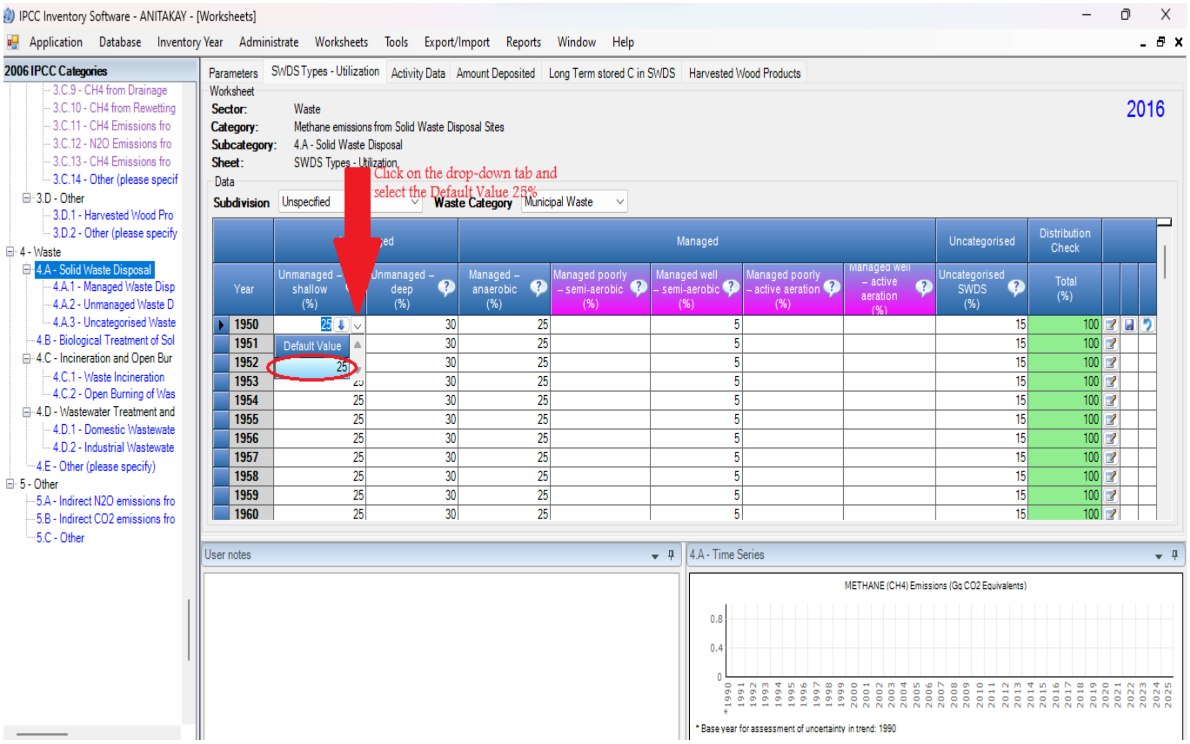
1.15 Click on the save button (see Illustration below)



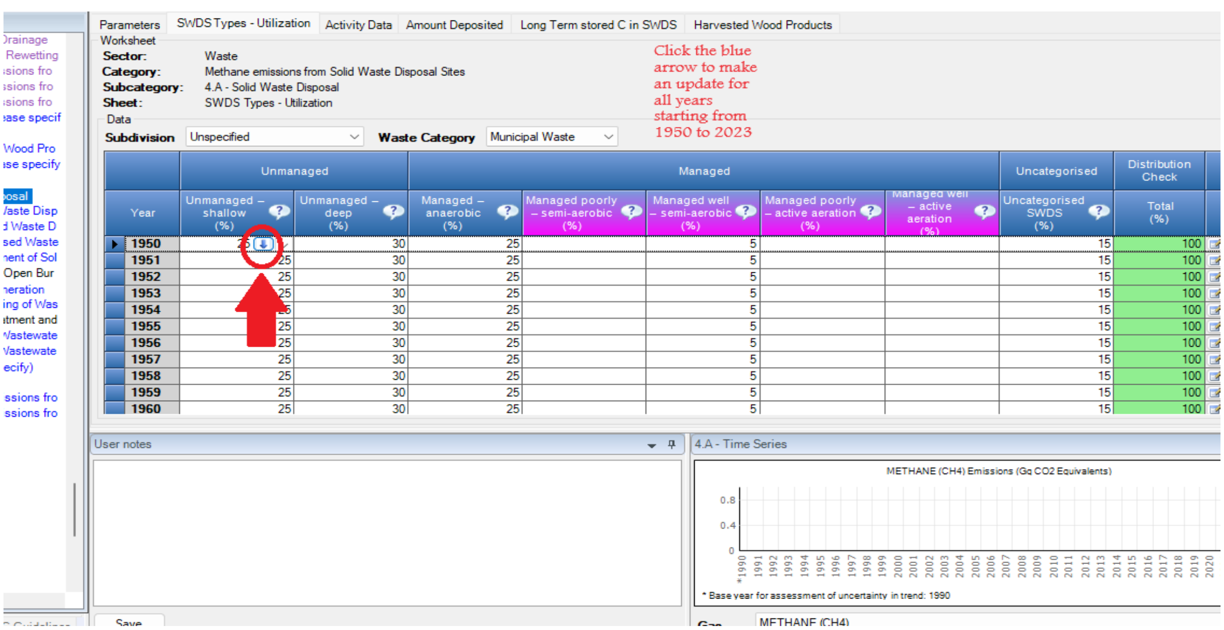
1.16 Click on the “SWDS Type – Utilization” tab at the near top of the page (see illustration below)



1.17 Click on the drop-down tab under the “Unmanaged shallow (%)” tab and select the Default factor 25.



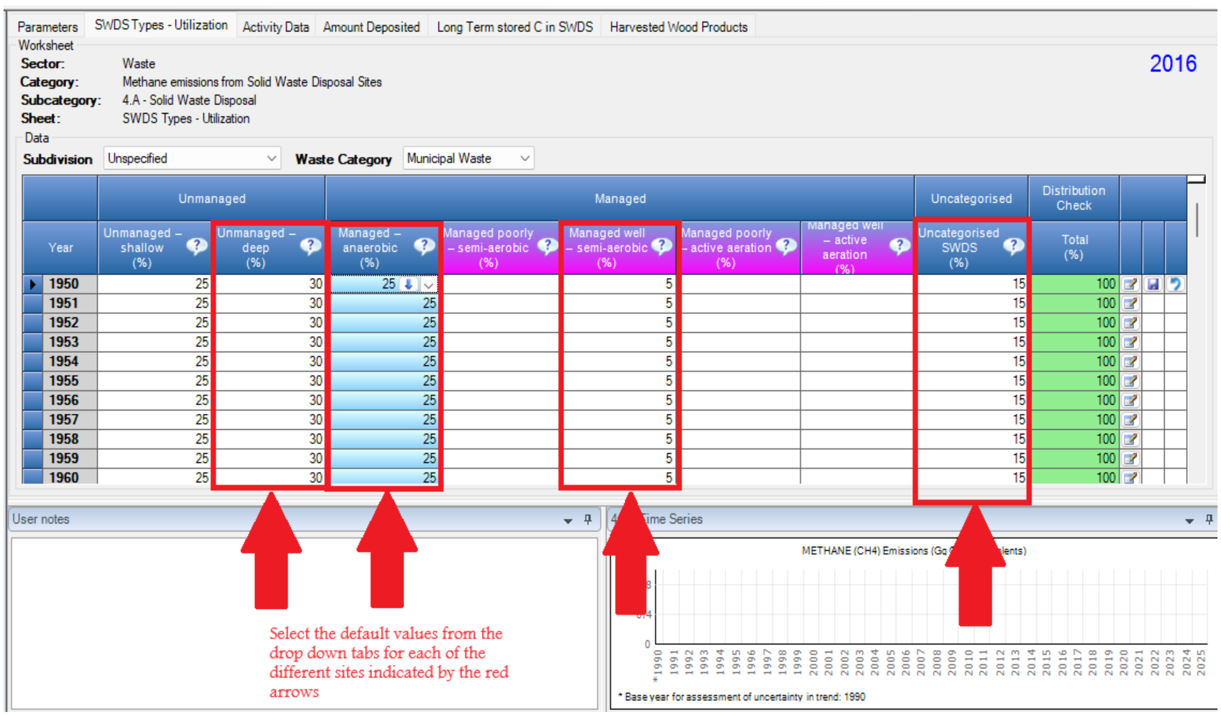
1.18 click on the blue arrow beside the drop-down sign under the Unmanaged- Shallow to update all the years starting from 1950 to 2025. (%) (See illustration below).



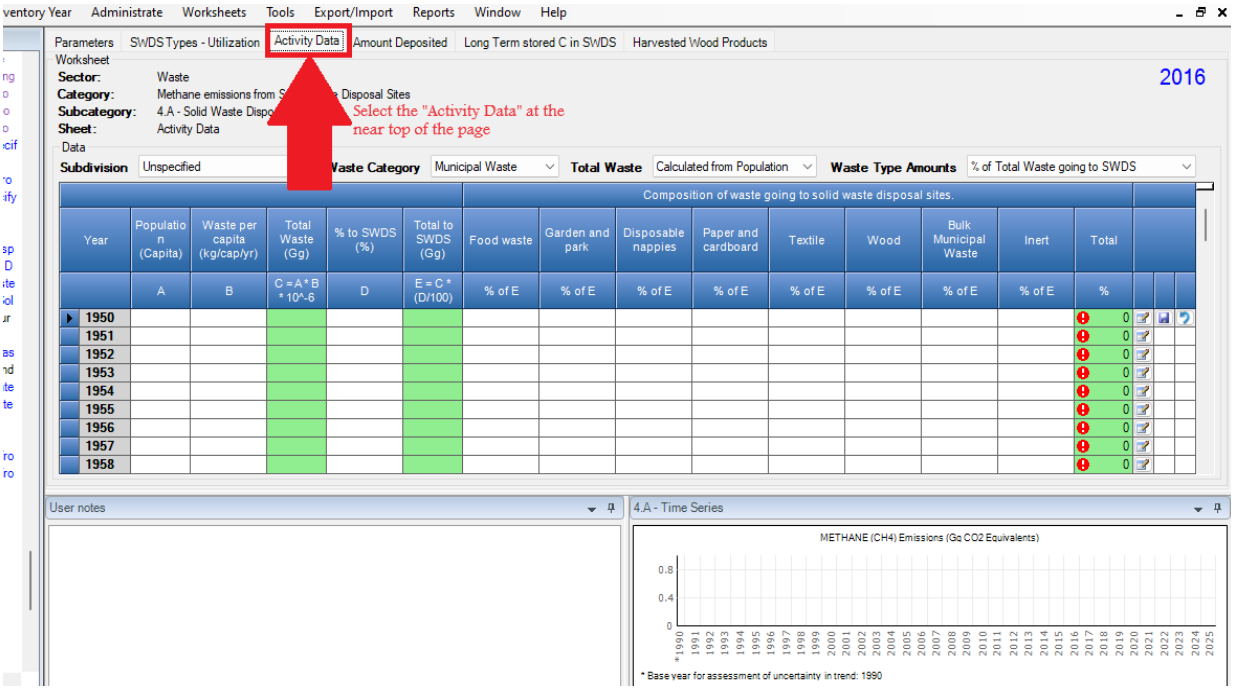
1.19 Replicate steps 2.5 and 2.6 using the IPCC default values for the following tabs (see illustration below):

Table 6: Default values for each of the different types of sites.
They should all give a total of 100%.

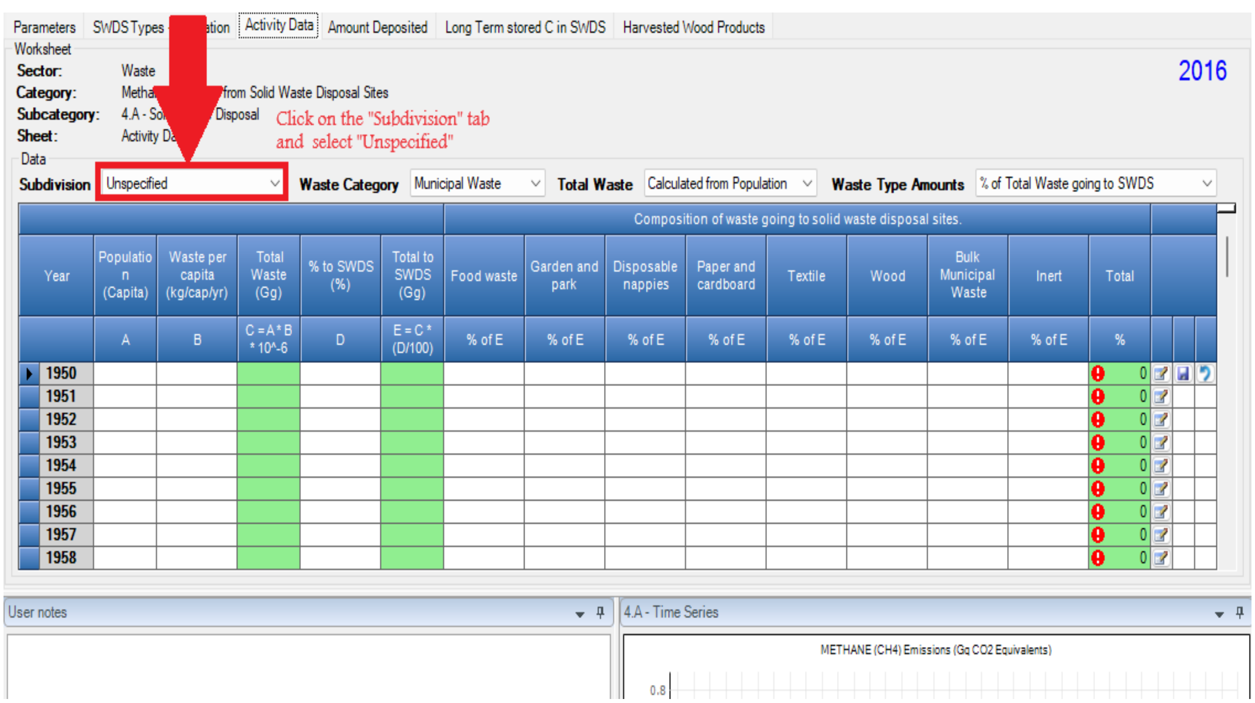
Unmanaged		**Managed**		**Uncategorized**	**Distribution Check**
Unmanaged - Shallow %	Unmanaged- Deep %	Managed- Anaerobic	Managed well – semi-aerobic %	Uncategorized SWDS %	Total (%)
25	30	25	5	15	**100%**



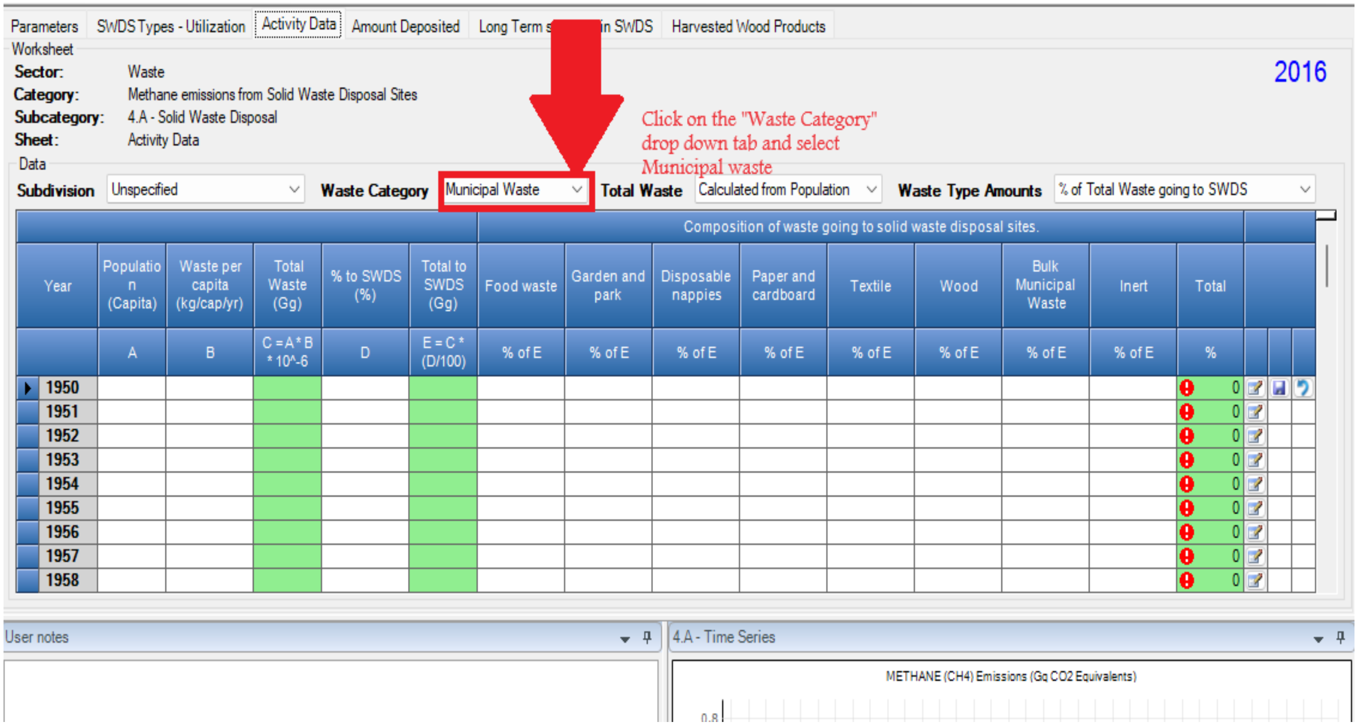
1.20 Select "Activity Data" at the near top of the page (See illustration below)



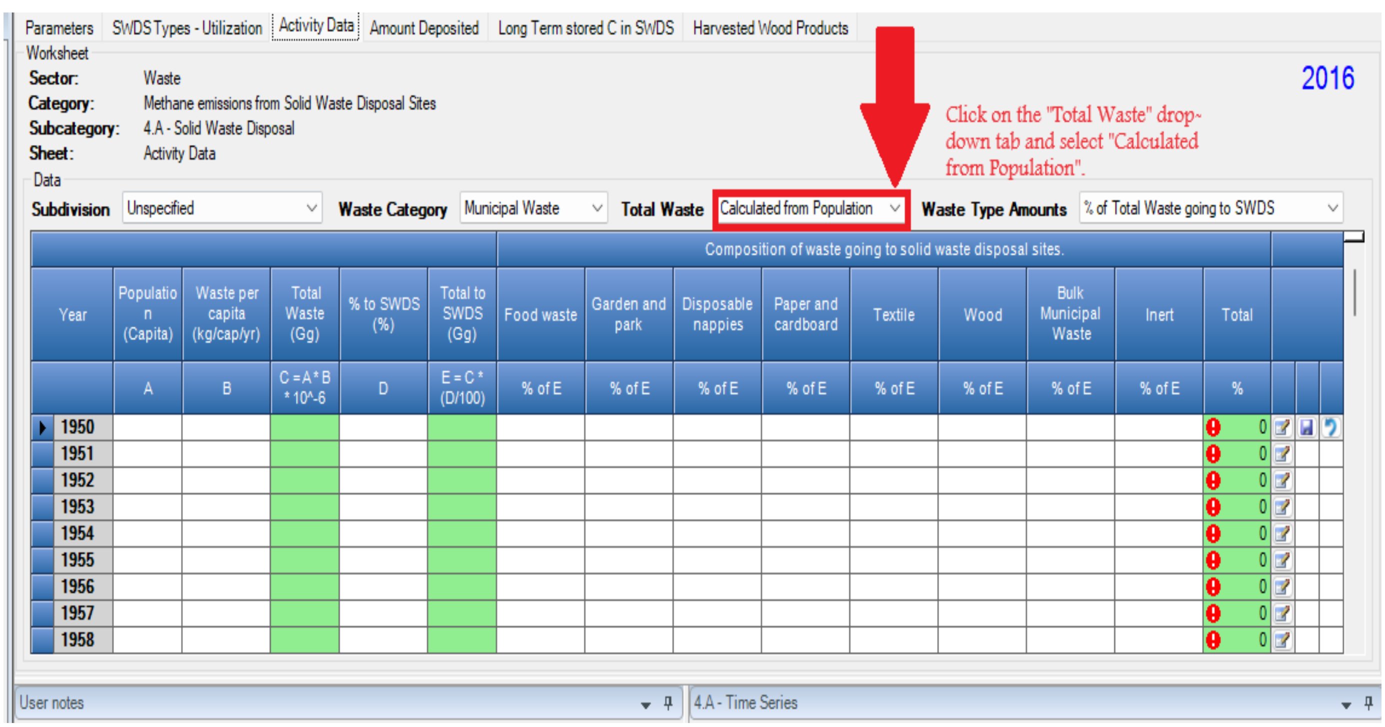
1.21 Click on the "subdivision" tab and select "Unspecified" (see illustration below).



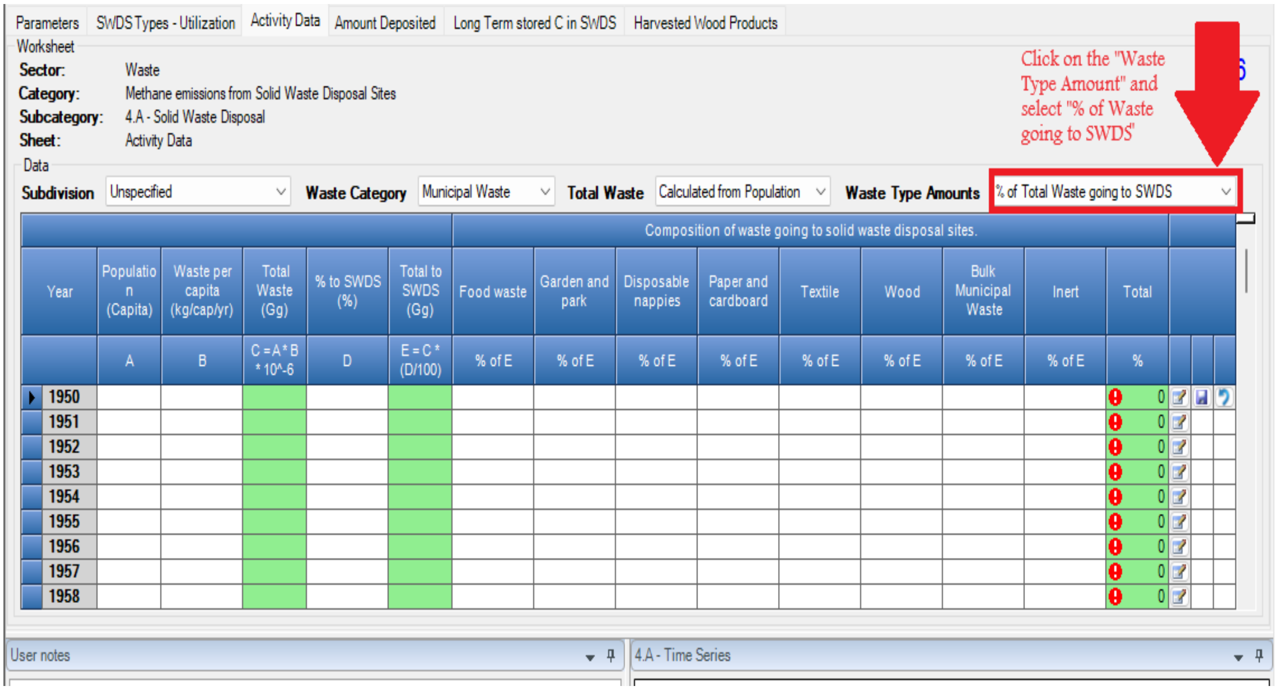
1.22 Click on the Waste Sector tab and select “Municipal Waste”, see illustration below.



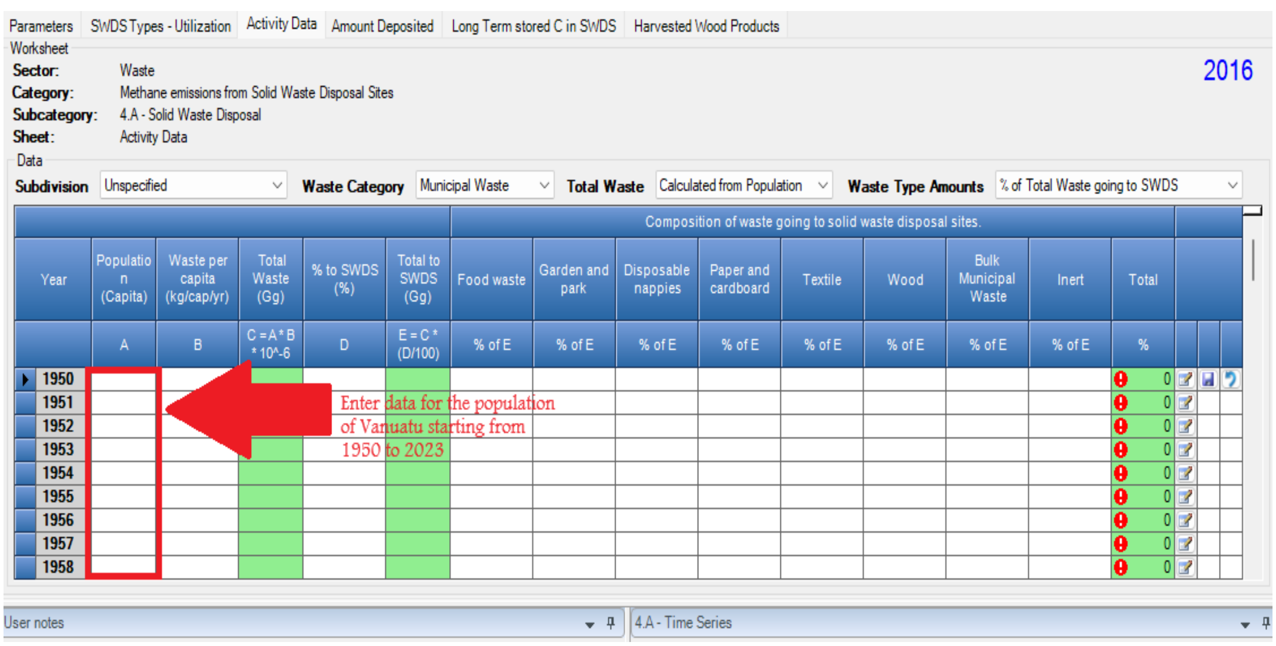
1.23 Click on the Total Waste drop-down tab and select “Calculated from the population”



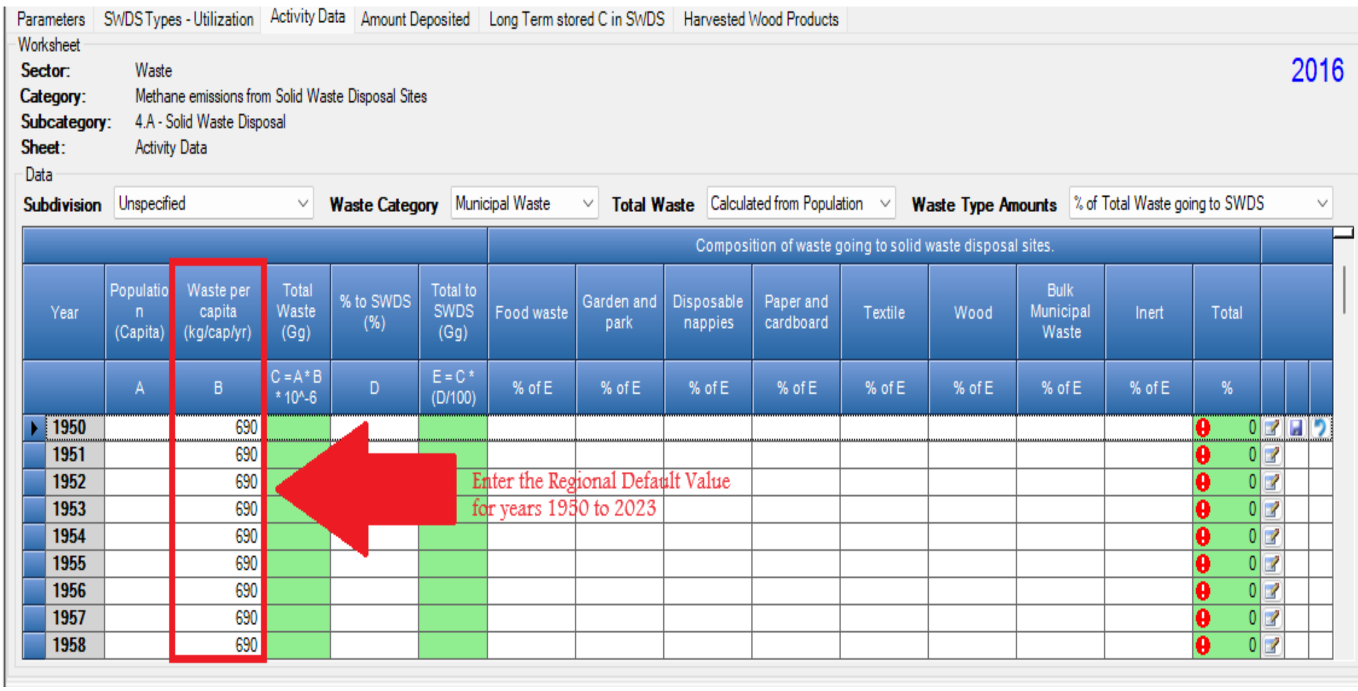
1.24 Click on the "Waste Type Amounts" drop-down tab and select "% of Total Waste going to SWDS".



