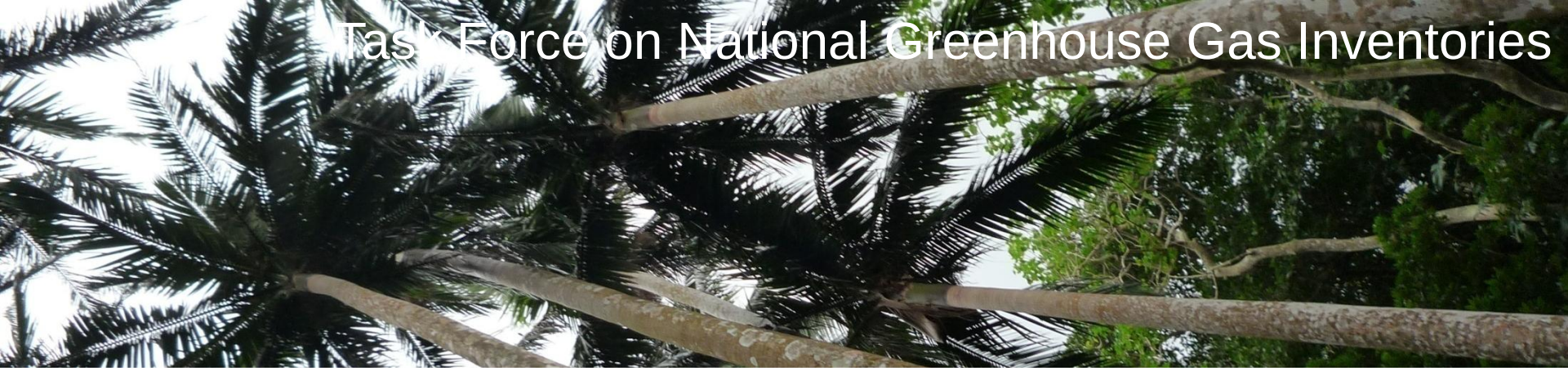


2006 IPCC Guidelines for National Greenhouse Gas Inventories: Waste Sector

Regional African Workshops on REDD+ National Forest Monitoring Systems and Greenhouse Gas National Inventory Systems

25-27 February 2014

Livingstone, Zambia

Baasansuren Jamsranjav

Technical Support Unit, IPCC TFI

WMO UNEP

INTERGOVERNMENTAL PANEL ON climate change

Waste Sector

- Volume 5 (Waste) gives methodological guidance for estimation of CO_2, CH_4 and N_2O emissions from following categories:
  - Solid waste disposal (4A)
  - Biological treatment of solid waste (4B)
  - Incineration and open burning of waste (4C)
  - Wastewater treatment and discharge (4D)
- Typically, CH_4 emissions from solid waste disposal sites (SWDS) are the largest source in the Waste sector
- Biogenic CO_2 emissions are not included in the Waste sector
- All greenhouse gas (GHG) emissions from waste-to-energy should be estimated and reported under the Energy sector

Major Developments in the 2006 IPCC Guidelines

- Improved accuracy
  - Updated methods and improved default values
  - The previous Tier 1 method is replaced by a first order decay (FOD) method including a simple spreadsheet model (IPCC Waste Model)

  http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html

- More complete:
  - Guidance is given on more sources
    - Biological treatment of solid waste
    - Open burning of waste
  - Inclusion of methods to estimate N_2O emissions
    - Discharge of wastewater into waterways
    - Advanced wastewater treatment plants

Solid Waste Disposal on Land

- CH_4 is generated as a result of degradation of organic material under anaerobic conditions
- Methodology for estimating CH_4 emissions from SWDS is based on the FOD method
  - Degradable organic component in waste at landfills decays slowly throughout a few decades during which significant amount of CH_4 and CO_2 are formed (some N_2O, NMVOCs, NO_x and CO)
  - Amount of product is proportional to the amount of reactive material in waste (mass of degradable organic carbon (DOC) decomposable under anaerobic conditions)
  - A simple spreadsheet model to assist countries in using the FOD method
- FOD method requires data for historical disposals of waste
  - The 2006 Guidelines provide guidance on how to estimate historical waste disposal data