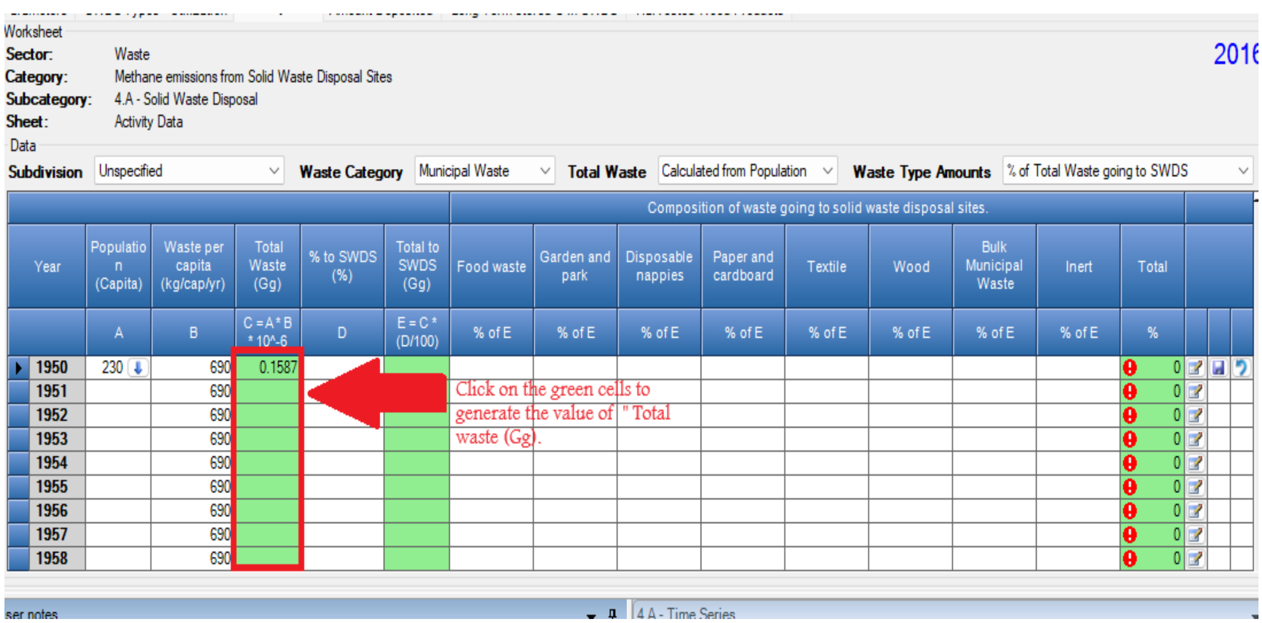
1.25 Enter the data for the population under the "Population n (Capita)" tab for the years 1950 to 2023 (see Illustration below).



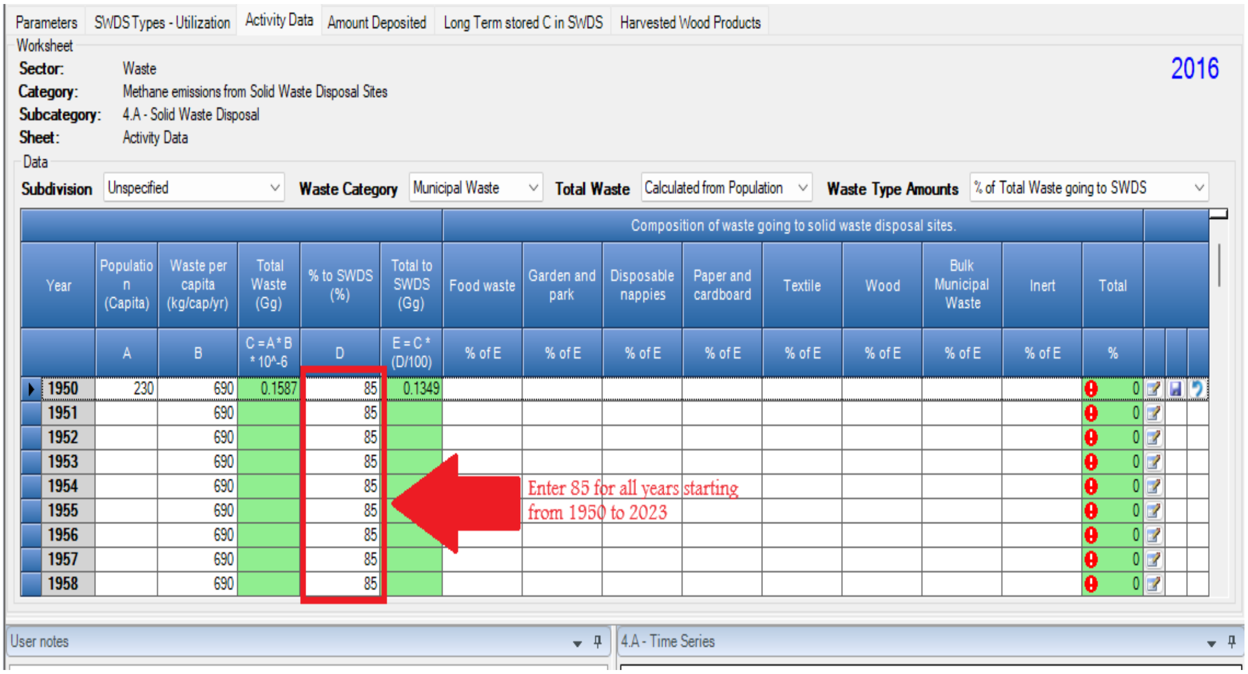
1.26 Under the "Waste per Capita (Kg/cap/yr.)" tab, enter 690 as the Regional Default value. Enter national data if available. See illustration below. (See 2006 IPCC Guideline, Vol.5, pg. 19, Table 2A.1).



1.27 Click on the green cell below "Total Waste (Gg)" to generate the value (see illustration below).

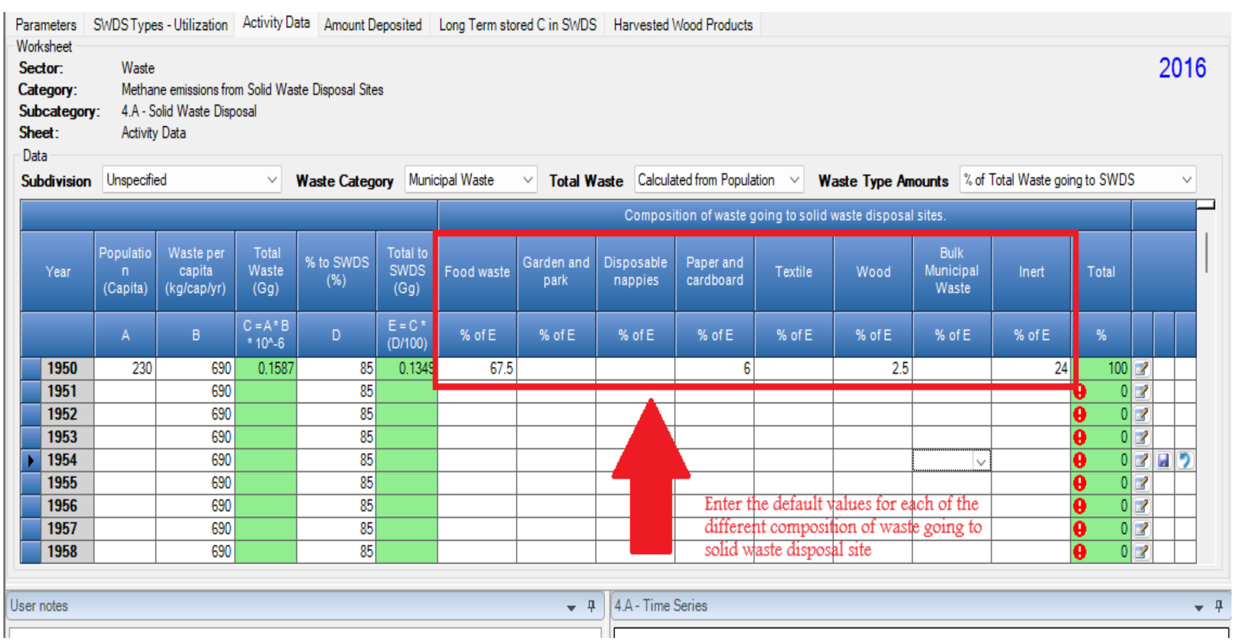


1.28 Under the "% to SWDS (%)", enter 85 for all years starting from 1950 to 2023 (see illustration below).



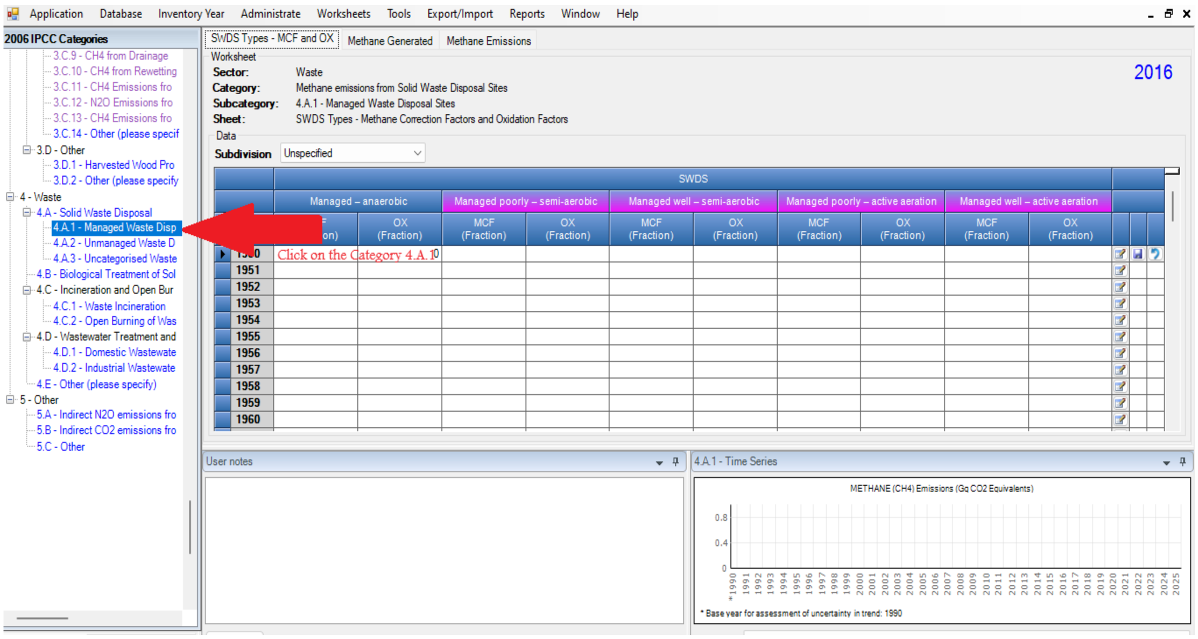
1.29 Click the green cell under the "Total to SWDS) to generate the value.

1.30 For each of the following waste compositions going to a solid waste disposal facility, enter the default values by clicking on the drop-down button and choosing the default value (See Illustration below). (See 2006 IPCC guidelines, Vol.5, page12, Table 2.3). Enter national data if available.



1.31 Click on the Green cell under the “Total” tab, it should total up to 100%.

1.32 Go to the “2006 IPCC categories” tab and select “4.A.1 – Managed Waste Disposal Sites” (See illustration below).

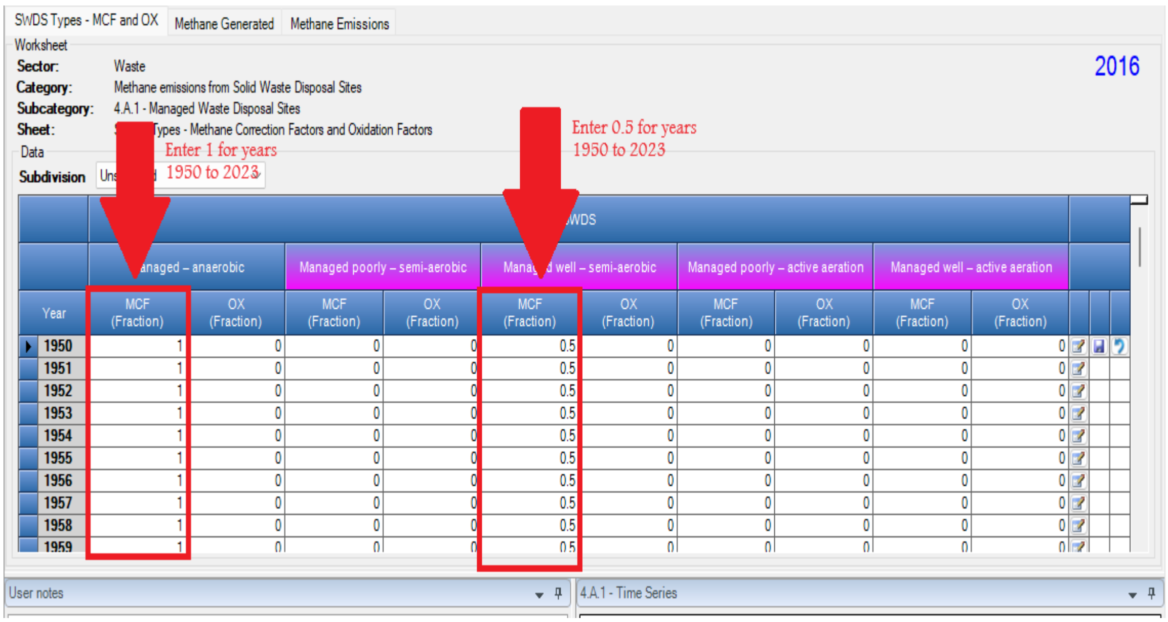


1.33 Enter the following default values from the table below for the Managed – anaerobic and Managed Well- semi-aerobic into the cells for the years 1950 to 2023. For the other SWDS enter 0. (See illustration below).

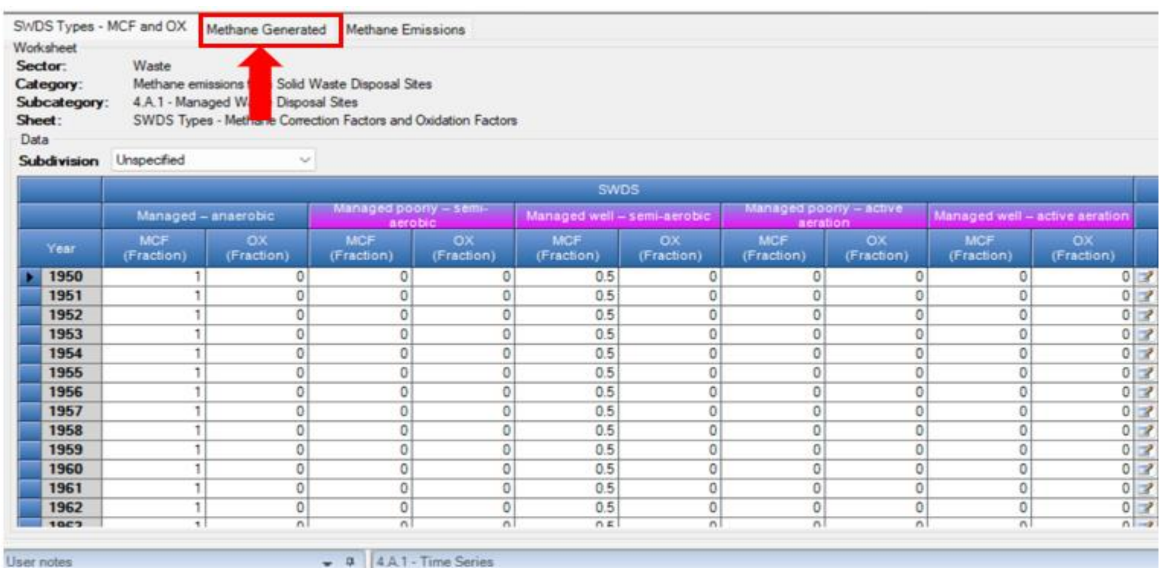
Table 7: Default value for MCF (fraction) and OX for the 2 types of SWDS

	Managed - anaerobic		Managed well- Semi aerobic	
Year	MCF (fraction)	OX (fraction)	MCF	OX (fraction)
1950 - 2023	1	0	0.5	0

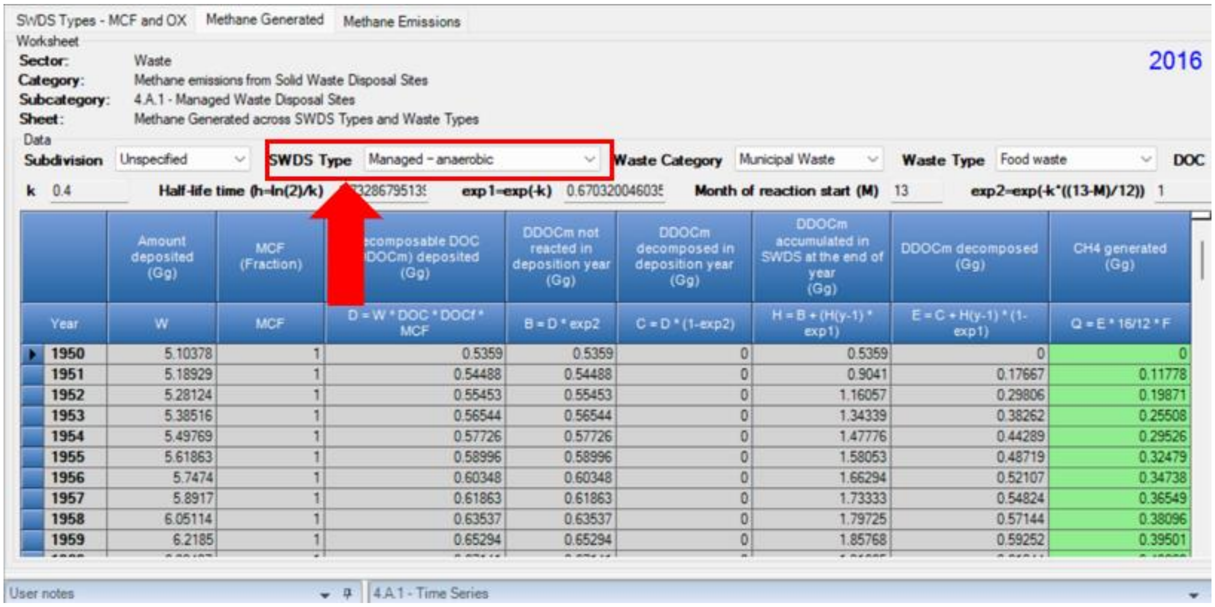
(See 2006 IPCC Guidelines, Vol.5, pg 14, Table 3.1)



1.34 Click on “Methane Generated” tab at the upper corner of the page (see illustration below).

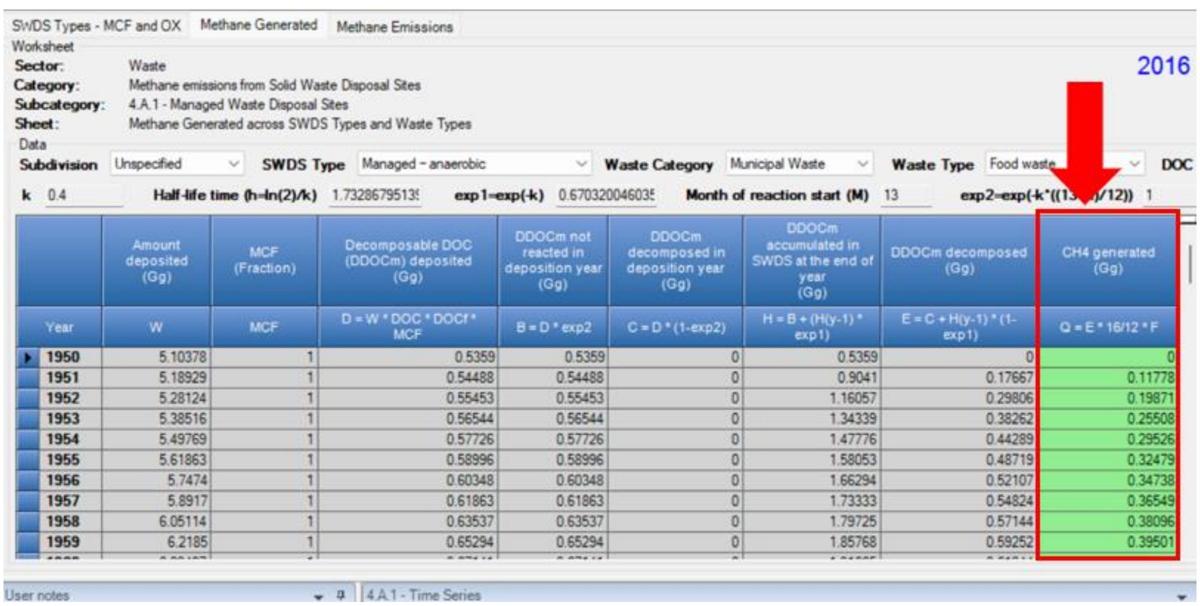


1.35 Click on the "SWDS Type" and select "Managed – anaerobic" (see illustration below).



	Amount deposited (Gg)	MCF (Fraction)	ecomposable DOC (DDOCm) deposited (Gg)	DDOCm not reacted in deposition year (Gg)	DDOCm decomposed in deposition year (Gg)	DDOCm accumulated in SWDS at the end of year (Gg)	DDOCm decomposed (Gg)	CH4 generated (Gg)
Year	W	MCF	D = W * DOC * DOCf * MCF	B = D * exp2	C = D * (1-exp2)	H = B + (H(y-1) * exp1)	E = C + H(y-1) * (1-exp1)	Q = E * 16/12 * F
1950	5.10378	1	0.5359	0.5359	0	0.5359	0	0
1951	5.18929	1	0.54488	0.54488	0	0.9041	0.17667	0.11778
1952	5.28124	1	0.55453	0.55453	0	1.16057	0.29806	0.19871
1953	5.38516	1	0.56544	0.56544	0	1.34339	0.38262	0.25508
1954	5.49769	1	0.57726	0.57726	0	1.47776	0.44289	0.29526
1955	5.61863	1	0.58996	0.58996	0	1.58053	0.48719	0.32479
1956	5.7474	1	0.60348	0.60348	0	1.66294	0.52107	0.34738
1957	5.8917	1	0.61863	0.61863	0	1.73333	0.54824	0.36549
1958	6.05114	1	0.63537	0.63537	0	1.79725	0.57144	0.38096
1959	6.2185	1	0.65294	0.65294	0	1.85768	0.59252	0.39501

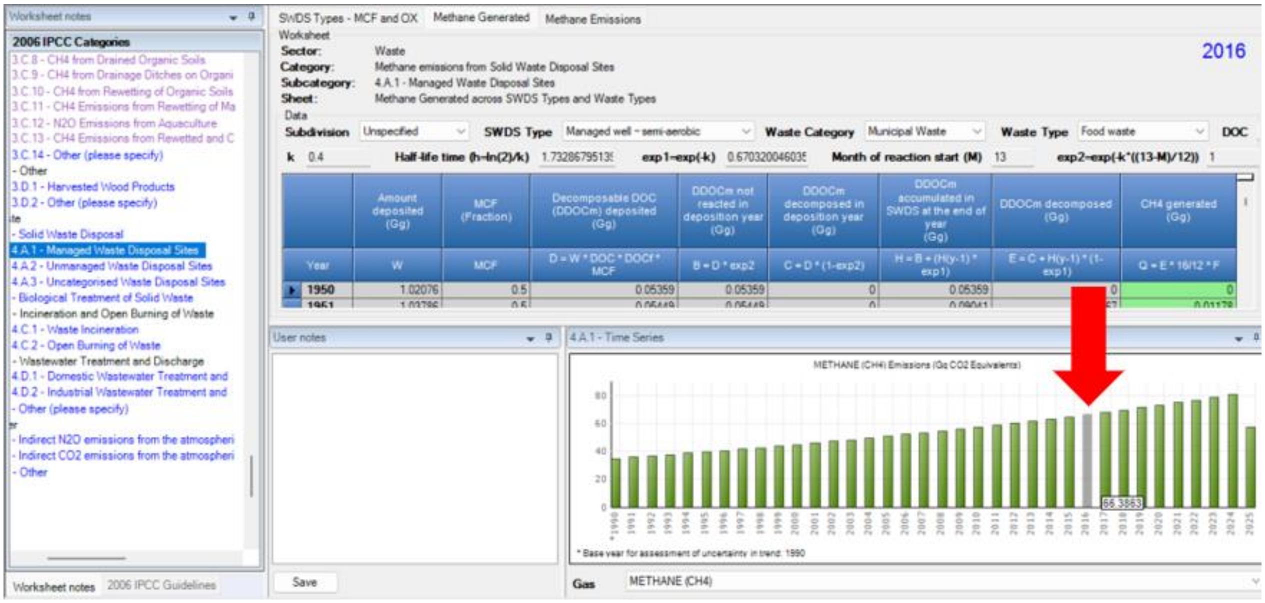
1.36 The green cell under the "CH_4 generated (Gg) will give the amount of methane generated for each year (see illustration below).



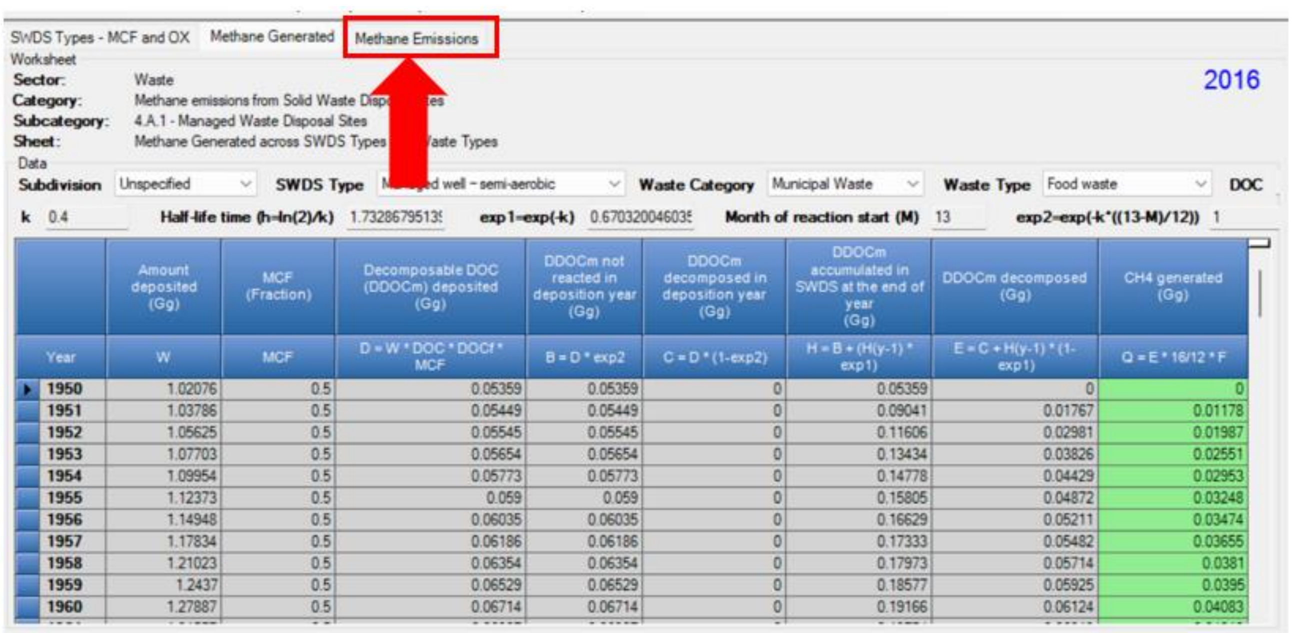
	Amount deposited (Gg)	MCF (Fraction)	Decomposable DOC (DDOCm) deposited (Gg)	DDOCm not reacted in deposition year (Gg)	DDOCm decomposed in deposition year (Gg)	DDOCm accumulated in SWDS at the end of year (Gg)	DDOCm decomposed (Gg)	CH4 generated (Gg)
Year	W	MCF	D = W * DOC * DOCf * MCF	B = D * exp2	C = D * (1-exp2)	H = B + (H(y-1) * exp1)	E = C + H(y-1) * (1-exp1)	Q = E * 16/12 * F
1950	5.10378	1	0.5359	0.5359	0	0.5359	0	0
1951	5.18929	1	0.54488	0.54488	0	0.9041	0.17667	0.11778
1952	5.28124	1	0.55453	0.55453	0	1.16057	0.29806	0.19871
1953	5.38516	1	0.56544	0.56544	0	1.34339	0.38262	0.25508
1954	5.49769	1	0.57726	0.57726	0	1.47776	0.44289	0.29526
1955	5.61863	1	0.58996	0.58996	0	1.58053	0.48719	0.32479
1956	5.7474	1	0.60348	0.60348	0	1.66294	0.52107	0.34738
1957	5.8917	1	0.61863	0.61863	0	1.73333	0.54824	0.36549
1958	6.05114	1	0.63537	0.63537	0	1.79725	0.57144	0.38096
1959	6.2185	1	0.65294	0.65294	0	1.85768	0.59252	0.39501

1.37 Repeat steps 1.35 and 1.36 by selecting "Managed well- semi aerobic" from the "SWDS Type".

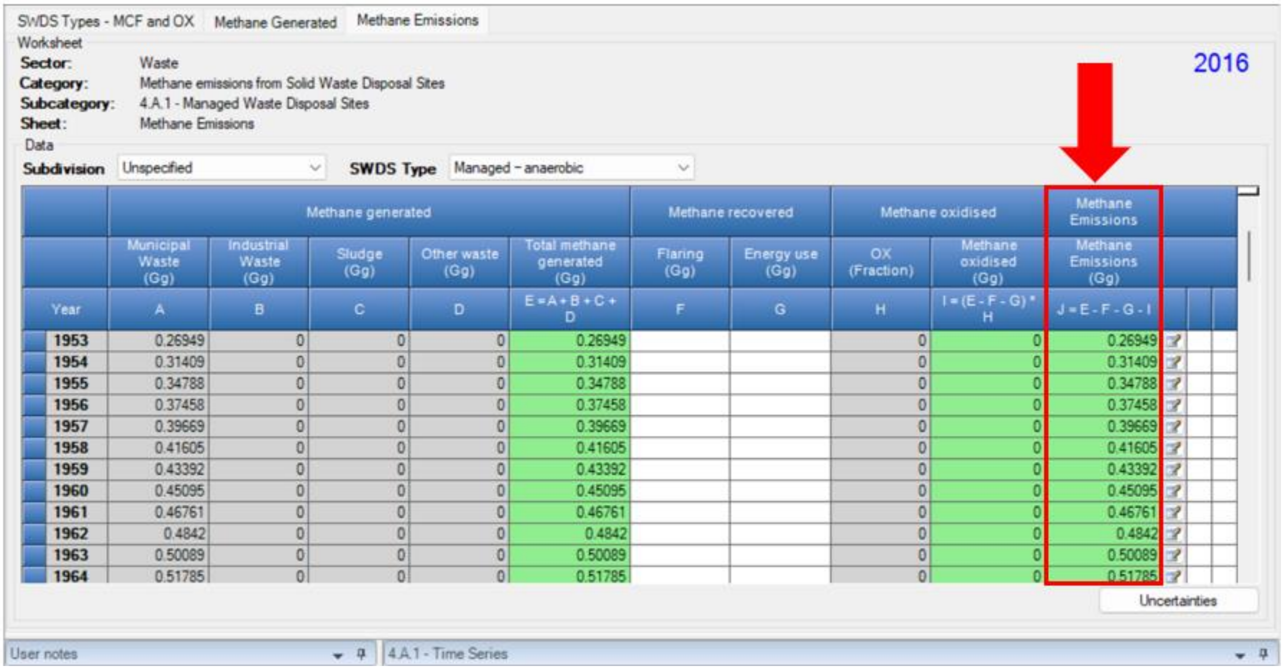
1.38 Run the Cursor over the graph below to give the CH_4 Emissions (Gg Co_2 Equivalent) (see illustration below).



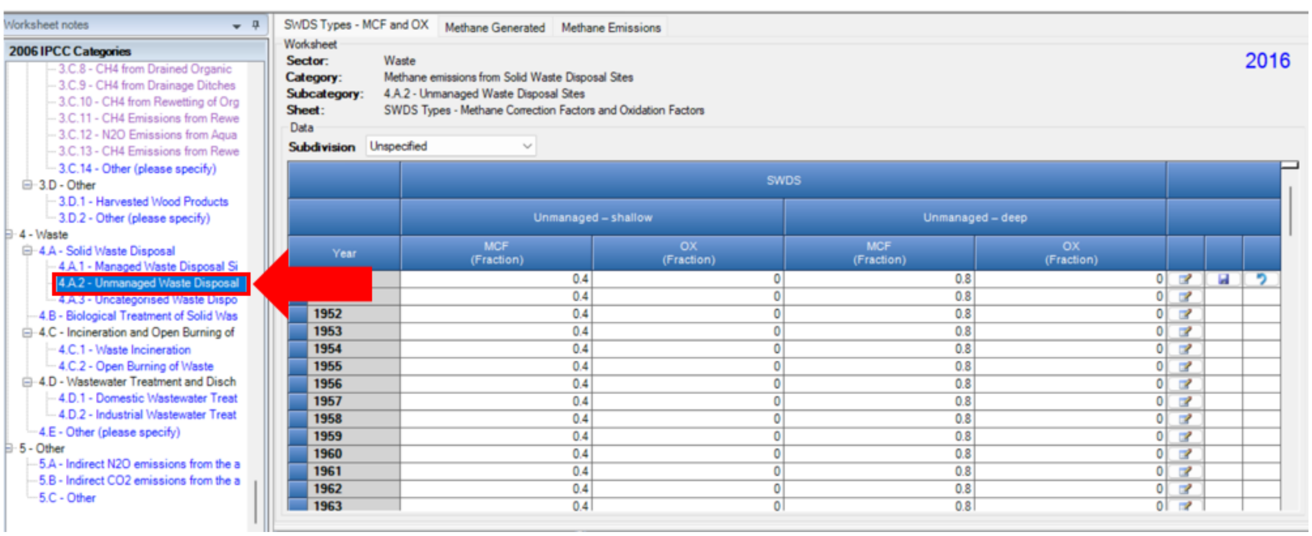
1.39 Click on the tab “Methane Emissions” at the top-hand corner of the page (see illustration below)



1.40 Green cells under the "Methane Emissions" tab display the total methane emission for a given year for the designated SWDS type (see illustration below).



1.41 Click on the 4.A.2 – "Unmanaged Waste Disposal" under the "2006 IPCC categories" tab (see illustration below)

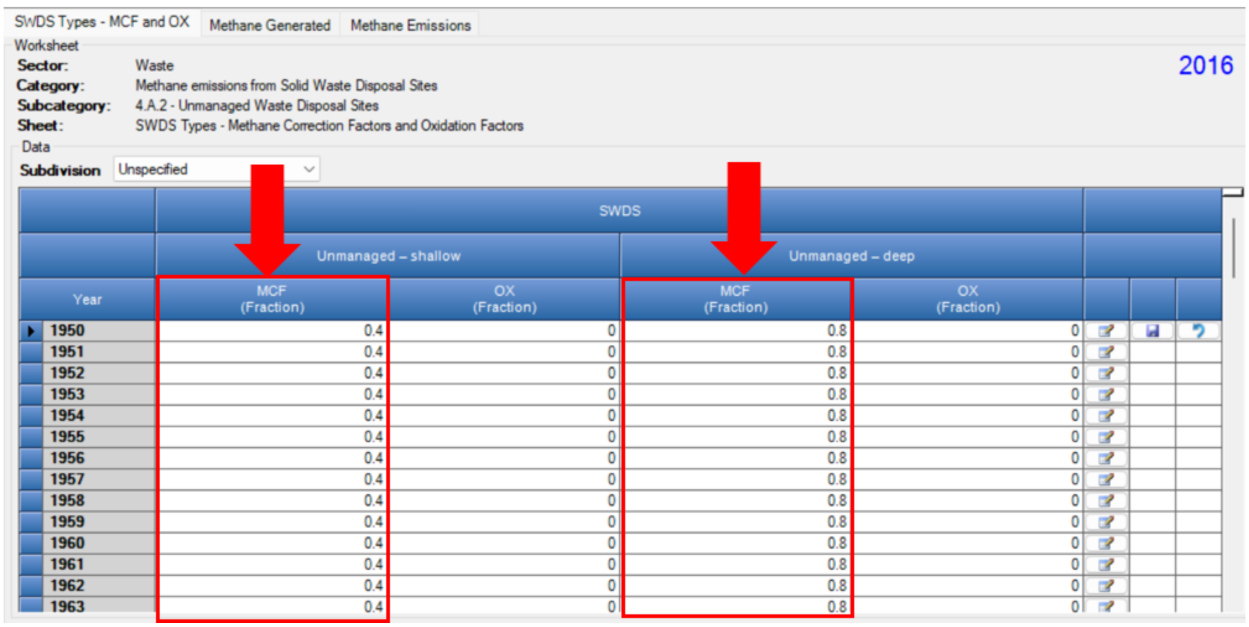


1.42 Under "SWDS Types – MCF and OX" tab, enter the following default value from the table below into the cells accordingly for all years 1950 to 2023 (see illustration below).

Table 8: Default values for MCF and OX under the Unmanaged Waste Disposal Sites

SWDS			
Unmanaged Shallow		**Unmanaged Deep**	
MCF (Fraction)	OX (Fraction)	MCF (Fraction)	OX (Fraction)
0.4	0	0.8	0

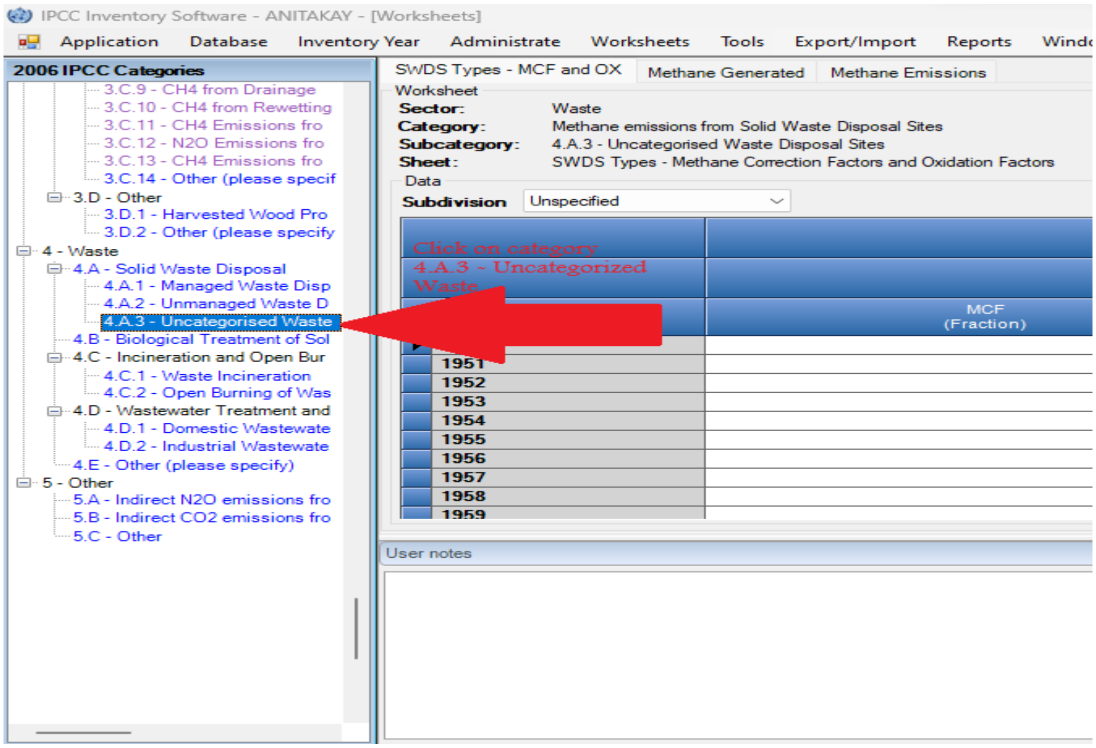
(See 2006 IPCC Guidelines, Vol.5, pg 14, Table 3.1)



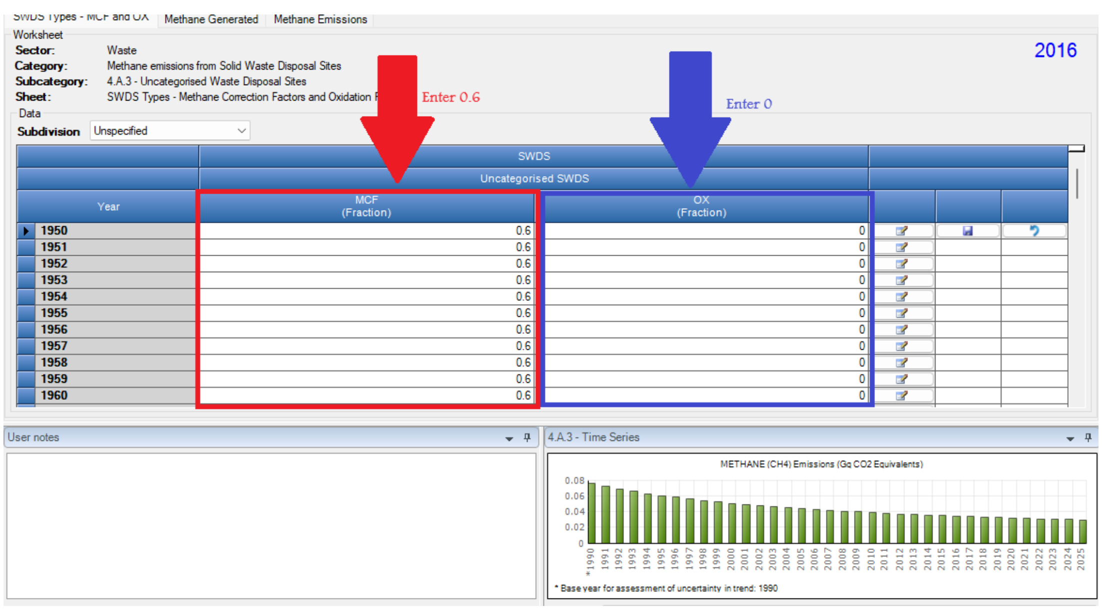
1.43 Run the cursor over the graph to give the CH_4 Emissions (Gg Co_2 Equivalent) (see illustration in step 4.0).

1.44 Repeat steps 1.34 to 1.40 for category "4.A.2 – Unmanaged Waste Disposal".

1.45 Click on the category "4.A.3-Uncategorised Waste Disposal" under the "2006 IPCC categories" (see illustration below).



1.46 under the "SWDS Types -MCF and OX" tab, enter the IPCC default value for MCF = 0.6 and OX = 0 (see illustration below)



1.47 Run the Cursor over the graph below to give the CH_4 Emissions (Gg Co_2 Equivalent) (see illustration in step 1.38)

1.48 Repeat steps 1.34 to 1.40 for the category "4.A.3-Uncategorised Waste Disposal".

4.3.3 TIME SERIES

According to the report produced by The Republic of Vanuatu Third National Communication to the United Nations Framework Convention on Climate Change (2020), the key source of emission from solid waste managed and disposed of included emissions from anaerobic decomposition of waste management of aerobic decomposition at the Bouffa landfill site[2].

Tier 1 method – IPCC First Order Decay (FOD) was used in the Third National Inventory report (2020) which covered the years 2008 to 2015. The method mainly consisted of the usage of Default value, default activity data, and default parameters [1].

Estimates of MSW generation in Vanuatu are based on the urban populations of Port Vila, Luganville, and Lenakel in the lack of activity statistics. The majority of data is gathered from urban regions rather than rural ones because those locations are typically dispersed and fail to identify many hazards. An average figure of 1-1.5 kg/person/day was extracted from a 2015 study in which the J-PRISM team was involved [1].

The Director General of the Ministry of Climate Change used office notifications to notify relevant ministries and departments, specified organizations, the public-private sector, and other institutions to collect data for this inventory period. The Department of Climate Change is responsible for maintaining the gathered data, database repository, and archives [1].

Following the 2006 IPCC Guidelines, Vol. 5, Figure 3.1, the Tier 1 Method Approach specifically IPCC First Order Decay (FOD) will be used for this inventory. Estimated Emissions will be calculated using historical data and present up-to-date data.

To collect information, the Project Coordinator and the Consultants will notify Offices relevant to ministries and stakeholders such as the:

- Department of Environmental Protection and Conservation (DEPC)
- Department of Water Resources (DWR)
- Port Vila City Council (PVCC)
- Environment Unit, Public Health at the Ministry of Health
- Department of Climate Change (DOCC)
- UNELCO Engie
- Public Works Department (PWD)

The channels for requesting activity data meetings are the Electronic Single Window, emails, dialogues, and interviews. Consultants may ask the Prime Minister's Office for a Confidential Agreement or Right to Information (RTI) in specific situations where data is unavailable.

[2] *The Republic of Vanuatu Third National Communication to the United Nations Framework Convention on Climate Change | Vanuatu Environment Data Portal* (2020)

Table 9: Annual emissions data from the base year of 1994 through 2023, including the emissions values, their units, the emission factors, and the methods used to estimate the emissions.

Year	Emissions	Units	EF	Methods
1994	NE	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
1995	NE	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
1996	NE	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
1997	NE	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
1998	NE	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
1999	NE	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2000	NE	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2001	NE	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2002	NE	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2003	NE	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2004	NE	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2005	NE	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2006	NE	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2007	22.44	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2008	23.3	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2009	24.1	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2010	24.9	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2011	25.8	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2012	26.7	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2013	27.7	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2014	28.6	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2015	29.6	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2016	NE	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2017	NE	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2018	NE	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2019	NE	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2020	NE	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2021	NE	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2022	NE	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1
2023	NE	kt CO_2-e	0.15Kg CH_4/ kg DOC	Tier 1

Where:

NE = Not Estimated

In improving this, the sector concern should strengthen the monitoring and reporting system for past years that are missing to satisfy the inventory process in moving forward.

The base year for MSW begins in 1994, and the collection of data will begin from 1994 to 2023. The emissions were calculated using the Tier 1 methodology approach with the default IPCC parameters and EF. The values in the Emissions need to be updated therefore no information has been placed in the table for years 1994 to 2006 and from 2016 to 2023.

<u>Identifying Trends, Big Variations, And Outliers with A Transparent Explanation</u>

As may be observed from the graph below, which was taken from the Third National Inventory (2020), when it comes to identifying trends and outliers The graph below shows that between 2007 and 2017, there was an increase in Gg CH_4 emissions (MSW). The growing population is the cause of the increase in emissions.

Certain trends in data can be caused by a variety of factors, including changes in underlying conditions, external influences, or anomalies such as outliers.

1. Inadequate data management system
2. The majority of the data was erased from the government system following a hack, even after it was restored.

Figure 2: Emissions of CH_4 and N_2O (in Gg) from Solid Waste Disposal and Wastewater, 2007–2015

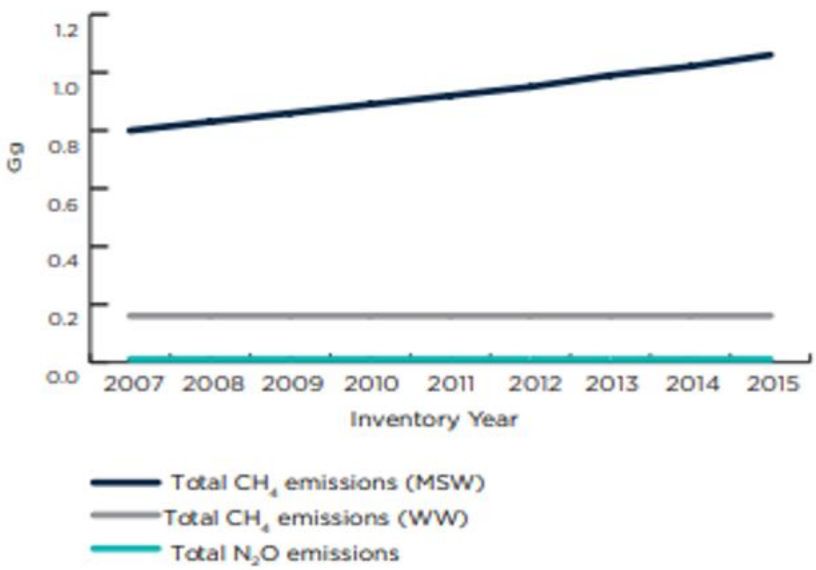


Figure 4.2: Source: Vanuatu's Third National Inventory (2020).

The figure depicts an increase in the CH_4 (g) emissions across the years of 2007 to 2015 compared to the other categories of Waste such as Wastewater in grey and blue in the graph above.

4.3.4. QUALITY CONTROL/ QUALITY CHECK

QUALITY CONTROL (QC) METHOD

Table 10: QC activities and procedures that will be followed

The three consultants will handle the QC and Procedures based on the color in the table, Anita Kay-Pink, Florancza- Green, and Zechariah Bani- Blue.

QUALITY CONTROL CHECK	PROCEDURES	TIME TAKEN TO COMPLETE PROCEDURE (DAYS)	COMMENTS
Check the Assumptions and criteria for the selection of activity data, emissions factor, and other estimation parameters	• Confirm that estimates are reported for all categories and all years from the appropriate base year to the period of the current inventory.		
	• For subcategories, confirm that the entire category is being covered.		
	• Provide a clear definition of 'Other' type categories.		
	• Check that known data gaps that result in incomplete estimates are documented, including a qualitative evaluation of the importance of the estimate concerning total emissions (e.g., subcategories classified as 'not estimated', see Chapter 8, Reporting Guidance and Tables).		
Check for transcriptions Errors in the data input and references	• Confirm that bibliographical data references are properly cited in the internal documentation.		
	• Cross-check a sample of input data from each category (either measurements or		

	parameters used in calculations) for transcription errors.		
Check that emissions and removals are calculated correctly	• Reproduce a set of emissions and removal calculations.		
	• Use a simple approximation method that gives similar results to the original and more complex calculation to ensure that there is no data input error or calculation error.		
Check that parameters and units are correctly recorded and that appropriate conversion factors are used.	• Check that units are properly labeled in calculation sheets.		
	• Check that units are correctly carried through from beginning to end of calculations.		
	• Check that conversion factors are correct.		
	• Check that temporal and spatial adjustment factors are used correctly.		
Check the integrity of database files	• Examine the included intrinsic documentation (see also Box 6.4) to:		
	1. Confirm that the appropriate data processing steps are correctly represented in the database.		
	2. Confirm that data relationships are correctly represented in the database.		
	3. Ensure that data fields are properly labeled and have the correct design specifications.		
	4. Ensure that adequate documentation of database and model structure and operation are archived.		