Solid Waste Disposal on Land

- CH_4 emissions in year *T* from SWDS (Gg)

$$CH_4 Emissions = \left[\sum_x CH_4 generated_{x,T} - R_T \right] * (1 - OX_T)$$

T : inventory year

X : waste category or type/material

R_T : recovered CH_4 in year *T*, Gg

OX_T : oxidation factor in year *T*, fraction

- CH_4 generated is calculated on the basis of Decomposable Degradable Organic Carbon (DDOCm)
  - DDOCm is part of the organic carbon that will degrade under the anaerobic conditions in SWDS which is a key input to FOD method

Biological Treatment of Solid Waste

- Composting and anaerobic digestion of organic waste (food waste, garden and park waste etc.) produce GHGs
- Chapter 4 provides guidance for estimation of CH_4 and N_2O emissions from composting and anaerobic digestion of organic waste
  - Collect data on the amount and type of solid waste which is treated biologically. The default data should be used only when country-specific data are not available
  - Estimate the CH_4 and N_2O emissions from biological treatment of solid waste. Use default or country-specific emission factors in accordance with the guidance provided
  - Subtract the amount of recovered gas from the amount of CH_4 generated to estimate net annual CH_4 emissions, when CH_4 emissions from anaerobic digestion are recovered.

Biological Treatment of Solid waste: CH_4 Emissions

- Default method for estimation of CH_4 emissions:

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

CH_4 Emissions: total CH_4 emissions in inventory year, Gg CH_4
M_i : mass of organic waste treated by biological treatment type *i*, Gg
EF_i : emission factor for treatment *i*, g CH_4/kg waste treated
i : composting or anaerobic digestion
R : total amount of CH_4 recovered in inventory year, Gg CH_4. **If the recovered gas is flared, the emissions should be reported in Waste Sector**

Biological Treatment of Solid Waste: N_2O Emissions

- Default method for estimation of N_2O emissions:

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

N_2O Emissions: total N_2O emissions in inventory year, Gg N_2O

M_i : mass of organic waste treated by biological treatment type *i*, Gg

EF_i : emission factor for treatment *i*, g N_2O/kg waste treated

i : composting or anaerobic digestion

Incineration and Open Burning of Waste

- Guidance for estimation of GHG emissions (CO_2, CH_4 and N_2O) in Chapter 5
  - Where possible, default values for AD, EFs and other parameters are provided
- Amount of fossil carbon is the most important factor determining the CO_2 emissions as only CO_2 emissions of fossil origin (e.g., plastics, certain textiles, rubber, liquid solvents, and waste oil) should be included in emission estimates
- CH_4 emissions result from incomplete combustion of waste and can be affected by temperature, residence time, and air to waste ratio
- N_2O emissions are mainly determined by technology, combustion temperature (emitted at relatively low combustion temperatures 500-950^oC) and waste composition
- GHG emissions from incineration with energy recovery are reported in the Energy Sector

Incineration and Open Burning of Waste: CO_2 Emissions

- Based on the total amount of waste combusted:

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

CO_2 Emissions: CO_2 emissions in inventory year, Gg/yr

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

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

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

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

OF_i : oxidation factor, (fraction)

44/12 : conversion factor from C to CO_2

i : type of waste incinerated/open-burned such as MSW, industrial solid waste (ISW), sewage sludge, hazardous waste, clinical waste, etc.

Incineration and Open Burning of Waste: CO_2 Emissions

- For municipal solid waste:

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

CO_2 Emissions: CO_2 emissions in inventory year, Gg/yr

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

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

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

CF_j : fraction of carbon in the dry matter (i.e., carbon content) of component ***j***

FCF_j : fraction of fossil carbon in the total carbon of component ***j***

OF_j : oxidation factor, (fraction)

44/12 : conversion factor from C to CO_2

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

Incineration and Open Burning of Waste: CH_4 Emissions

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

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

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

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

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

i : category or type of waste incinerated/open-burned (MSW, ISW, hazardous waste, clinical waste, sewage sludge, etc.)