Check for consistency in data between categories.	Identify parameters (e.g., activity data, constants) that are common to multiple categories and confirm that there is consistency in the values used for these parameters in the emission/removal calculations.		
Check that the movement of inventory data among processing steps is correct.	• Check that emissions and removal data are correctly aggregated from lower reporting levels to higher reporting levels when preparing summaries.		
	• Check that emissions and removal data are correctly transcribed between different intermediate products.		
Check that uncertainties in emissions and removals are estimated and calculated correctly.	• Check that the qualifications of individuals providing expert judgment for uncertainty estimates are appropriate.		
	• Check that qualifications, assumptions, and expert judgments are recorded.		
	• Check that calculated uncertainties are complete and calculated correctly.		
	• If necessary, duplicate uncertainty calculations on a small sample of the probability distributions used by Monte Carlo analyses (for example, using uncertainty calculations according to Approach 1).		
Check time series consistency.	• Check for temporal consistency in time series input data for each category.		
	• Check for consistency in the algorithm/method used for calculations throughout the time series.		
	• Check methodological and data changes resulting in recalculations.		

	• Check that the effects of mitigation activities have been appropriately reflected in time series calculations.		
Check Completeness	• Confirm that estimates are reported for all categories and all years from the appropriate base year to the period of the current inventory.		
	For subcategories, confirm that the entire category is being covered.		
	• Provide a clear definition of 'Other' type categories.		
	• Check that known data gaps that result in incomplete estimates are documented, including a qualitative evaluation of the importance of the estimate concerning total emissions (e.g., subcategories classified as 'not estimated', see Chapter 8, Reporting Guidance and Tables)		

Trend Check	• Confirm that estimates are reported for all categories and all years from the appropriate base year to the period of the current inventory.		
	• Check the value of implied emission factors (aggregate emissions divided by activity data) across time series.		
	1. Do any of the year's show outliers that are not explained?		
	2. If they remain static across time series, are changes in emissions or removals being captured?		
	• Check if there are any unusual and unexplained trends noticed for activity data or other parameters across the time series.		

Review of internal documentation and archiving.	• Check that there is detailed internal documentation to support the estimates and enable the reproduction of the emission, removal, and uncertainty estimates.		
	• Check that inventory data, supporting data, and inventory records are archived and stored to facilitate detailed review.		
	• Check that the archive is closed and retained in a secure place following completion of the inventory.		
	• Check the integrity of any data archiving arrangements of outside organizations involved in inventory preparation		

(Table 6.1 GENERAL INVENTORY QC PROCEDURES, volume 1, 2006 IPCC Guidelines for National Greenhouse Gas Inventories).

Table 11: Responsibilities assigned to each party

Displayed are the corresponding timelines indicating the duration required for each party to complete their respective tasks

Quality Control Method	Responsibilities	Timeline (Time for completion)
GHG Inventory Team Members (Consultant)	1. Implement QA/QC at all levels of transparency	2 Months
	2. Collect data, Inventory Preparation and Reporting	
	3. Conduct Checks on the consistency of data and information provided by the different stakeholders to ensure data integrity, correctness, and completeness	
TWGS (Technical Working Groups) Specific group consisting of Experts and Professionals	1. Technical Review of sub-category activity data, Emission Factor, Estimation Parameters, and Calculation method	2 - 3 Weeks
	2. Final Check of the Report	
Municipal	According to the United Nations Development Programme (UNDP) and the Government of Vanuatu, municipalities are responsible for managing solid waste in the country. This includes the collection, transportation, disposal, and sometimes treatment of solid waste. To effectively manage waste and allocate resources, accurate data on waste generation is essential.	2 Weeks upon request
Environment Department	The Department of Environmental Protection and Conservation oversees environmental protection and regulation. The department may have information on the generation of MSW	2 Weeks upon request

4.3.5 UNCERTAINTIES

Uncertainty in the method

As stated by the 2006 IPCC guidelines the following are the reasons behind uncertainty in the method [3].

A first-order decay reaction may not always be followed in the complex chemical reactions that convert carbon molecules to CH_4. Reaction rates will fluctuate depending on the circumstances at the particular SWDS, and higher-order reactions might be involved. Restrictions on water access and regional differences in bacterial populations may limit reactions [2].

• There are variations in SWDS. Even within a single site, conditions like temperature, moisture content, waste composition, and compaction can fluctuate significantly, and even more between sites within a country. It is challenging to choose "average" parameter values that are typical for an entire nation [2].

• Using the FOD approach adds to the ambiguity around past waste disposal amounts and degradation rates (half-lives). Neither of these has been studied or understood in great detail [2].

• Using the FOD approach adds to the ambiguity around past waste disposal amounts and degradation rates (half-lives). Neither of these has been studied or understood in great detail (2006 IPCC Guidelines, Vol. 5) [2].

Uncertainty Associated with Data Uncertainty

Using the FOD approach adds to the ambiguity around past waste disposal amounts and degradation rates (half-lives). Neither of these has been studied or understood in great detail (2006 IPCC Guidelines, Vol. 5) [2].

The degree of uncertainty in waste disposal data varies depending on how the data is obtained; it can be reduced when the amounts of waste in the SWDS are weighed; it will be higher if the estimates are based on waste delivery vehicle capacity or visual estimation; and it can be highest for estimates based on default activity data. The quality of CH_4 emission estimates is directly related to the quality and availability of the waste generation, composition, and management data used to derive these estimates (2006 IPCC Guidelines, Vol. 5) [2].

The activity data in the waste sector includes the total municipal solid waste, total industrial waste, waste composition, and the fraction of solid waste sent to solid waste disposal sites Waste scavenging at the SWDS must be considered while analyzing the waste disposal data; otherwise, the data's level of uncertainty will rise [2].

[3] nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

Scavenging will also raise speculations about the composition of the waste that ends up in the SWDS and, in turn, about how much DOC is in the trash generally. Uncertainty estimates for the default model parameters are given in Table 4.12. The estimations are based on expert assessment. waste creation can be estimated using population (or urban population) and per-capita waste generation rates. Uncertainty may be introduced if the population does not match the population from which waste is collected. In many countries, waste is usually collected only from city dwellers. An urban area's population may fluctuate daily or seasonally due to labor force mobility [2].

Uncertainty Associated with Parameters

The following Uncertainties have been extracted straight from the (2006 IPCC Guidelines, Vol. 5, Pg. 26).

Methane correction factor (MCF) There are two sources of uncertainty in the MCF.
• Uncertainty in the value of the MCF for each type of site (managed-anaerobic, managed-semi-aerobic, unmanaged deep and/or high-water table, unmanaged shallow): These MCF values are based on one experimental study and expert judgment and not on measured data [2].

• Uncertainty in the classification of sites into the different site types: For example, the distinction between deep and shallow sites (5 m depth of waste) is based on expert opinion. Inevitably, few, if any, countries will be able to classify their unmanaged waste disposal sites into deep and shallow based on measured data. It can also be difficult to determine the sites that meet the IPCC criteria for managed sites. Degradable organic carbon (DOC)

• Uncertainty in setting the DOC for different types of waste types/materials (paper, food, etc.): There are few studies of DOC, and different types of paper, food, wood, and textiles can have very different DOC values. The water content of the waste also has an influence. DOC for industrial waste is very poorly known. Degradable organic carbon (DOC) There are two sources of uncertainty in DOC values [2].

• Uncertainty in the waste composition affects estimates of total DOC in the SWDS: Waste composition varies widely even within countries (for example, between urban and rural populations, between households on different incomes, and between seasons) as well as between countries [2].

Fraction Of Degradable Organic Carbon Which Decomposes (DOC_f)
The uncertainty in DOCf is very high. There have been few studies, and it is difficult to replicate real SWDS conditions in experimental studies [2].

Fraction Of CH_4 In Landfill Gas (*F*)
The CH_4 fraction of generated landfill gas, *F*, is usually taken to be 0.5 but can vary between 0.5 and 0.55, depending on several factors (see Section 3.2.3). The uncertainty in this figure is

relatively low, as *F* depends largely on the stoichiometry of the chemical reaction producing CH_4. The concentration of CH_4 in recovered landfill gas may be lower than the actual value because of potential dilution by air, so *F* values estimated in this way will not necessarily be representative [2].

Methane recovery (R)

CH_4 recovery is the amount of CH_4 generated at SWDS that is recovered and burned in a flare or energy recovery device. The uncertainty depends on the method used to estimate recovered CH_4. The uncertainty is likely to be relatively small compared to other uncertainties if metering is used. If other methods are used, for example by estimating the efficiency of CH_4 recovery equipment, the uncertainty will be larger [2]. (See Section 3.2.3.).

Oxidation Factor (OX)

The oxidation factor is very uncertain because it is difficult to measure, and varies considerably with the thickness and nature of the cover material, atmospheric conditions and climate, the flux of methane, and the escape of methane through cracks/fissures in the cover material. Field and laboratory studies that determine oxidation of CH_4 only through uniform and homogeneous soil layers may lead to overestimations of oxidation in landfill-cover soils [2].

The Half-Life

There is high uncertainty in the estimates of half-life because it is difficult to measure decay rates under conditions equivalent to those prevailing in real SWDS. Also, since there is considerable variation in half-life with waste composition, climate, and site type, it is difficult to select values representative of a whole country [2].

Uncertainty estimates for MSW_T (total MSW generated) and MSW_F (fraction of MSW_T disposed at SWDS) and the default model parameters are given in Table 4.12.

Table 12: Estimates of uncertainties associated with the default activity data and parameters in the FOD method for CH_4 emissions from SWDs

Activity data and Emission Factors	Uncertainty Range
Total Municipal Solid Waste (MSWT)	Country-specific: 30% is a typical value for countries that collect waste generation data regularly. ±10% for countries with high-quality data (e.g., weighing at all SWDS and other treatment facilities). For countries with poor quality data: more than a factor of two.
A fraction of MSWT sent to SWDS (MSWF)	±10% for countries with high-quality data (e.g., weighing at all SWDS). ±30% for countries collecting data on disposal at SWDS. For countries with poor quality data: more than a factor of two.
The total uncertainty of Waste composition	±10% for countries with high-quality data (e.g., regular sampling at representative SWDS). ±30% for countries with country-specific data based on studies including periodic sampling. For countries with poor quality data: more than a factor of two.
Degradable Organic Carbon (DOC)7	For IPCC default values: ±20% For country-specific values: Based on representative sampling and analyses: ±10%
Fraction of Degradable Organic Carbon Decomposed (DOCf)	For IPCC default value (0.5): ± 20% For country-specific value ± 10% for countries based on the experimental data over longer periods.
Methane Correction Factor (MCF) = 1.0 = 0.8 = 0.5 = 0.4 = 0.6	For IPCC default value： –10%, +0% ±20% ±20% ±30% –50%, +60%
Fraction of CH_4 in generated Landfill Gas (F) = 0.5	For IPCC default value: ±5%
Methane Recovery (R)	The uncertainty range will depend on how the amounts of CH_4 recovered and flared or utilized are estimated: ± 10% if metering is in place. ± 50% if metering is not in place.

Oxidation Factor (OX)	Include OX in the uncertainty analysis if a value other than zero has been used for OX itself. In this case, the justification for a non-zero value should include consideration of uncertainties.
half-life (t1/2)	Ranges for the IPCC default values are provided in Annex Table A4.5. Country-specific values should include consideration of uncertainties.
Source: Expert judgment by Lead Authors of the Chapter.	

4.3.6 METHODOLOGY CHOICE FOR DOMESTIC WASTEWATER

The decisions implemented during this operation are indicated by the red arrows.

Figure 3: Decision Tree for Method Selection in Estimating Actual Emissions from Sub-Category 4.D.1 Domestic Wastewater Treatment and Discharge

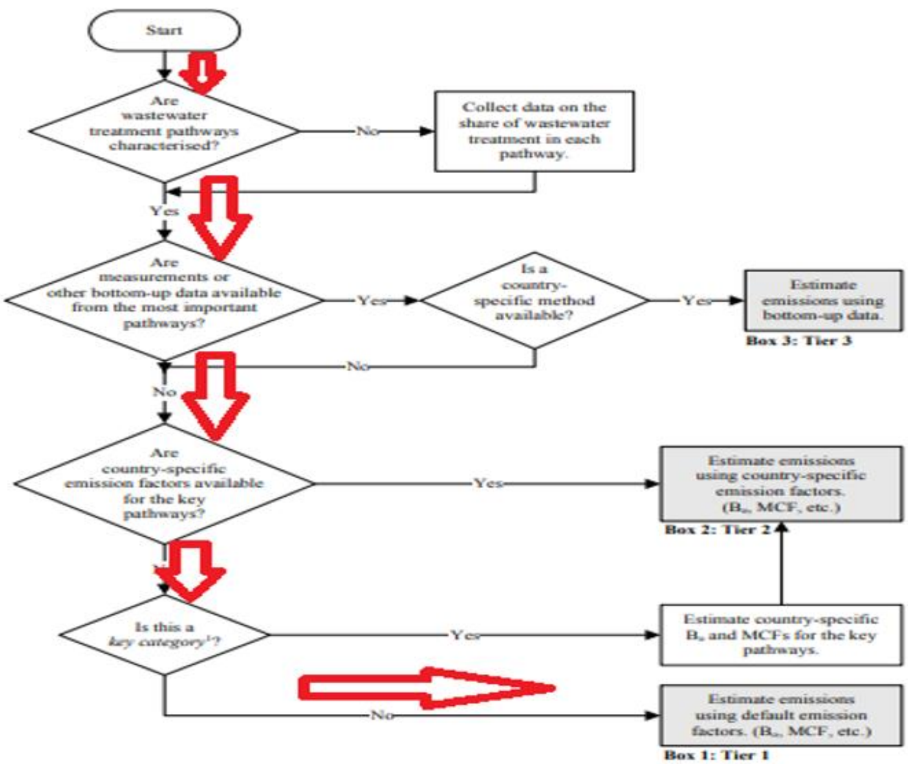


Figure 4.3 (See 2006 IPCC Guidelines, Vol. 5, Figure 6.2)

Note: Due to the national circumstances (lack of resources) Vanuatu does not have yet reliable country-specific emission factors and parameters and therefore, is applying the default parameters and Tier 1 methods to estimate emissions from the 4.D.1 Sub-Category.

EQUATIONS USED

Equation 1

EQUATION 6.3

Total Organically Degradable Material in Domestic Wastewater

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

Where:

- **TOW**: total organics in wastewater in inventory year, kg BOD/yr. (Biochemical Oxygen Demand (BOD) is the amount of carbon that is aerobically biodegradable) (See 2006 IPCC Guidelines, Vol.5, Pg. 13, Equation 6.3)
- **P**: country population in inventory year, number of people (See 2006 IPCC Guidelines, Vol.5, Pg. 13, Equation 6.3).
- **BOD**: country-specific per capita BOD in inventory year, g/person/day (Biochemical Oxygen Demand) (See 2006 IPCC Guidelines, Vol.5, Pg. 13, Equation 6.3)
    - conversion from grams BOD to kg BOD (See 2006 IPCC Guidelines, Vol.5, Pg. 13, Equation 6.3)
- **I**: correction factor for additional industrial BOD discharged into sewers (for collected the default is 1.25, for uncollected the default is 1.00). In some countries, information from industrial discharge permits may be available to improve this parameter (See 2006 IPCC Guidelines, Vol.5, Pg. 13, Equation 6.3)

Equation 2:

EQUATION 6.1

Total CH_4 Emissions From Domestic Wastewater

$$N2O\ EMISSIONS = [\sum (U_i \times T_{i,j} \times EF)](TOW - S) - R$$

Where:

- **TOW**: total organics in wastewater in inventory year, kg BOD/yr. (See 2006 IPCC Guidelines, Vol.5, Pg. 1, Equation 6.1)
- **S**: organic component removed as sludge in inventory year, kg BOD/yr. (See 2006 IPCC Guidelines, Vol.5, Pg. 1, Equation 6.1)

- **U_i**: fraction of population in income group I in inventory year (these are rural population and high/low-income urban population) (See 2006 IPCC Guidelines, Vol.5, Pg. 1, Equation 6.1).
- **$T_{i,j}$**: degree of utilization of treatment/discharge pathway or system, j, for each income group fraction I in inventory year (See 2006 IPCC Guidelines, Vol.5, Pg. 1, Equation 6.1).
- **I**: income group: rural, urban high income, and urban low income (See 2006 IPCC Guidelines, Vol.5, Pg. 1, Equation 6.1)
- **j**: each treatment/discharge pathway or system (See 2006 IPCC Guidelines, Vol.5, Pg. 1, Equation 6.1)
- **EF_j**: emission factor, kg CH_4 / kg BOD (See 2006 IPCC Guidelines, Vol.5, Pg. 1, Equation 6.1)
- **R**: amount of CH_4 recovered in inventory year, kg CH_4 /yr (See 2006 IPCC Guidelines, Vol.5, Pg. 1, Equation 6.1)

Equation 3:

EQUATION 6.7

Domestic wastewater: N_2O emissions

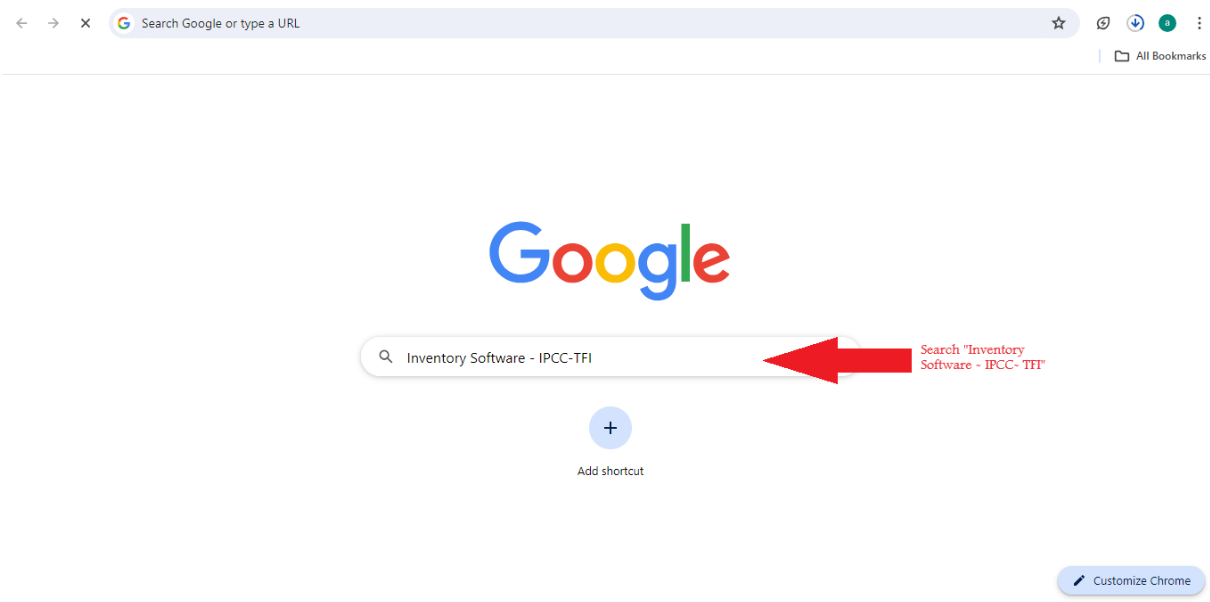
$$N_2O\ Emissions = N_{EFFLUENT} \bullet EF_{EFFLUENT} \bullet 44/28$$

Where:

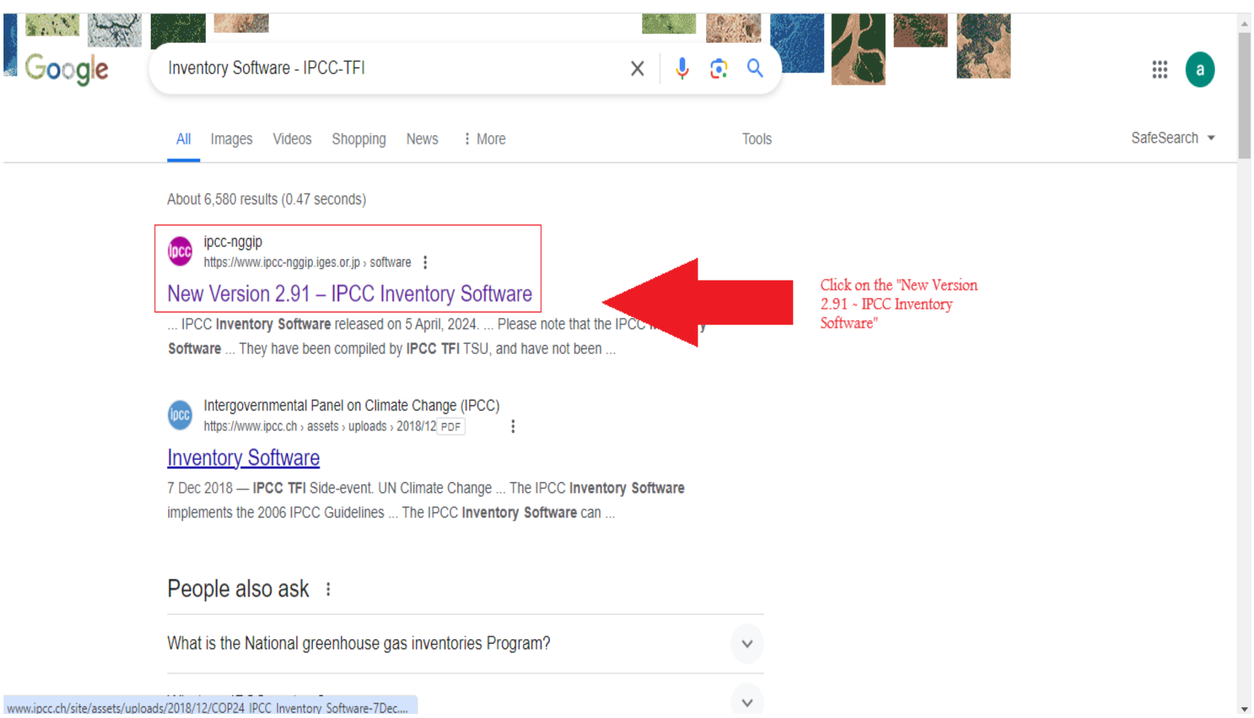
- **N_2O emissions** = N_2O emissions in inventory year, kg N_2O/yr (2006 IPCC Guidelines, Vol. 5, Pg. 25, Equation 6.7)
- **$N_{EFFLUENT}$** = Nitrogen in the effluent discharged to aquatic environments, kg N/yr (2006 IPCC Guidelines, Vol. 5, Pg. 25, Equation 6.7)
- **$EF_{EFFLUENT}$** = Emission factor for N_2O emissions from discharged to wastewater, kg N_2O-N/kg N (2006 IPCC Guidelines, Vol. 5, Pg. 25, Equation 6.7)
- The factor 44/28 is the conversion of kg N_2O-N into kg N_2O (2006 IPCC Guidelines, Vol. 5, Pg. 25, Equation 6.7).

4.3.7 STEP – BY – STEP CALCULATION, DOCUMENTING RESOURCES USED

1.0 Open Google chrome and search "Inventory Software – IPCC-TFI" (See illustration below)



1.1: Click on the "New Version 2.91 – IPCC Inventory Software (See illustration below)



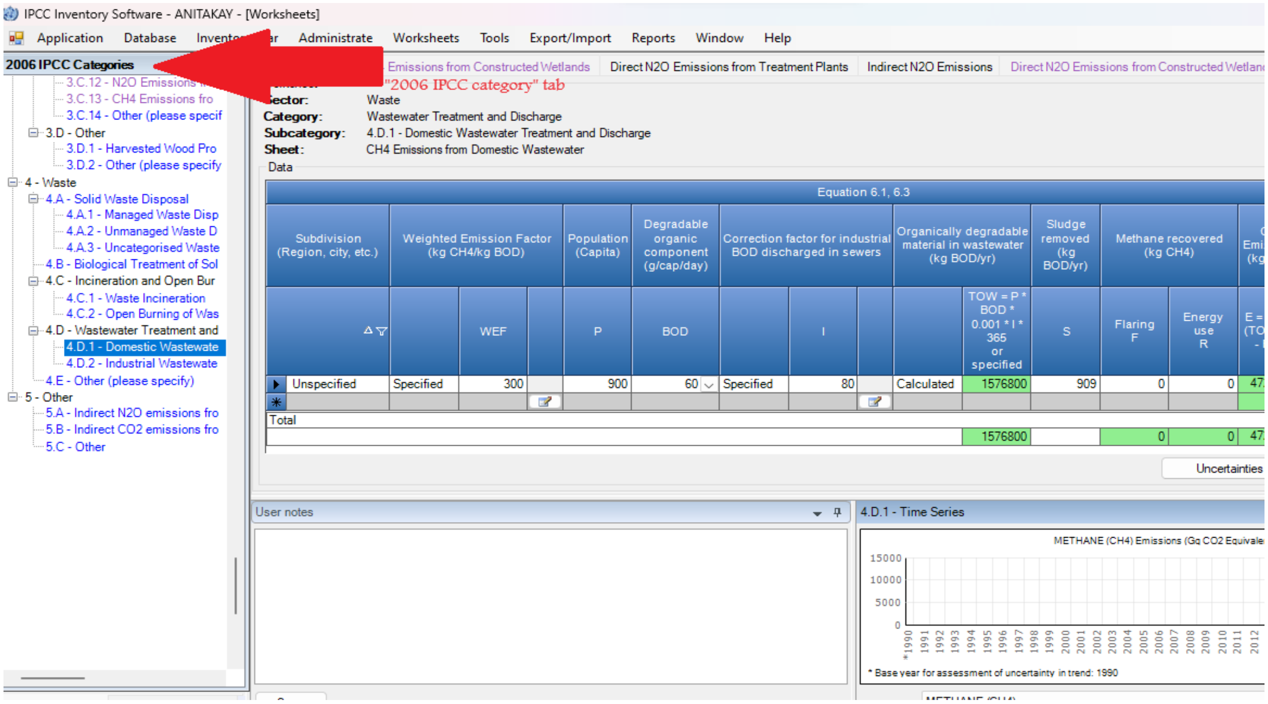
1.2: Click on the “ver 2.91 IPCC inventory Software – 32bit” and download the software (See illustration below).

1.3: Launch the Ver. 2.901 IPCC Inventory Software - **32bit** and follow the installation steps to install to your PC.