- The amount and composition of waste should be consistent with the activity data used for estimating CO_2 and N_2O emissions from incineration/open burning

Incineration and Open Burning of Waste: N_2O Emissions

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

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

IW_i : amount of incinerated/open-burned waste of type *i* , *Gg/yr*

EF_i : N_2O emission factor (kg N_2O/Gg of waste) for waste of type *i*

10^{-6} : conversion from kilogram to gigagram

i : category or type of waste incinerated/open-burned (MSW, ISW, hazardous waste, clinical waste, sewage sludge, etc.)

Amount of Waste Open-burned

- Statistics may not be available. Where the data on waste amount are not available, total amount of MSW open-burned can be estimated

$$MSW_B = P \bullet P_{frac} \bullet MSW_P \bullet B_{frac} \bullet 365 \bullet 10^{-6}$$

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

P : population (capita)

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

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

B_{frac} : fraction of the waste amount that is burned relative to the total amount of waste treated

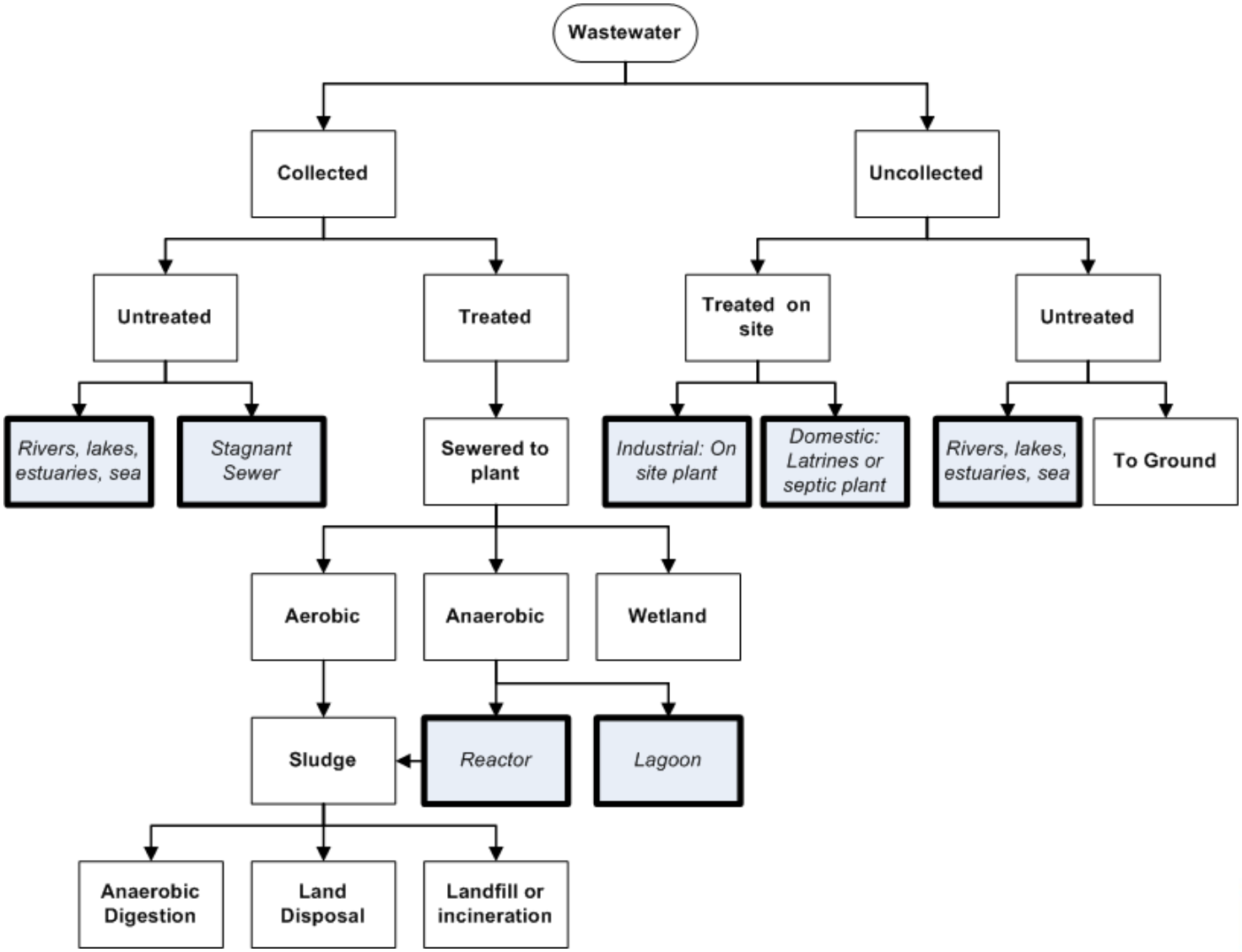
365 : number of days by year

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

Wastewater Treatment and Discharge

- Wastewater (domestic, commercial and industrial) may be treated on site (uncollected), sewered to a centralized plant (collected) or disposed untreated
- Treatment and disposal of wastewater produce GHGs such as CO_2, CH_4 and N_2O
  - CO_2 is of biogenic origin and not considered in the emission estimates
- CH_4 production depends primarily on the amount of degradable organic material in the wastewater, the temperature and the type of treatment system
- CH_4 generated can be recovered and combusted in a flare or energy device
  - The flared or recovered for energy use should be subtracted from total emissions
  - Where CH_4 is recovered for energy use, then the resulting GHG emissions should be reported under Energy Sector
- The N_2O emissions are associated with the degradation of nitrogen components in the wastewater (e.g., urea, nitrate and protein)
  - The N_2O emissions can occur as direct emissions from treatment plants or from indirect emissions from wastewater after disposal of effluent into waterways, lakes or the sea

Wastewater Treatment Systems and Discharge Pathways



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Domestic Wastewater Treatment: CH_4 Emissions