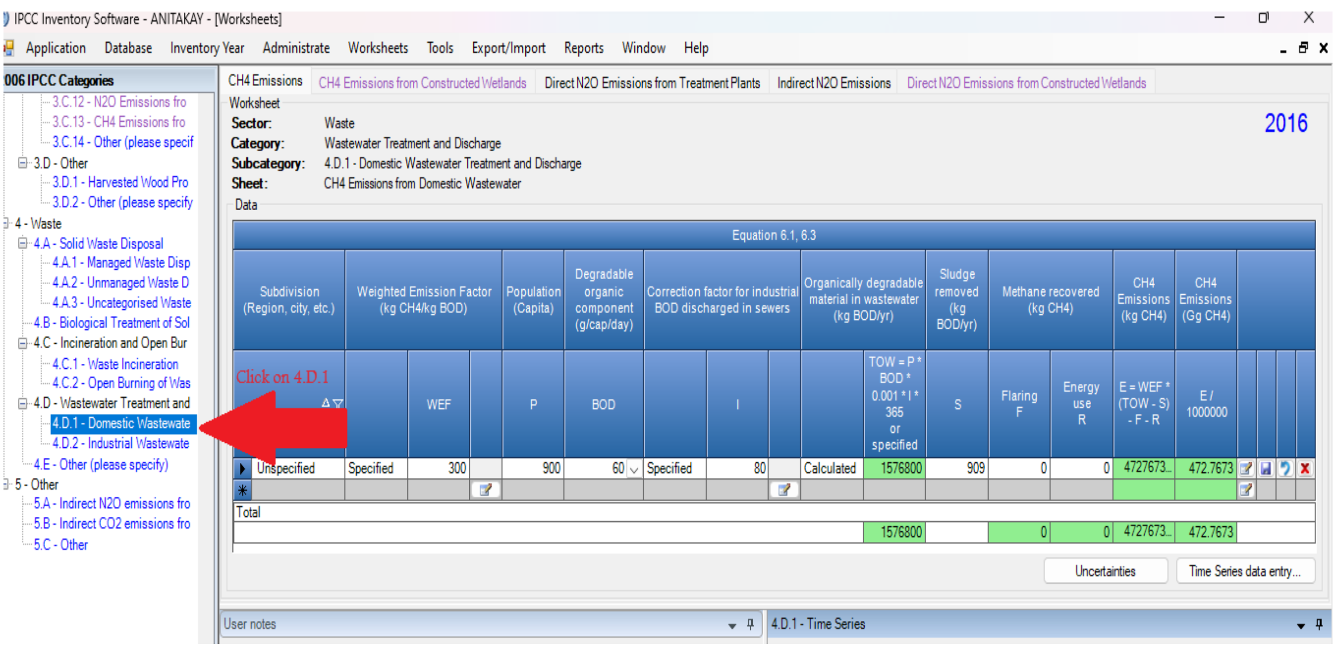
1.4: Create your password and username. If you have an existing account, type in your username and password.

1.5: Type in the year of your choosing or the current inventory year.

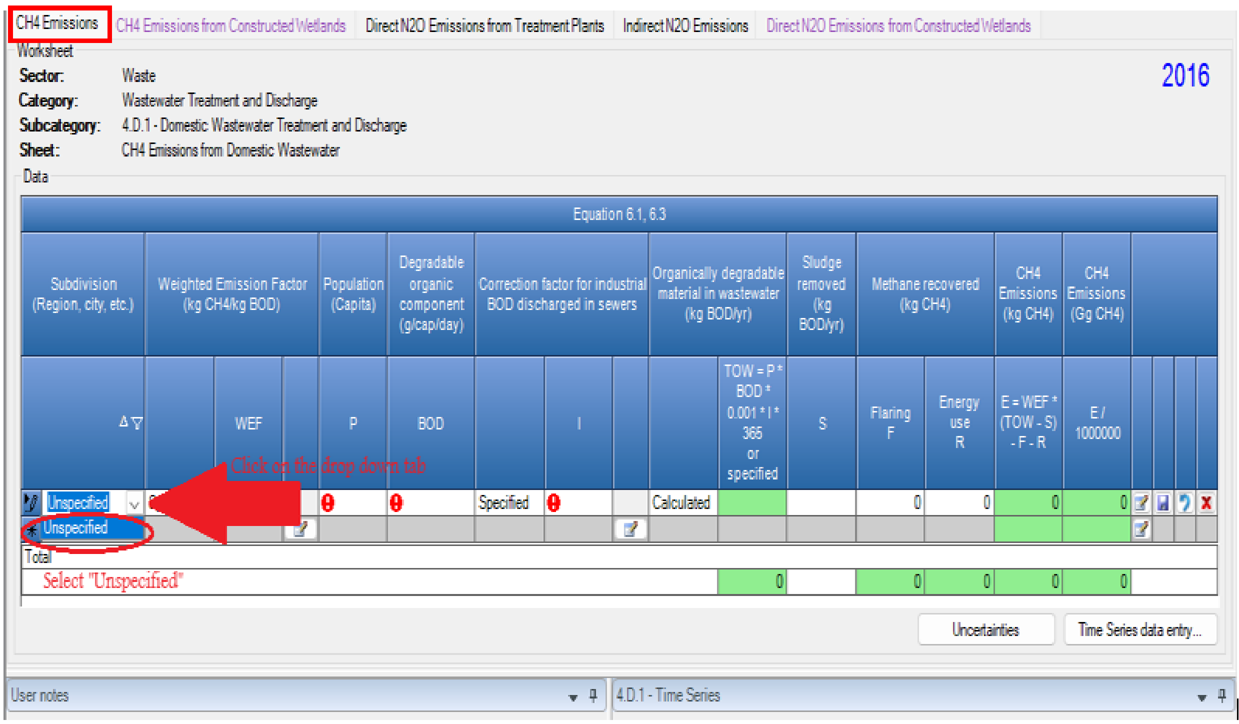
1.6: Scroll down the “2006 IPCC Category” tab on the left-hand side of the page till you reach 4.D “Waste Water Treatment and Discharge”.



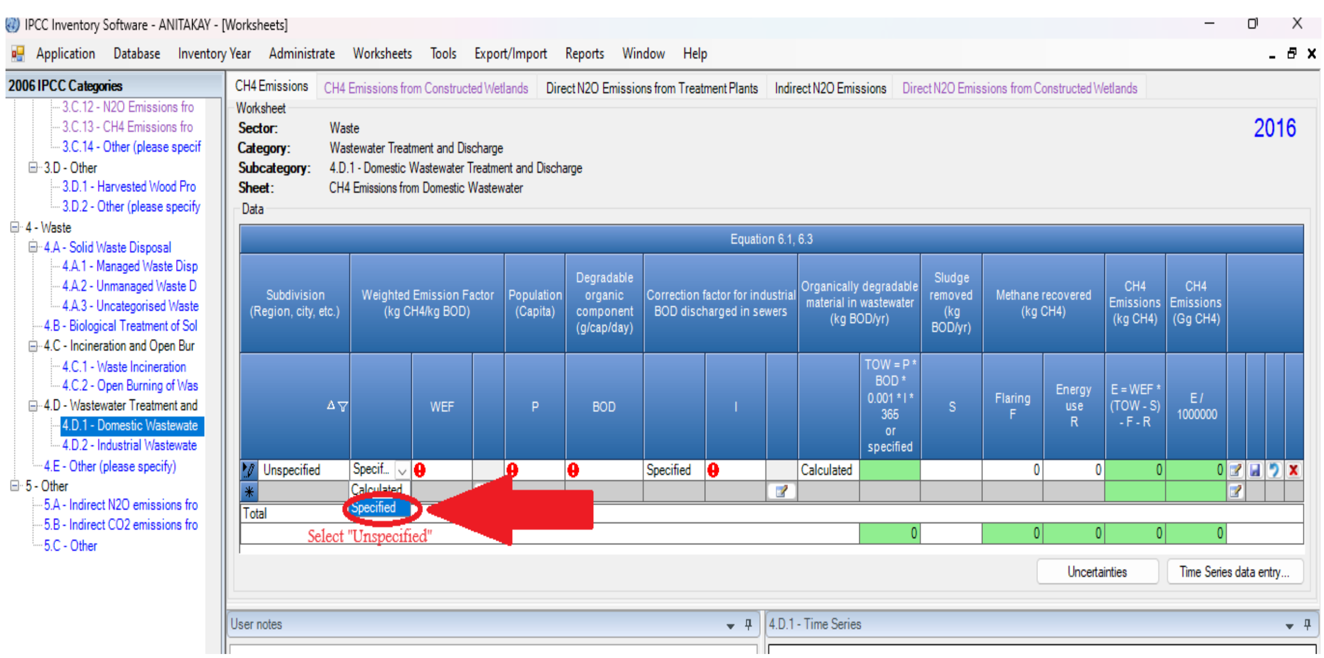
1.7: Click on the subcategory 4.D.1 “Domestic Wastewater Treatment and Discharge”.



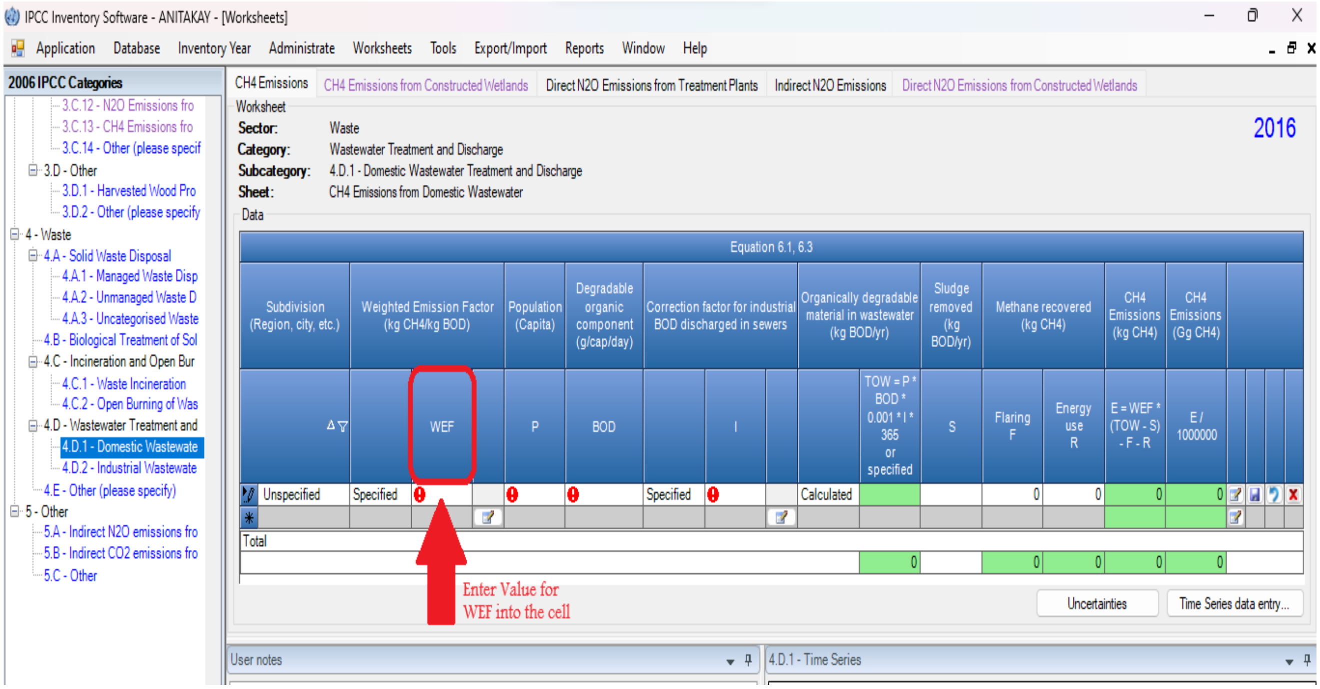
1.8: Under the “CH_4 Emission” tab, the table under the “Subdivision (Region, City, etc.)” tab, click on the drop-down tab and select “Unspecified” (see illustration below)



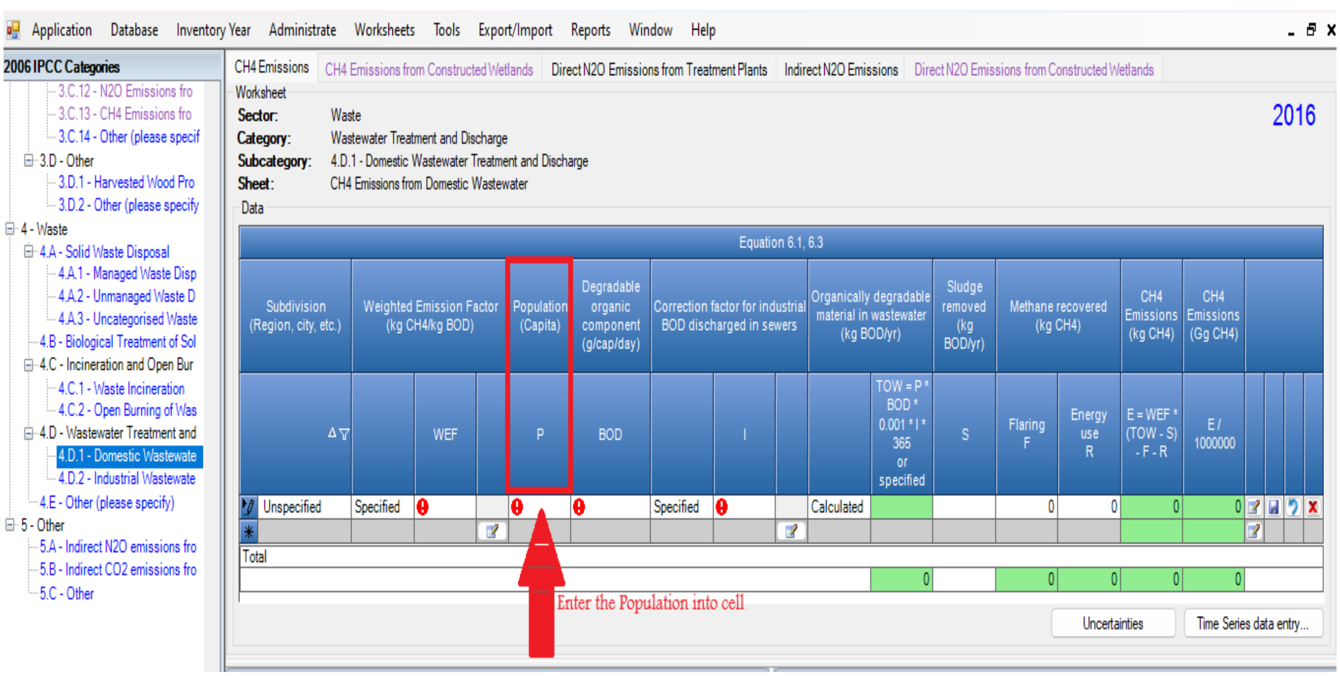
1.9: Select the drop-down tab under the “Weight Emission Factor (KgCH_4 BOD)” in the table and select “Specified” (see illustration below)



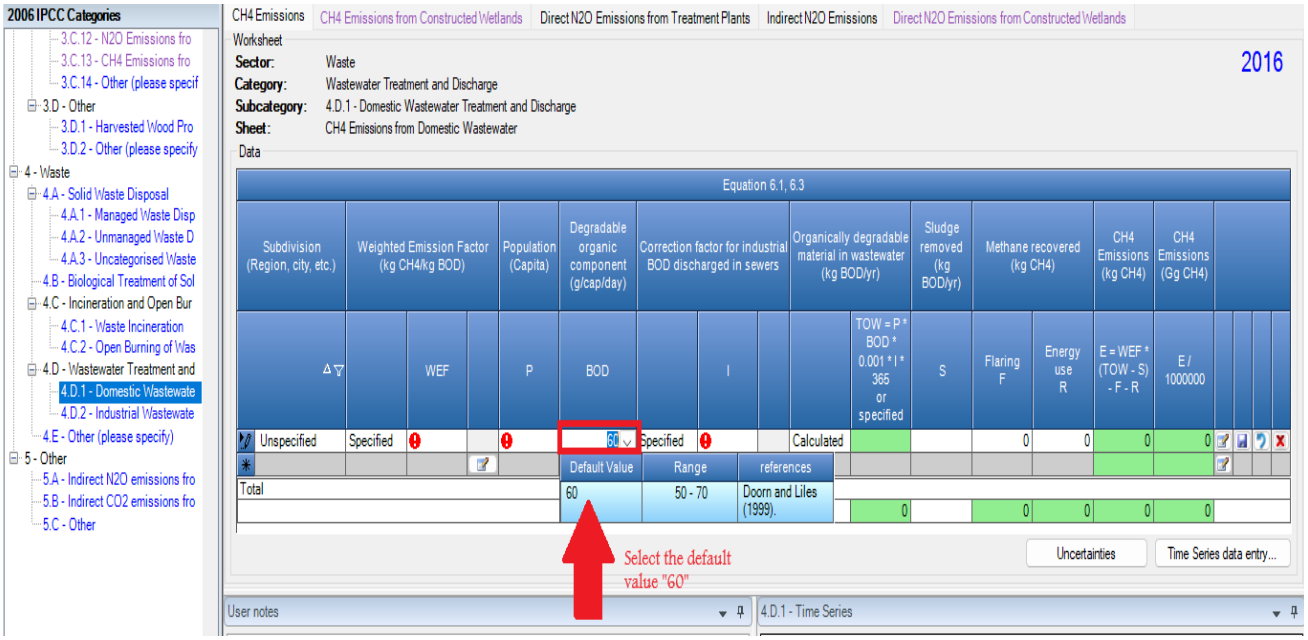
1.10: Under the same tab “Weight Emission Factor (KgCH_4 BOD)” within the table, Enter the value for the WEF (See Illustration below). Use default if national data is unavailable.



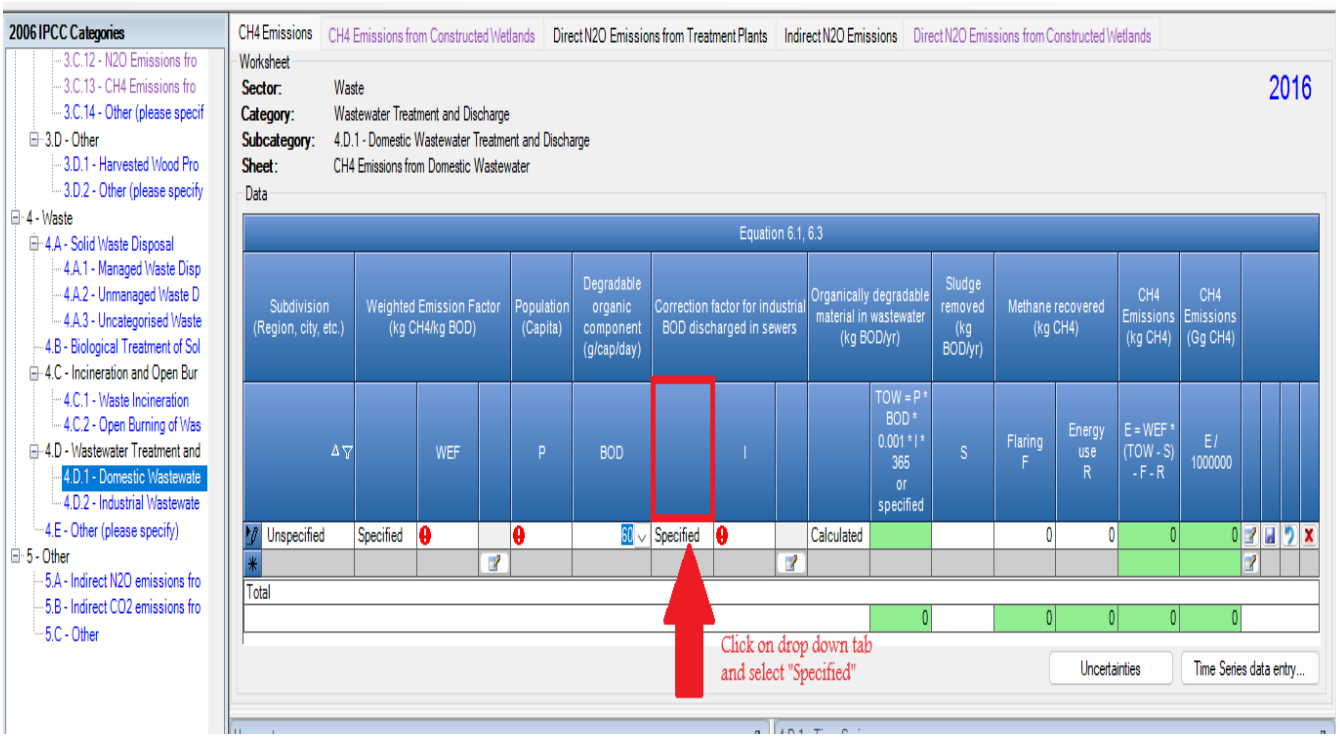
1.11: Under the “Population” column in the table, enter the Population of the chosen inventory year into the Cell. (See illustration below)



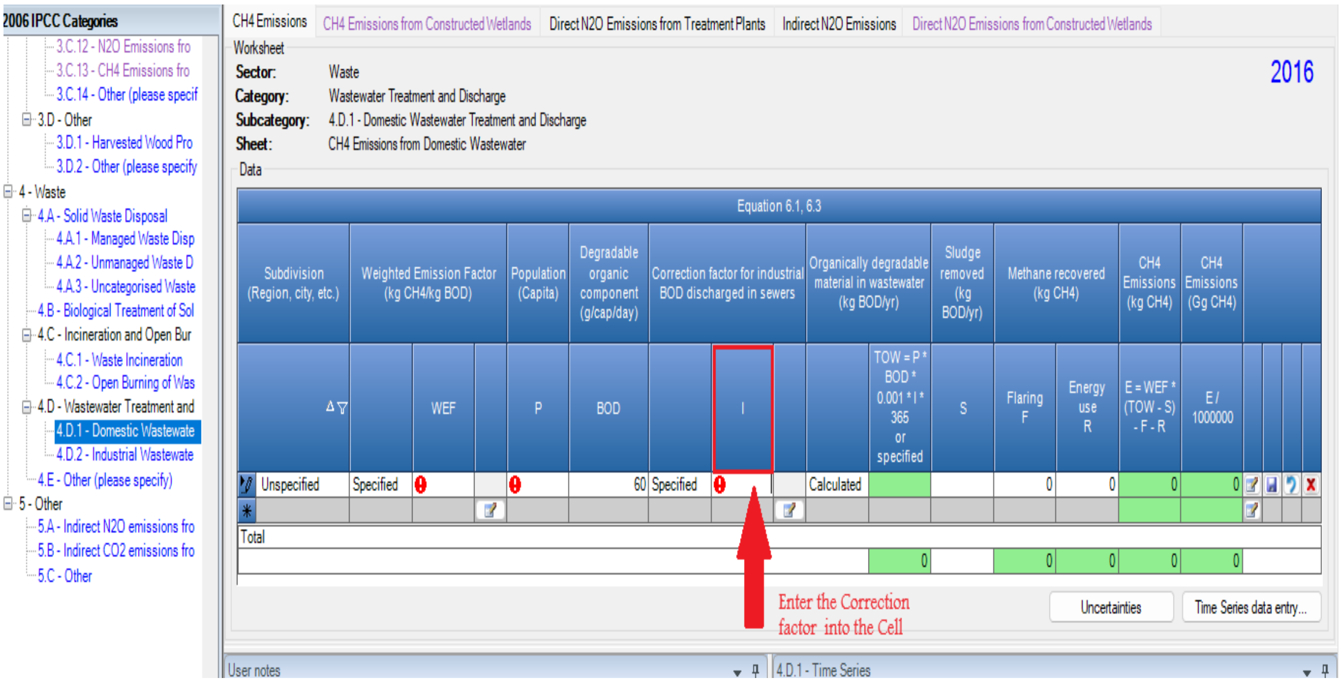
1.12: Click on the drop-down tab under the “Degradable Organic Component (g/cap/day)” select the default value “60” (see Illustration below)



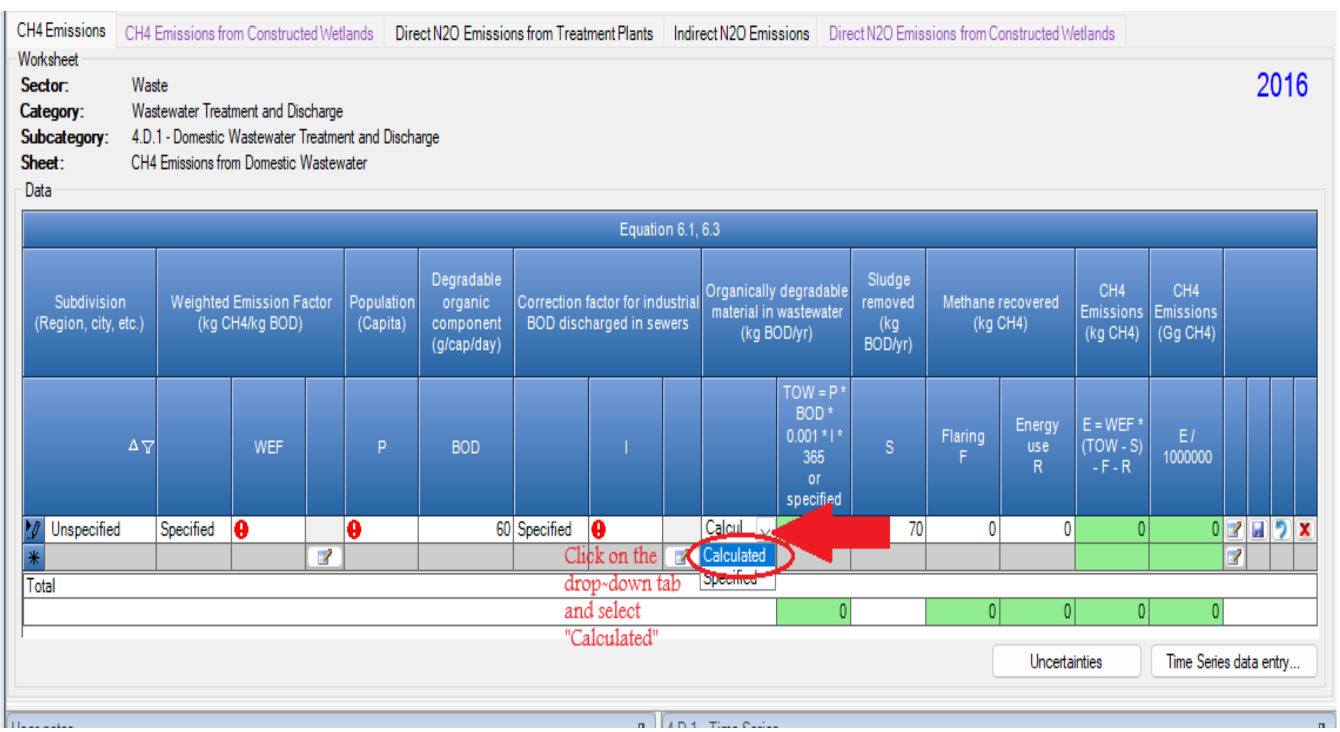
1.13: Under the first column in the tab “Correction factor for industrial BOD discharge in sewers” in the table click on the drop-down tab and select “Specified” (see illustration below).



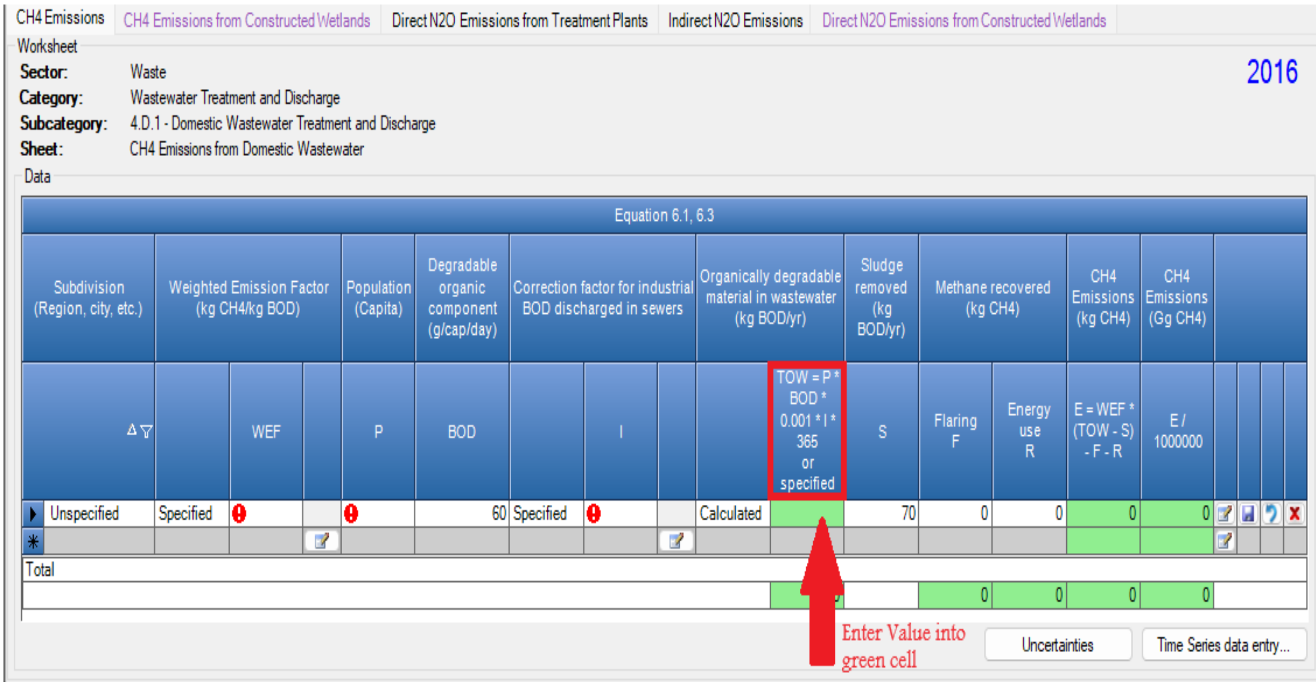
1.14: Enter the Correction factor (I) into the cell under the tab “Correction factor for industrial BOD discharge in sewers”. Use default value of 1.25 if national data is unavailable. (See illustration below).



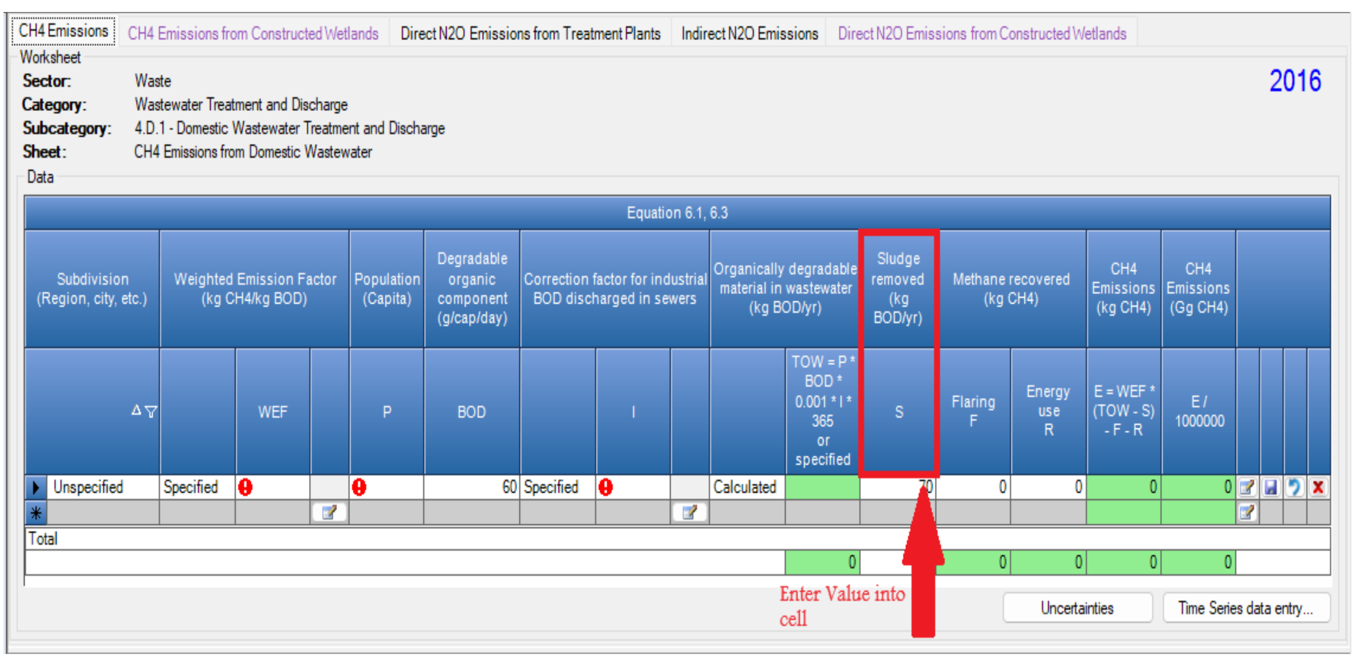
1.15: Click on the drop-down tab under the “Organically degradable material in wastewater (Kg BOD/yr.)” in the table and select “Calculated” (See illustration below).



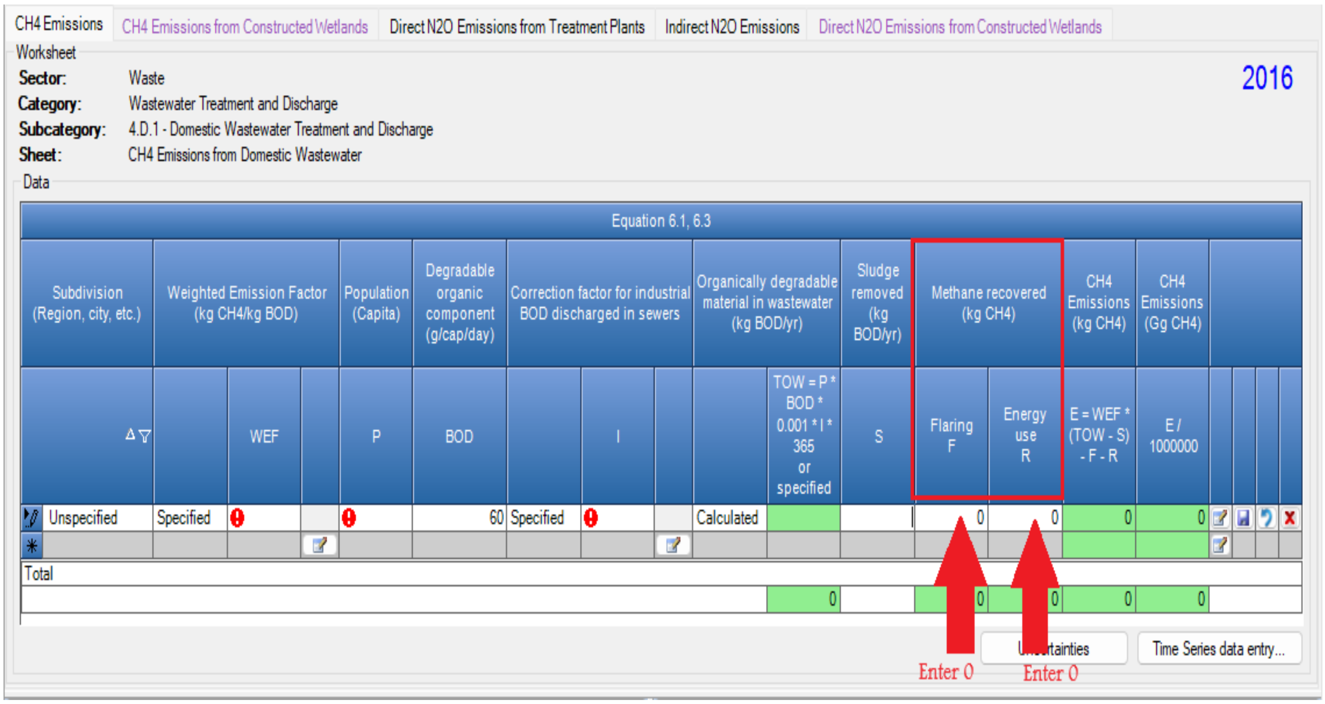
1.16: Under the same tab "Organically degradable material in wastewater (Kg BOD/yr)", click on the green cell to generate the value for the "TOW".



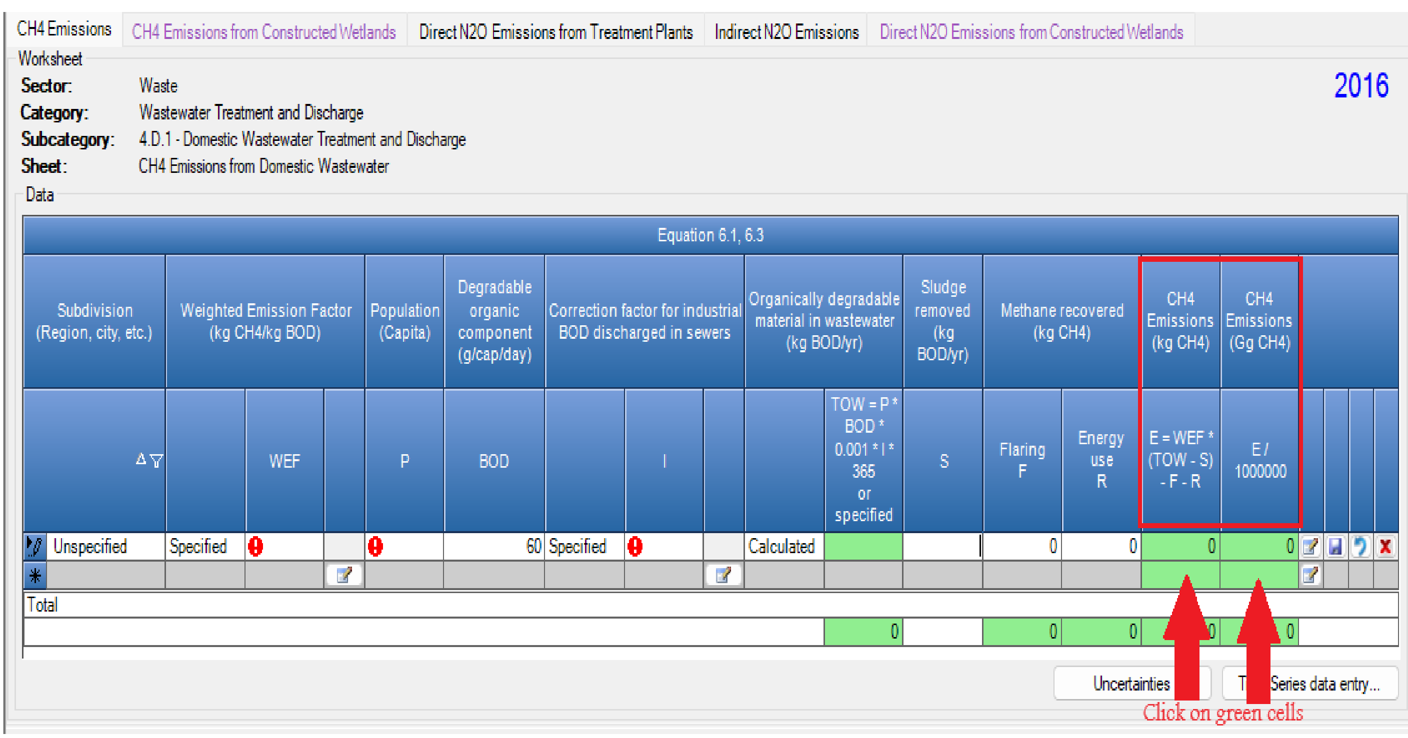
1.17: Under the tab "Sludge removed (kg BOD /year)", enter the data value 0 into the cell since sludge is not removed in Vanuatu. (See illustration below).



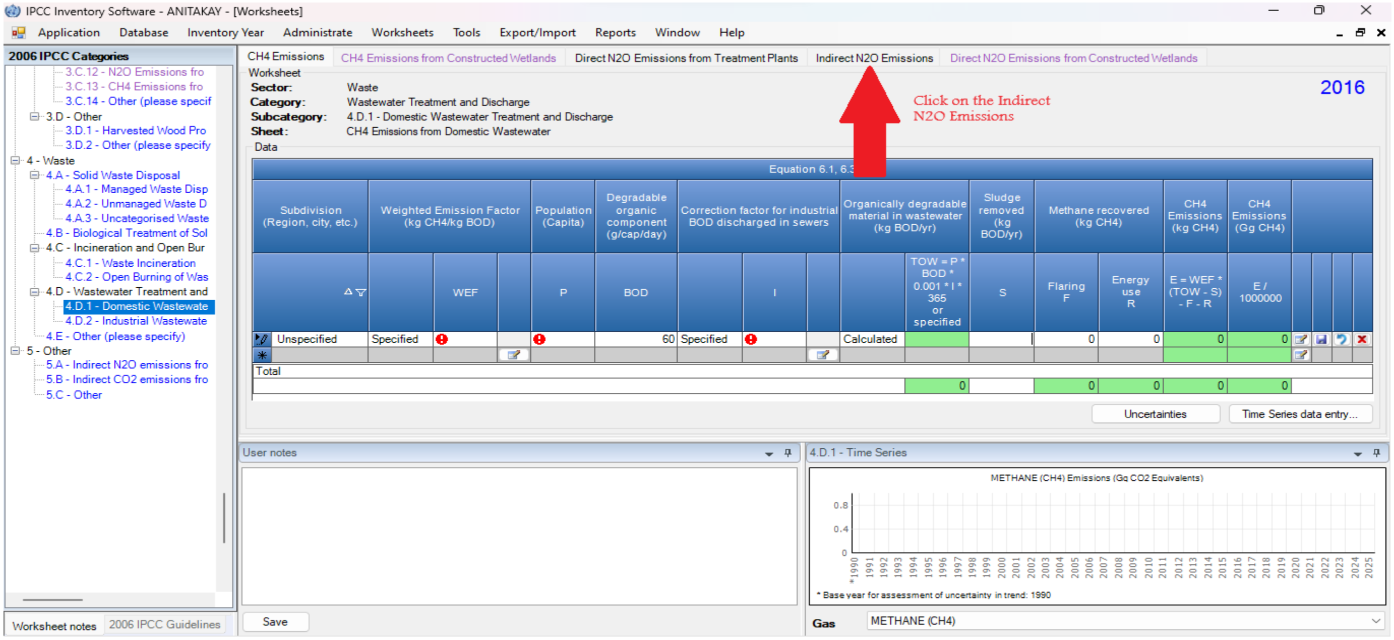
1.18: Methane is not recovered in Vanuatu, therefore Enter 0 for both "Flaring" and "Energy use R" under the tab "Methane Recovered" (See Illustration below).



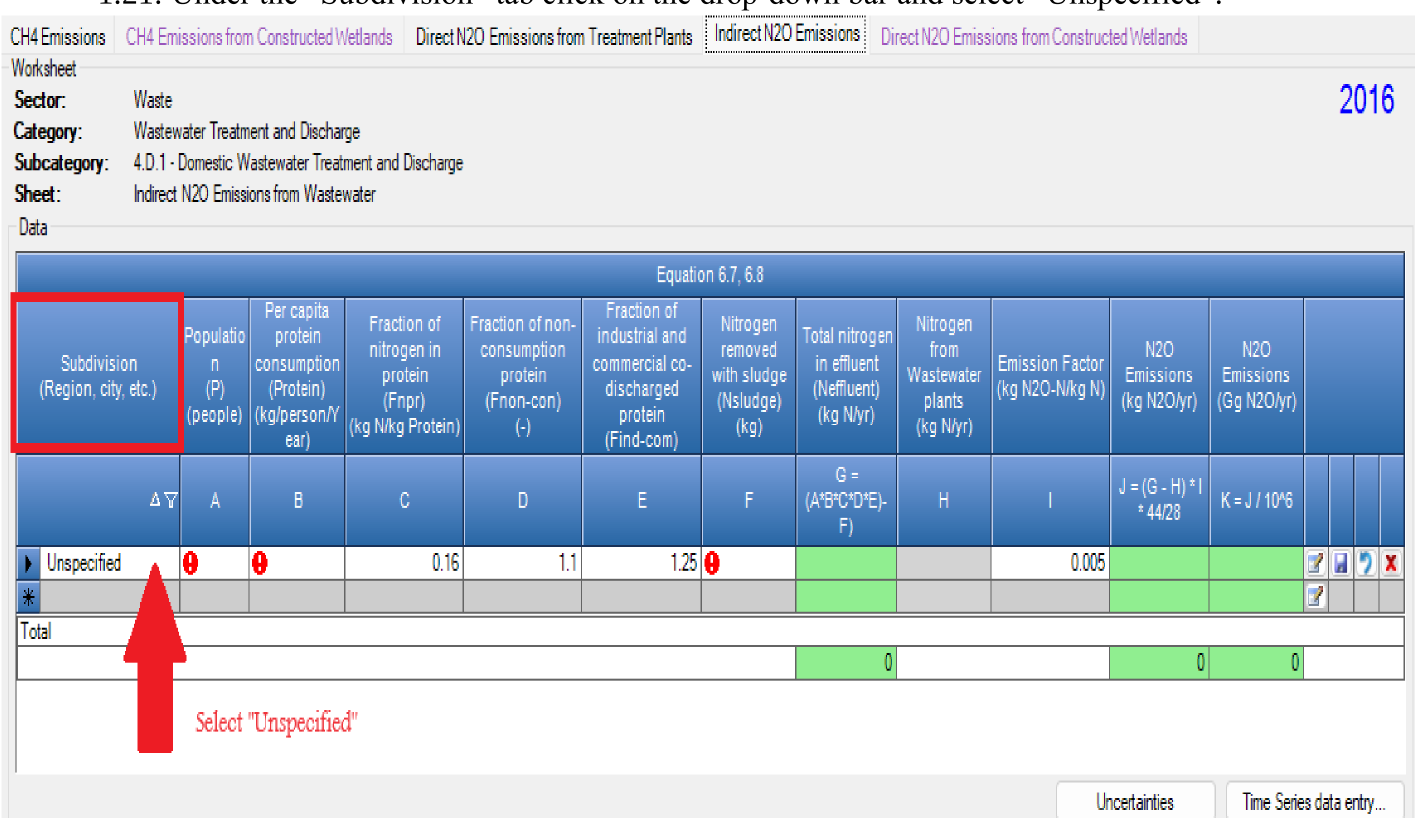
1.19: Click on the green cells under CH_4 Emissions (kg CH_4) and CH_4 Emissions (Gg CH_4) to generate values (see Illustration below).



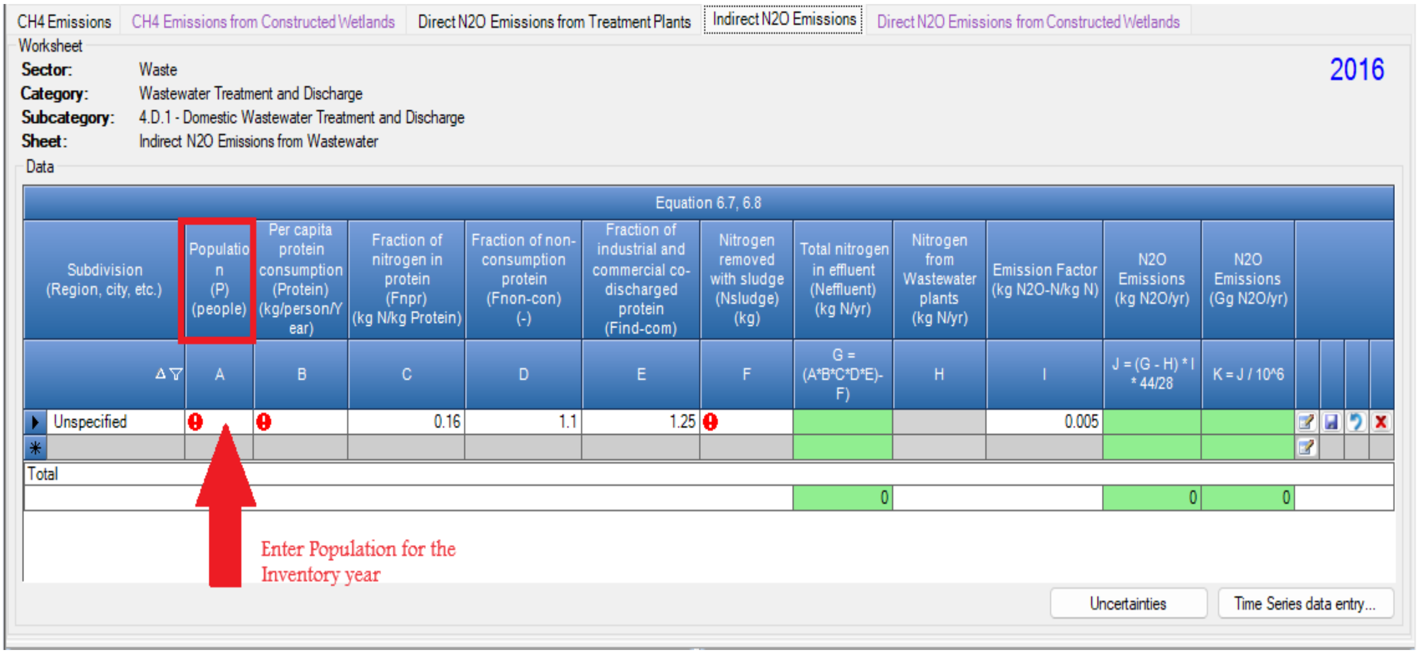
1.20: Within the same Subcategory 4.D.1, click on the Indirect N_2O Emissions from the top-hand corner of the IPCC software page (see Illustration below).



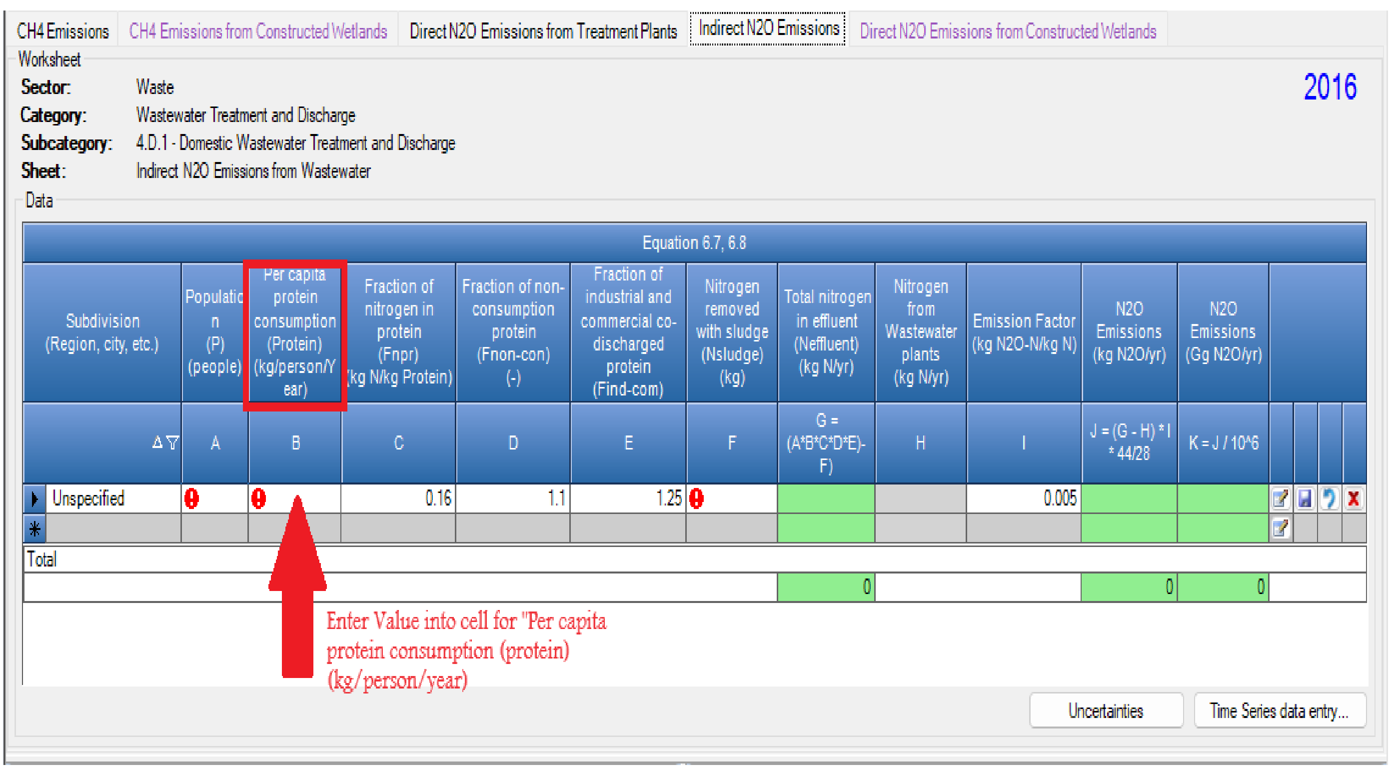
1.21: Under the "Subdivision" tab click on the drop-down bar and select "Unspecified".



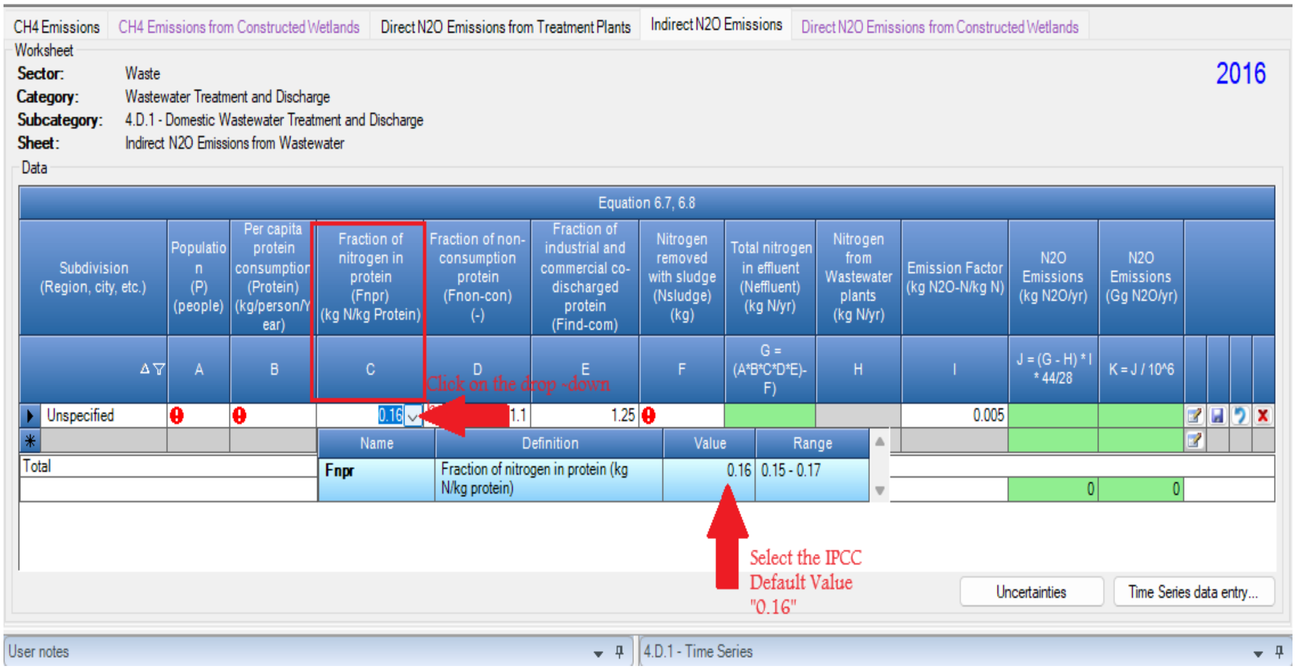
1.22: Enter the population for the selected Inventory year under the "Population (P) (People)" (see illustration below).



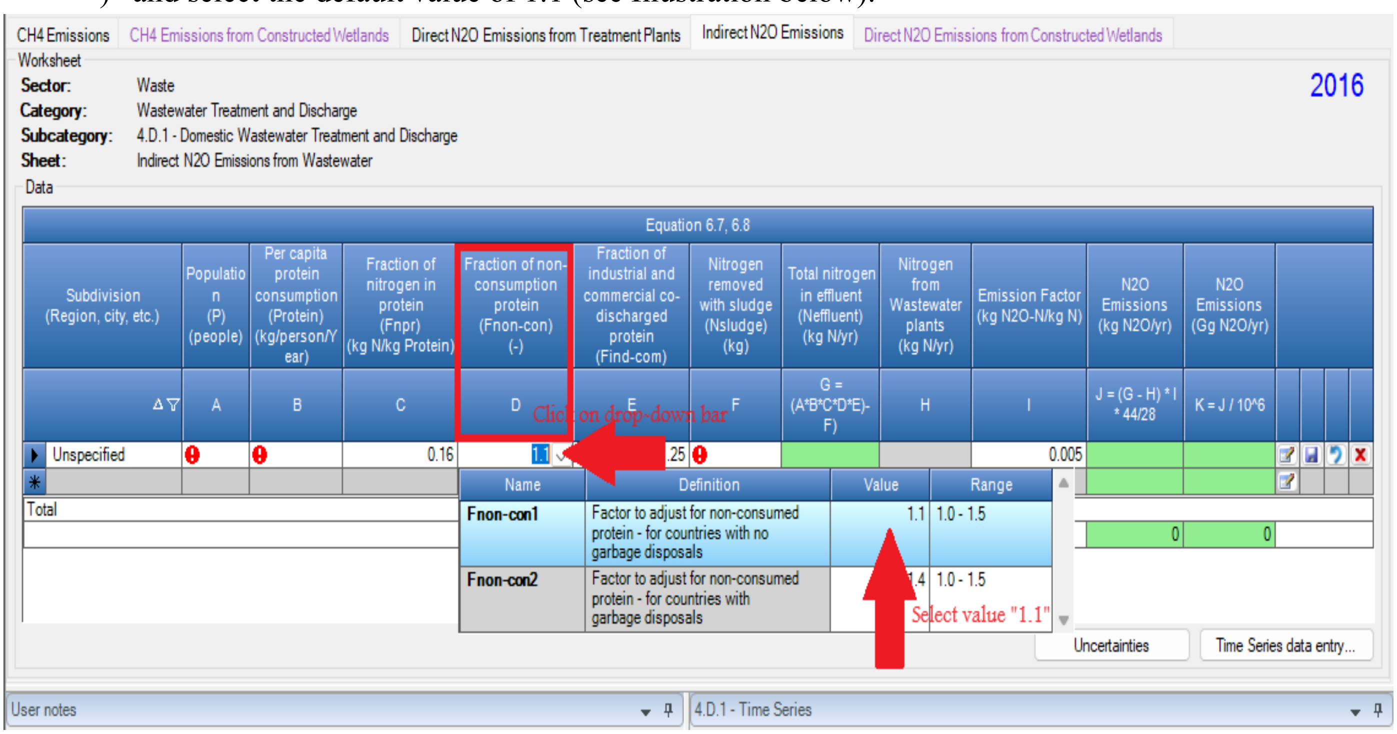
1.23: Enter the value for the "Per capita protein consumption (protein) (Kg/person/year)" (See illustration below).



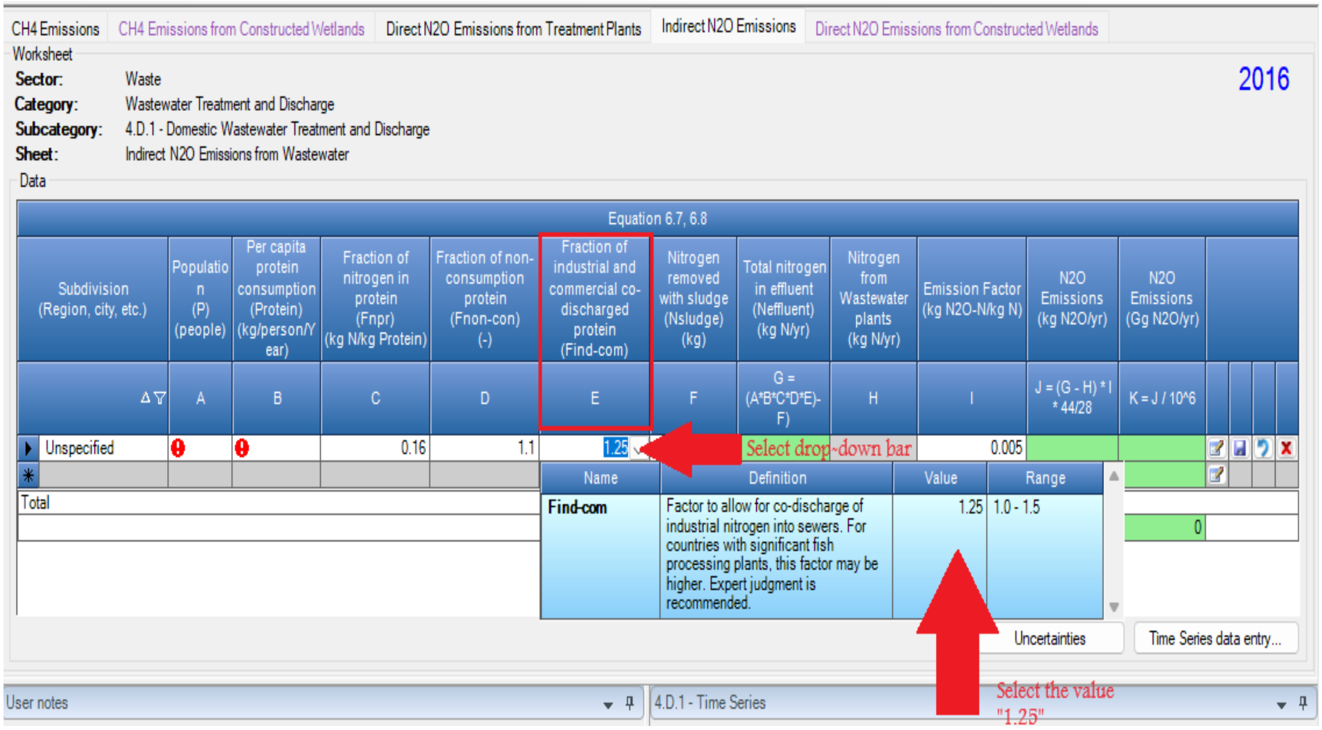
1.24: Click on the drop-down bar under the “Fraction of Nitrogen in Protein (Fnpr) (Kg N/ Kg protein)” and select the default value of 0.16 (see illustration below).



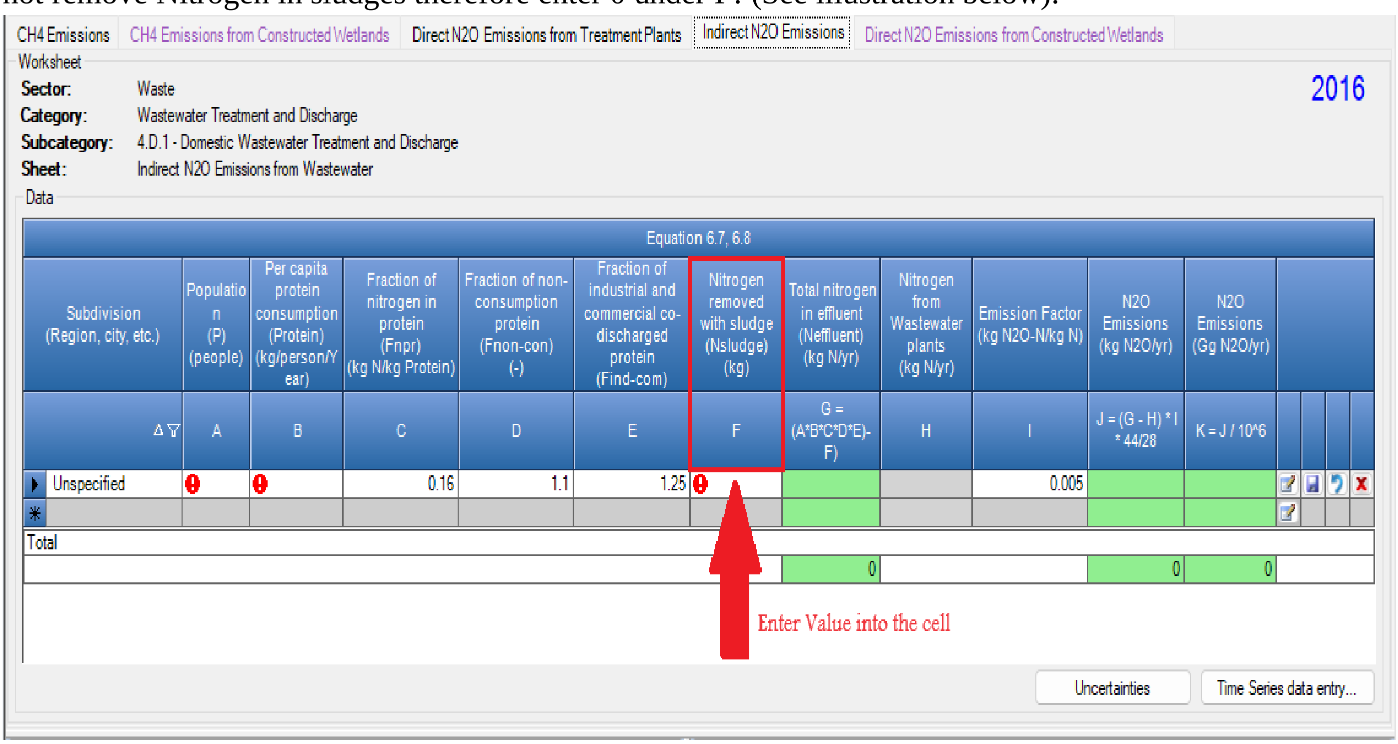
1.25: Click on the drop-down bar under the “Fraction of non-consumption protein (Fnon-con) (-)” and select the default value of 1.1 (see Illustration below).



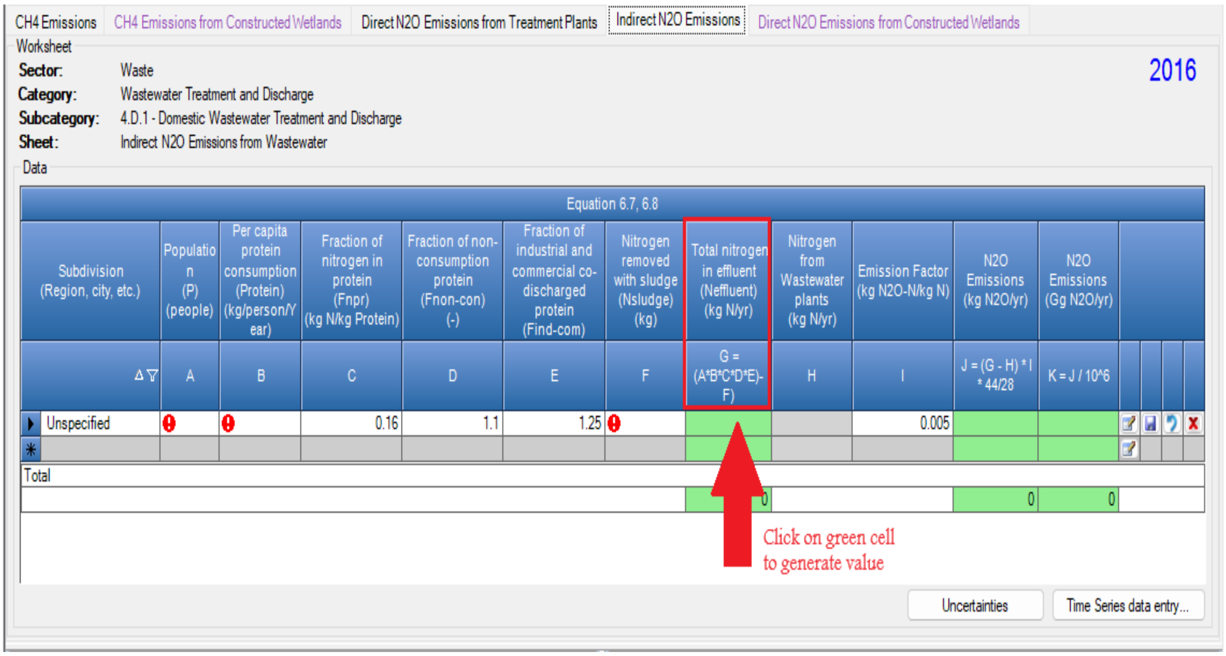
1.26: Click on the tab under the "Fraction of industrial and Commercial co-discharge protein (Find-com) and select the default value of 1.25 (see Illustration below).



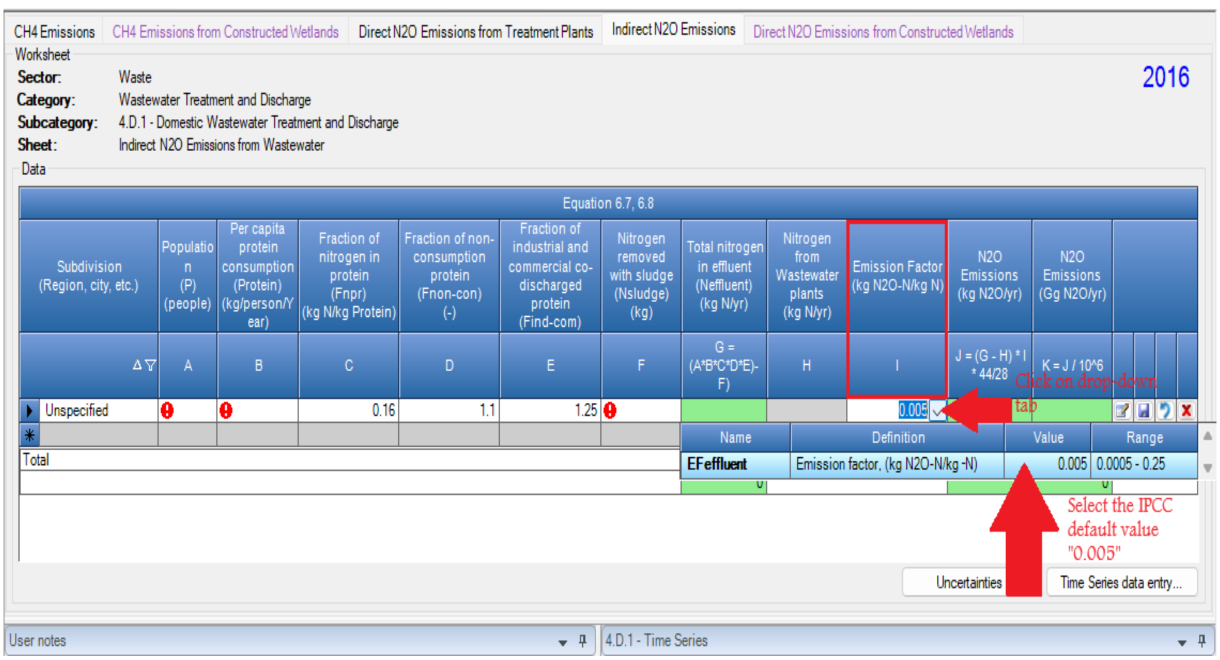
1.27: Enter the value in the cell under the "Nitrogen removed with Sludge (NSludge)(kg)". Vanuatu do not remove Nitrogen in sludges therefore enter 0 under *F*. (See illustration below).



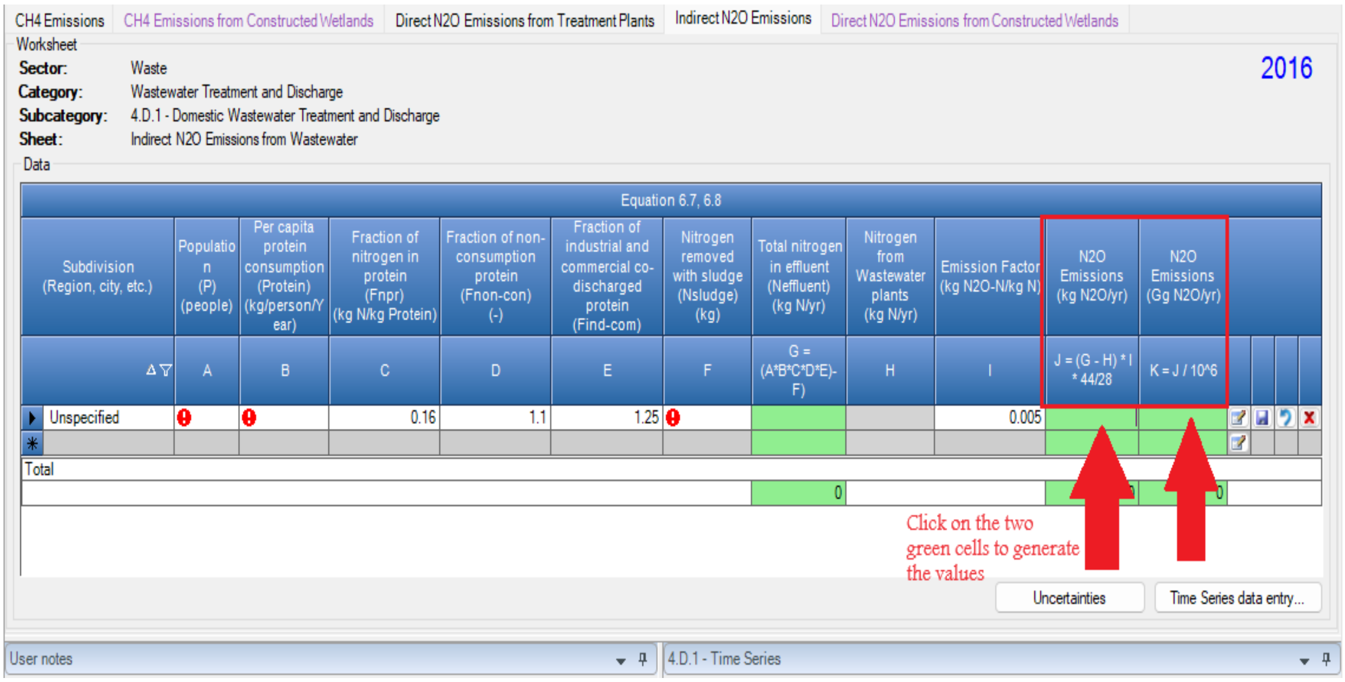
1.28: Click on the green cell under the tab "Total Nitrogen in Effluent (Effluent (Kg N/yr.)" to generate the value (see illustration below).



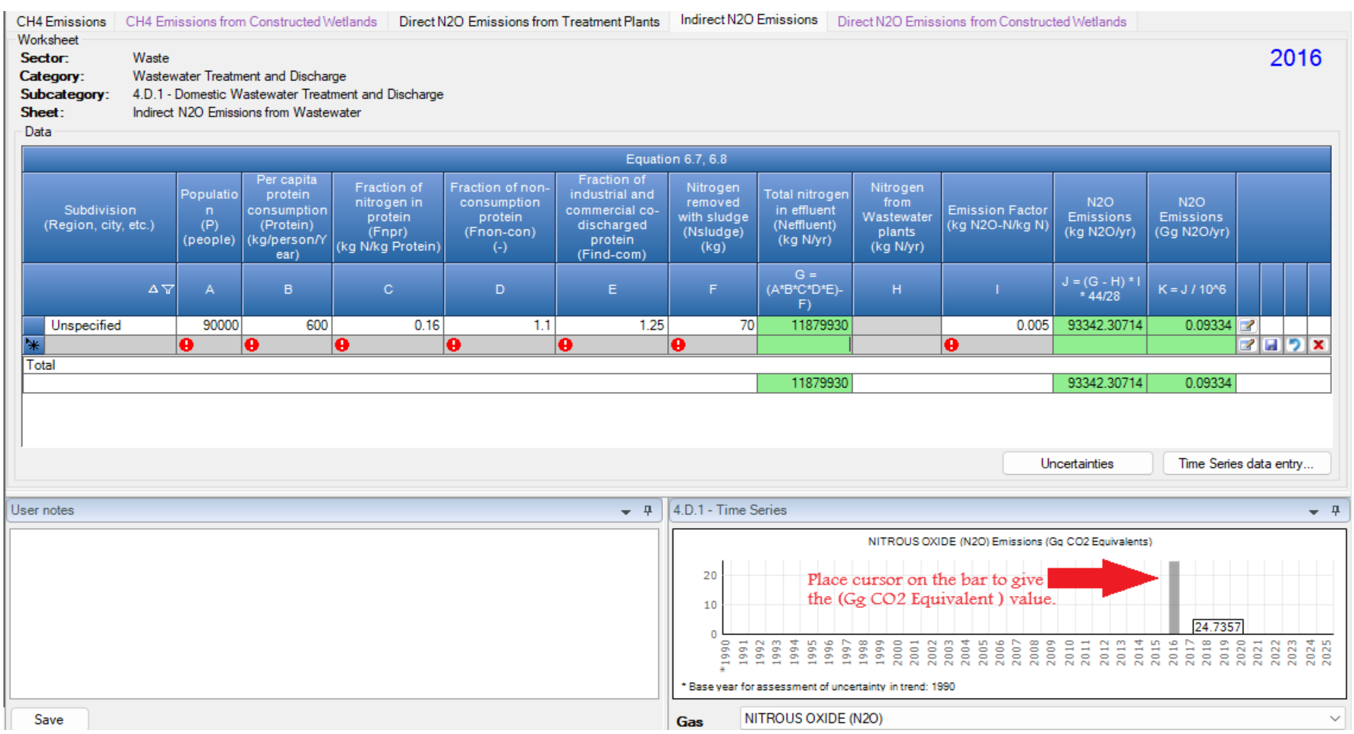
1.29: Click on the drop-down tab under the tab "Emission factor (Kg N_2O – N/Kg N)" and select the default value 0.005 (see Illustration below).



1.30: Click on the green cells under the tabs "N_2O Emissions (Kg N_2O / yr.)" and "(N_2O Emissions (Gg N_2O/ yr.) to generate the Emissions value for N_2O (see illustration below).



1.31: Place the cursor on the bar in the graph below entitled "Nitrous Oxide (N_2O) Emissions (Gg CO_2 Equivalent)" to find the Global Warming Potential (GWP) (See illustration below).



4.3.8. QUALITY CONTROL/ QUALITY CHECK

Table 13: The QC activities and procedures that will be followed

It is indicated in the table below. The Three consultants will handle the QC and Procedures based on the color in the table, Kay – pink, Florencza Abel – Green, and Zacky Bani – Blue.

QUALITY CONTROL CHECK	PROCEDURES	TIME TAKEN TO COMPLETE PROCEDURE (DAYS)	COMMENTS
Check the Assumptions and criteria for the selection of activity data, emissions factor, and other estimation parameters	• Confirm that estimates are reported for all categories and all years from the appropriate base year to the period of the current inventory.		
	• For subcategories, confirm that the entire category is being covered.		
	• Provide a clear definition of 'Other' type categories.		
	• Check that known data gaps that result in incomplete estimates are documented, including a qualitative evaluation of the importance of the estimate concerning total emissions (e.g., subcategories classified as 'not estimated', see Chapter 8, Reporting Guidance and Tables).		
Check for transcriptions Errors in the data input and references	• Confirm that bibliographical data references are properly cited in the internal documentation.		
	• Cross-check a sample of input data from each category (either measurements or parameters used in calculations) for transcription errors.		
Check that emissions and removals are calculated correctly	• Reproduce a set of emissions and removal calculations.		
	• Use a simple approximation method that gives similar results to the original and more complex calculation to ensure that there is no data input error or calculation error.		
Check that parameters and units are correctly	• Check that units are properly labeled in calculation sheets.		

recorded and that appropriate conversion factors are used.	• Check that units are correctly carried through from beginning to end of calculations. • Check that conversion factors are correct. • Check that temporal and spatial adjustment factors are used correctly.		
Check the integrity of database files	• Examine the included intrinsic documentation (see also Box 6.4) to: 1. Confirm that the appropriate data processing steps are correctly represented in the database. 2. Confirm that data relationships are correctly represented in the database. 3. Ensure that data fields are properly labeled and have the correct design specifications. 4. Ensure that adequate documentation of database and model structure and operation are archived.		
Check for consistency in data between categories.	Identify parameters (e.g., activity data, constants) that are common to multiple categories and confirm that there is consistency in the values used for these parameters in the emission/removal calculations.		
Check that the movement of inventory data among processing steps is correct.	• Check that emissions and removal data are correctly aggregated from lower reporting levels to higher reporting levels when preparing summaries. • Check that emissions and removal data are correctly transcribed between different intermediate products.		
Check that uncertainties in emissions and removals are estimated and calculated correctly.	• Check that the qualifications of individuals providing expert judgment for uncertainty estimates are appropriate. • Check that qualifications, assumptions, and expert judgments are recorded. • Check that calculated uncertainties are complete and calculated correctly. • If necessary, duplicate uncertainty calculations on a small sample of the probability distributions used by Monte Carlo analyses (for example, using		

	uncertainty calculations according to Approach 1).		
Check time series consistency.	• Check for temporal consistency in time series input data for each category.		
	• Check for consistency in the algorithm/method used for calculations throughout the time series.		
	• Check methodological and data changes resulting in recalculations.		
	• Check that the effects of mitigation activities have been appropriately reflected in time series calculations.		
Check Completeness	• Confirm that estimates are reported for all categories and all years from the appropriate base year to the period of the current inventory.		
	For subcategories, confirm that the entire category is being covered.		
	• Provide a clear definition of 'Other' type categories.		
	• Check that known data gaps that result in incomplete estimates are documented, including a qualitative evaluation of the importance of the estimate concerning total emissions (e.g., subcategories classified as 'not estimated', see Chapter 8, Reporting Guidance and Tables)		

Trend Check	• Confirm that estimates are reported for all categories and all years from the appropriate base year to the period of the current inventory.		
	• Check the value of implied emission factors (aggregate emissions divided by activity data) across time series.		
	1. Do any year's show outliers that are not explained?		
	2. If they remain static across time series, are changes in emissions or removals being captured?		
	• Check if there are any unusual and unexplained trends noticed for activity data or other parameters across the time series.		

Review of internal documentation and archiving.	• Check that there is detailed internal documentation to support the estimates and enable the reproduction of the emission, removal, and uncertainty estimates.		
	• Check that inventory data, supporting data, and inventory records are archived and stored to facilitate detailed review.		
	• Check that the archive is closed and retained in a secure place following completion of the inventory.		
	• Check the integrity of any data archiving arrangements of outside organizations involved in inventory preparation		

(Table 6.1 GENERAL INVENTORY QC PROCEDURES, Volume 1, 2006 IPCC Guidelines for National Greenhouse Gas Inventories).

4.3.9 TIME SERIES

Tier 1 method was used in the last National Inventory report. The method mainly consisted of the usage of Default value, default activity data, and default parameters [1].

The Director General of the Ministry of Climate Change used office notifications to notify relevant ministries and departments, specified organizations, the public-private sector, and other institutions to collect data for this inventory period. The Department of Climate Change is responsible for maintaining the gathered data, database repository, and archives [4]

Following the 2006 IPCC Guidelines, Vol. 5, figure 6.2, the Tier 1 Method Approach specifically will be used for this inventory. Estimated Emissions will be calculated using historical data and present up-to-date data.

To collect information, the Project Coordinator and the Consultants will notify Offices relevant to ministries and stakeholders such as the:

- Department of Environmental Protection and Conservation (DEPC)
- Department of Water Resources (DWR)
- Port Vila City Council (PVCC)
- Environment Unit, Public Health at the Ministry of Health
- Department of Climate Change (DOCC)
- UNELCO Engie
- Public Works Department (PWD)

The channels for requesting activity data meetings are the Electronic Single Window, emails, dialogues, and interviews. Consultants may ask the Prime Minister's Office for a Confidential Agreement or Right to Information (RTI) in specific situations where data is unavailable.

Table 14: Annual emissions of CH_4 and N_2O from the base year of 1994 to 2023, including the emissions values, emission factors, and the methods used to estimate these emissions.

Year	CH_4 Emission (Gg)	Emission Factor (Kg N_2O - N/Kg N)	N_2O Emission (Gg)	Weighted Emission Factor (Kg CH_4 / Kg BOD)	Total CO_2e Emission (Gg)	Method
1994	NE	0.05	NE	0.6	NE	TIER 1
1995	NE	0.05	NE	0.6	NE	TIER 1
1996	NE	0.05	NE	0.6	NE	TIER 1
1997	NE	0.05	NE	0.6	NE	TIER 1
1998	NE	0.05	NE	0.6	NE	TIER 1

[4] *The Republic of Vanuatu Third National Communication to the the United Nations Framework Convention on Climate Change | Vanuatu Environment Data Portal* (2020)

1999	NE	0.05	NE	0.6	NE	TIER 1
2000	NE	0.05	NE	0.6	NE	TIER 1
2001	NE	0.05	NE	0.6	NE	TIER 1
2002	NE	0.05	NE	0.6	NE	TIER 1
2003	NE	0.05	NE	0.6	NE	TIER 1
2004	NE	0.05	NE	0.6	NE	TIER 1
2005	NE	0.05	NE	0.6	NE	TIER 1
2006	NE	0.05	NE	0.6	NE	TIER 1
2007	0.157	0.05	0.0102	0.6	7.11	TIER 1
2008	0.157	0.05	0.0105	0.6	7.174	TIER 1
2009	0.157	0.05	0.0107	0.6	7.239	TIER 1
2010	0.157	0.05	0.011	0.6	7.304	TIER 1
2011	0.157	0.05	0.0112	0.6	7.371	TIER 1
2012	0.157	0.05	0.0115	0.6	7.439	TIER 1
2013	0.157	0.05	0.0117	0.6	7.509	TIER 1
2014	0.157	0.05	0.012	0.6	7.581	TIER 1
2015	0.157	0.05	0.0123	0.6	7.654	TIER 1
2016	NE	0.05	NE	0.6	NE	TIER 1
2017	NE	0.05	NE	0.6	NE	TIER 1
2018	NE	0.05	NE	0.6	NE	TIER 1
2019	NE	0.05	NE	0.6	NE	TIER 1
2020	NE	0.05	NE	0.6	NE	TIER 1
2021	NE	0.05	NE	0.6	NE	TIER 1
2022	NE	0.05	NE	0.6	NE	TIER 1
2023	NE	0.05	NE	0.6	NE	TIER 1

Where:

NE: Not estimated

4.3.10 UNCERTAINTY

The list of the uncertainty below was extracted from the (2006 IPCC guidelines, Vol.5, pg. 16)

Uncertainty Within the Ch_4 Default Parameters

Chapter 3, Uncertainties, in Volume 1 provides advice on quantifying uncertainties in practice. It includes guidance on eliciting and using expert judgments that, combined with empirical data can provide overall uncertainty estimates. Table 6.7 provides default uncertainty ranges for emission factor and activity data of domestic wastewater. The following parameters are believed to be very uncertain (2006 IPCC guidelines, Vol.5, pg. 16):

• The degrees to which wastewater in developing countries is treated in latrines, septic tanks, or removed by sewer, for urban high, urban low-income groups, and rural populations (Ti, j) (2006 IPCC guidelines, Vol.5, pg. 16).

• The fraction of sewers that are 'open', as well as the degree to which open sewers in developing countries are anaerobic and will emit CH_4. This will depend on retention time, temperature, and other factors including the presence of a facultative layer and possibly toxic components to anaerobic bacteria (e.g., certain industrial wastewater discharges) (2006 IPCC guidelines, Vol.5, pg. 16).

• The amount of industrial TOW that is discharged into open or closed domestic sewers for each country is very difficult to quantify (2006 IPCC guidelines, Vol.5, pg. 16).

Table 4.15 illustrates the default uncertainty ranges for domestic wastewater this includes the Parameter, Emission Factor, Activity Data, and their Uncertainty.

Table 15: Default uncertainty ranges for Domestic Wastewater

Parameter	Uncertainty Range
Emission Factor	
Maximum CH_4 producing capacity (B_o)	± 30%
Fraction treated anaerobically (MCF)	The MCF is technology dependent. See Table 6.3. Thus, the uncertainty range is also technology dependent. The uncertainty range should be determined by expert judgement, bearing in mind that MCF is a fraction and must be between 0 and 1. Suggested ranges are provided below. Untreated systems and latrines, ± 50% Lagoons, poorly managed treatment plants± 30% Centralized well managed plant, digester, reactor, ± 10%
Activity Data	
Human population (P)	± 5%
BOD per person	± 30%
Fraction of population income group (U)	Good data on urbanization are available, however, the distinction between urban high income and urban low income may have to be based on expert judgment. ± 15%
Degree of utilization of treatment/ discharge pathway or system for each income group ($T_{i,j}$)	Can be as low as ± 3% for countries that have good records and only one or two systems. Can be ± 50% for an individual method/pathway. Verify that total $T_{i,j}$ = 100%
Correction factor for additional industrial BOD discharged into sewers (I)	For uncollected, the uncertainty is zero %. For collected the uncertainty is ± 20%
Source*:* Judgement by Expert Group (Authors of this section).	

(2006 IPCC Guidelines, Vol.5, pg. 16, Table 6.7)

Uncertainty Within the N_2O Default Parameters

The IPCC default factors contain a significant level of uncertainty. Very little effort has been made to improve the Default factor values in the category as of yet (2006 IPCC guideline). Table 6.11 (See 2006 IPCC Guidelines, Vol.5, Table 6.11) below includes uncertainty ranges based on expert judgment (2006 IPCC Guidelines, Vol.5, pg26).

Table 16: N_2O Methodology Default Emission factor and Activity data

	Definition	Default Value	Range
Emission Factor			
$EF_{EFFLUENT}$	Emission factor, (kg N_2O-N/kg –N)	0.005	0.0005 – 0.25
EF_{PLANTS}	Emission factor, (g N_2O/person/year)	3.2	2 – 8
Activity Data			
P	Number of people in country	Country-specific	± 10 %
Protein	Annual per capita protein consumption	Country-specific	± 10 %
FNPR	Fraction of nitrogen in protein (kg N/kg protein)	0.16	0.15 – 0.17
T_{plant}	Degree of utilization of large WWT plants	Country-specific	± 20 %
$F_{NON-CON}$	Factor to adjust for non-consumed protein	1.1 for countries with no garbage disposals, 1.4 for countries with garbage disposals	1.0 – 1.5
$F_{IND-COM}$	Factor to allow for co-discharge of industrial nitrogen into sewers. For countries with significant fish processing plants, this factor may be higher. Expert judgment is recommended.	1.25	1.0 – 1.5

(2006, IPCC Guidelines, Vol.5, Pg 27, Table 6.11)

4.4. IMPROVEMENT PLAN

4.4.1 VANUATU'S CURRENT INVENTORY PROCESS

The national Greenhouse Gas (GHG) inventory of anthropogenic (human- caused) GHG emissions and removals were estimated for the Republic of Vanuatu under the first, second, and third (draft) National Communications for 1994, 2000, and 2015 (Srikanth Subbarao, Subbarao Consulting Services, Naveen Pawar, Subbarao Consulting Services, 2020). However, the waste sector of Vanuatu comprises mainly solid waste and wastewater (Ministry of Climate Change, 2020). For first National Communications 1994, emissions for the waste sector were not estimated due to lack of resources. However, for the second and third National communications, emissions were estimated from the waste sector for the national greenhouse gas inventory 2007-2015.

Table 3.4.1.a Different Categories of Waste that is Relevant to Vanuatu. [5]

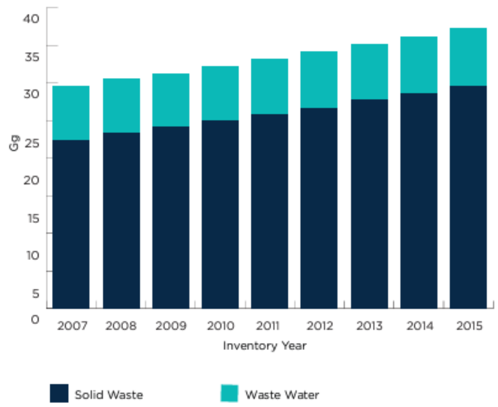
Categories	Remarks
4 - Waste	
4.A - Solid Waste Disposal	Estimated
4.B - Biological Treatment of Solid Waste	Not Occurring
4.C - Incineration and Open Burning of Waste	Not Estimated
4.D - Wastewater Treatment and Discharge	Estimated
4.E - Other (please specify)	Not Occurring

Source: Vanuatu's Third National Inventory (2020).

As mentioned above, this sector focuses mainly on two key categories, which is, solid waste management and disposal (excluding biological waste), and domestic and commercial wastewater handling (no industrial waste water generation). Therefore, emissions estimated is mostly methane (CH_4) and Nitrous Oxide (N_2O) from these categories.

[5] https://unfccc.int/sites/default/files/resource/Vanuatu%20Third%20National%20Communication%20Report.pdf

Figure 3.4.1 Waste Sector Emissions Gg CO2e: 2007-2015[6]



This is a representation of methane emissions for solid waste & wastewater. The graph shows an increase in methane emissions from 2007-2015.

Source: Vanuatu's Third National Inventory (2020).

4.4.2 AREAS IDENTIFIED FOR IMPROVEMENT AND IDENTIFIED GAPS

The improvement gap will be the waste sector data: The waste (Solid waste and waste water) activity data monitoring and reporting has been initiated in urban Centre's, therefore higher tier method (Tier 2) will be applied for the future inventory period (Ministry of Climate Change, 2020). There is also potential development of open burning estimates.

4.4.3: PROPOSED IMPROVEMENT ACTIONS

These are the outlined improvement actions the consultant needs to take into consideration while conducting the GHG inventory. This table shows detailed information on the data sources, how to access it, who is responsible and the relevant time it needs to collect data sets, thus, will result in accurate GHG inventory.

Department/ Organization	**Roles and Responsibility**	**Dates**	**Relevant Governing Arrangement**	**Contact Person**	**Comments**
Department of Water Resources (DWR)	To provide information on measurements and analysis of BOD, COD, and activity data on Domestic	First week of April– First week of May every year	A Memorandum of understanding or Right to Information (RTI) can be provided between DWR and DOCC	Department of water resources Tel: (678)22423/33435	For significant information and data collection, DOCC needs to send a prompt letter to DWR two

[6] https://unfccc.int/sites/default/files/resource/Vanuatu%20Third%20National%20Communication%20Report.pdf

	wastewater operations (collection and disposal of waste) in rural areas in Vanuatu.			Email: esteitoka@vanuatu.gov.vu	months prior. A follow-up email or call is crucial as well.
Department of Environmental Protection & Conservation (DEPC)	To provide relevant information on activity data and key parameters on SWD on land.	First week of April– First week of May every year	A Memorandum of understanding or Right to Information (RTI) can be provided between DEPC and DOCC	Environment Unit Name: Ionie Bolenga *(Principal Officer on Waste Management and Pollution Control)* Email: ibolenga@vanuatu.gov.vu Name: Annabelle Alilee (Pollution Control Officer) Email: aalilee@vanuatu.gov.vu	For significant information and data collection, DOCC needs to send a prompt letter to DEPC two months prior. A follow-up email or call is crucial as well.
Public Works Department (PWD)	To provide relevant information and data on the operation (collection and disposal) of domestic wastewater in Urban and sub-urban areas.	First week of April– First week of May every year	A Memorandum of understanding or Right to Information (RTI) can be provided between PWD and DOCC	Public Works Department Email: pwdheadoffice@vanuatu.gov.vu Tel: 33460 or 22790	For significant information and data collection, DOCC needs to send a prompt letter to PWD two months prior. A follow-up email or call is crucial as well.
UNELCO Engie	To provide relevant information and data on the operation	First week of April– First week of May every year	A Memorandum of understanding or Right to Information (RTI) can be provided	UNELCO ENGIE Email: unelco@engie.com	For significant information and data collection, DOCC needs to send a prompt

	(collection and disposal) of domestic wastewater in Urban and sub-urban areas.		between UNELCO and DOCC	Tel: 26000	letter to UNELCO two months prior. A follow-up email or call is crucial as well.
Port Vila City Council (PVCC)	To provide relevant information and data on the operation of SWD on land and domestic wastewater management within its jurisdiction.	First week of April– First week of May every year	A Memorandum of understanding or Right to Information (RTI) can be provided between PVCC and DOCC		For significant information and data collection, DOCC needs to send a prompt letter to PVCC two months prior. A follow-up email or call is crucial as well.
Department of Climate Change (DOCC)	DOCC is responsible to send a formal letter requesting relevant data and information on SWD on land and Domestic Wastewater to the Environmental Protection and Conservation, The Department of Water Resources, Public Works Department, UNELCO, Port Vila City Council, and the Environment Unit under the Ministry of Climate Change.	February – March every year	Provide a Memorandum of understanding or Right to Information (RTI) to the Environmental Protection and Conservation, The Department of Water Resources, Public Works Department, UNELCO, Port Vila City Council, and the Environment Unit under the Ministry of Climate Change	Name: Nelson Kalo Director of Climate Change Email: nekalo@vanuatu.gov.vu	DOCC is responsible for doing a follow-up to the departments or organization for the required data to be delivered upon schedule.

4.5 REFERENCES

Goodwin, J., Woodfield, M., Ibnoaf, M., Koch, M., & Yan, H. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 2: Approaches to Data Collection.* Institute for Global Environmental Strategies (IGES).

Ministry of Climate Change. (2020). *The Republic of Vanuatu, Third National Communication.* Port Vila.

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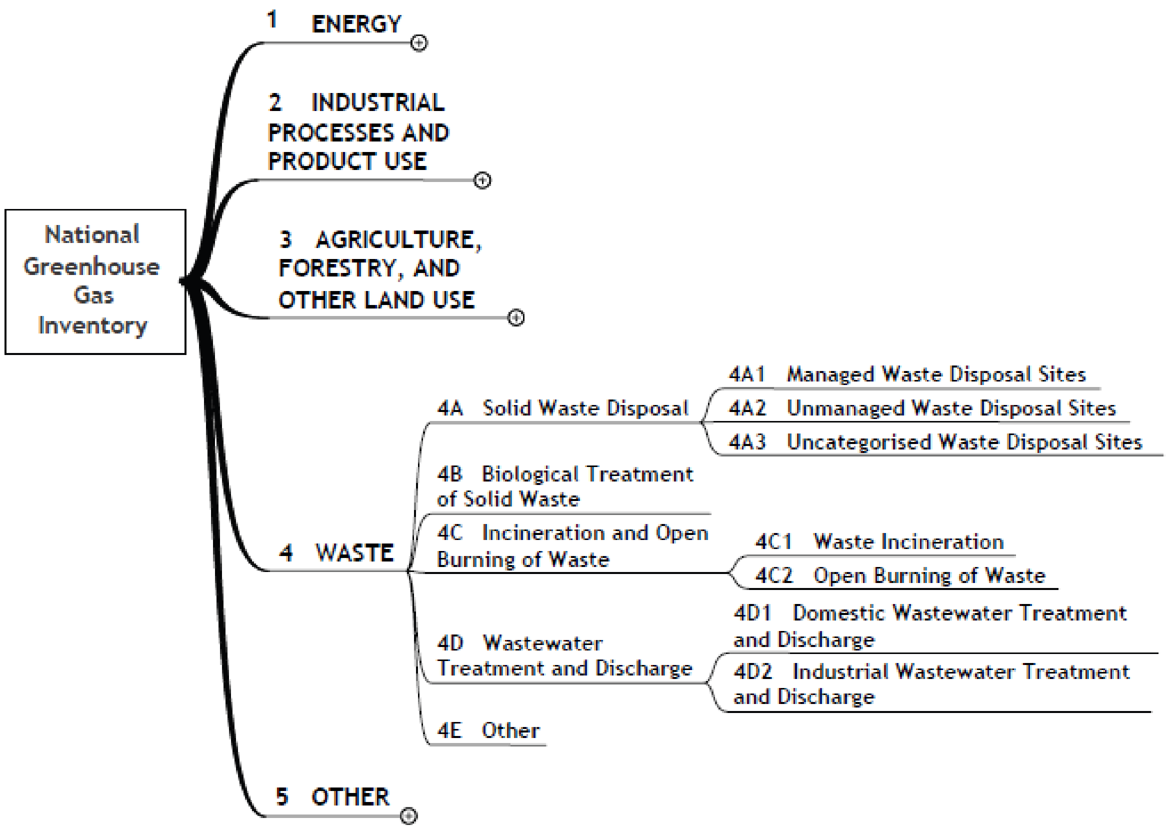
MOCC. (2021). *The Republic of Vanuatu First Biennal Update Report, UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC).* Port Vila: The Ministry of Climate Change Adaptation, Meteorology and Geo- Hazards, Energy, Environment and National Disaster Management Government of Vanuatu.

Pipatti, R., & Svardal, P. (2006). *SOLID WASTE DISPOSAL.* 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

4.6 ANNEX

Figure A4.1 Structure of Waste Sector



(See 2006 IPCC Guidelines, Volume 5 Chapter 1, Introduction, Figure 1.1)

TABLE A4.1: ESTIMATED BOD_5 VALUES IN DOMESTIC WASTEWATER FOR SELECTED REGIONS AND COUNTRIES

ESTIMATED BOD_5 VALUES IN DOMESTIC WASTEWATER FOR SELECTED REGIONS AND COUNTRIES

Country/Region	BOD_5 (g/person/day)	Range	Reference
Africa	37	35 – 45	1
Egypt	34	27 – 41	1
Asia, Middle East, Latin America	40	35 – 45	1
India	34	27 – 41	1
West Bank and Gaza Strip (Palestine)	50	32 – 68	1
Japan	42	40 – 45	1
Brazil	50	45 – 55	2
Canada, Europe, Russia, Oceania	60	50 – 70	1
Denmark	62	55 – 68	1
Germany	62	55 – 68	1
Greece	57	55 – 60	1
Italy	60	49 – 60	3
Sweden	75	68 – 82	1
Turkey	38	27 – 50	1
United States	85	50 – 120	4

Note: These values are based on an assessment of the literature. Please use national values, if available.

Reference:

1. Doorn and Liles (1999).
2. Feachem *et al*. (1983).
3. Masotti (1996).
4. Metcalf and Eddy (2003).

(See 2006 IPCC Guidelines, Volume 5 Chapter 6, Wastewater treatment and Discharge, Table 6.4)

TABLE A4.2: DEFAULT MAXIMUM CH_4 PRODUCING CAPACITY (B_O) FOR DOMESTIC WASTEWATER

DEFAULT MAXIMUM CH_4 PRODUCING CAPACITY (B_o) FOR DOMESTIC WASTEWATER
0.6 kg CH_4/kg BOD
0.25 kg CH_4/kg COD
Based on expert judgment by lead authors and on Doorn *et al*., (1997)

(See 2006 IPCC Guidelines, Volume 5 Chapter 6, Wastewater treatment and Discharge, Table 6.2)

TABLE A4.3: DEFAULT MCF VALUES FOR DOMESTIC WASTEWATER

DEFAULT MCF VALUES FOR DOMESTIC WASTEWATER			
Type of treatment and discharge pathway or system	**Comments**	**MCF [1]**	**Range**
Untreated system			
Sea, river and lake discharge	Rivers with high organics loadings can turn anaerobic.	0.1	0 – 0.2
Stagnant sewer	Open and warm	0.5	0.4 – 0.8
Flowing sewer (open or closed)	Fast moving, clean. (Insignificant amounts of CH_4 from pump stations, etc.)	0	0
Treated system			
Centralized, aerobic treatment plant	Must be well managed. Some CH_4 can be emitted from settling basins and other pockets.	0	0 – 0.1
Centralized, aerobic treatment plant	Not well managed. Overloaded.	0.3	0.2 – 0.4
Anaerobic digester for sludge	CH_4 recovery is not considered here.	0.8	0.8 – 1.0

Anaerobic reactor	CH_4 recovery is not considered here.	0.8	0.8 – 1.0
Anaerobic shallow lagoon	Depth less than 2 meters, use expert judgment.	0.2	0 – 0.3
Anaerobic deep lagoon	Depth more than 2 meters	0.8	0.8 – 1.0
Septic system	Half of BOD settles in anaerobic tank.	0.5	0.5
Latrine	Dry climate, ground water table lower than latrine, small family (3-5 persons)	0.1	0.05 – 0.15
Latrine	Dry climate, ground water table lower than latrine, communal (many users)	0.5	0.4 – 0.6
Latrine	Wet climate/flush water use, ground water table higher than latrine	0.7	0.7 – 1.0
Latrine	Regular sediment removal for fertilizer	0.1	0.1
1 Based on expert judgment by lead authors of this section.			

(See 2006 IPCC Guideline, Vol.5, Chapt.6 Wastewater, Section 6.2.2.2, Table 6.3)

TABLE A4.4: N_2O METHODOLOGY DEFAULT DATA

N_2O METHODOLOGY DEFAULT DATA			
	Definition	**Default Value**	**Range**
Emission Factor			
$EF_{EFFLUENT}$	Emission factor, (kg N_2O-N/kg –N)	0.005	0.0005 – 0.25
EF_{PLANTS}	Emission factor, (g N_2O/person/year)	3.2	2 – 8
Activity Data			
P	Number of people in country	Country-specific	± 10 %
Protein	Annual per capita protein consumption	Country-specific	± 10 %
F_{NPR}	Fraction of nitrogen in protein (kg N/kg protein)	0.16	0.15 – 0.17
T_{plant}	Degree of utilization of large WWT plants	Country-specific	± 20 %

$F_{NON-CON}$	Factor to adjust for non-consumed protein	1.1 for countries with no garbage disposals, 1.4 for countries with garbage disposals	1.0 – 1.5
$F_{IND-COM}$	Factor to allow for co-discharge of industrial nitrogen into sewers. For countries with significant fish processing plants, this factor may be higher. Expert judgment is recommended.	1.25	1.0 – 1.5

(See 2006 IPCC Guidelines, Volume 5 Chapter 6, Wastewater treatment and Discharge, Table 6.11)

TABLE A4.5: RECOMMENDED DEFAULT HALF-LIFE (t1/2) VALUES (YR) UNDER TIER 1

Type of Waste		Climate Zone*							
		Boreal and Temperate (MAT ≤ 20°C)				Tropical[1] (MAT > 20°C)			
		Dry (MAP/PET < 1)		Wet (MAP/PET > 1)		Dry (MAP < 1000 mm)		Moist and Wet (MAP ≥ 1000 mm)	
		Default	Range[2]	Default	Range[2]	Default	Range[2]	Default	Range[2]
Slowly degrading waste	**Paper/textiles waste**	17	14[3,5] – 23[3,4]	12	10 – 14[3,5]	15	12 – 17	10	8 – 12
	Wood/ straw waste	35	23[3,4] – 69[6,7]	23	17 – 35	28	17 – 35	20	14 – 23
Moderately degrading waste	**Other (non – food) organic putrescible/ Garden and park waste**	14	12 – 17	7	6 – 9[8]	11	9 – 14	4	3 – 5
Rapidly degrading waste	**Food waste/Sewage sludge**	12	9 – 14	4[4]	3[3,4] – 6[9]	8	6 – 10	2	1[10] – 4
Bulk Waste		14	12 – 17	7	6 – 9[8]	11	9 – 14	4	3 – 5[11]

(See 2006 IPCC Guidelines, Volume 5 Chapter 3, Solid Waste Disposal, Table 3.4)