- Total CH_4 emissions from domestic wastewater:

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

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

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

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

U_i: fraction of population in income group i in inventory year

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

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

j : each treatment/discharge pathway or system

EF_j : emission factor, kg CH_4/kg BOD

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

Domestic Wastewater Treatment: CH_4 Emissions

- Activity data is the total amount of organically degradable material in the wastewater (TOW).

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

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

P : country population in inventory year, (person)

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

0.001 : conversion from grams BOD to kg BOD

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

Domestic Wastewater: CH_4 Emissions

- Emission factor for each domestic wastewater treatment/discharge pathway or system

$$EF_j = B_0 \bullet MCF_j$$

EF_j : emission factor, kg CH_4 / kg BOD

j : each treatment/discharge pathway or system

B_o : maximum CH_4 producing capacity, kg CH_4/kg BOD.

MCF_j : CH_4 correction factor (fraction) and indicates the degree to which the system is anaerobic

Industrial Wastewater: CH_4 Emissions

- Industrial wastewater may be treated on-site or released into domestic sewer systems
- The CH_4 emissions from industrial wastewater treatment (on-site):

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

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

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

i : industrial sector

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

EF_i : emission factor for industry *i, kg CH_4/kg COD* for treatment/discharge pathway or systems. If more than one treatment practice is used in an industry this factor would need to be a weighted average.

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

Industrial Wastewater: CH_4 Emissions

- Emission factor for each industrial wastewater

$$EF_j = B_0 \bullet MCF_j$$

EF_j : emission factor, for each treatment/discharge pathway/systems, kg CH_4 / kg COD

j : each treatment/discharge pathway or system

B_o : maximum CH_4 producing capacity, kg CH_4/kg COD

MCF_j : CH_4 correction factor (fraction)

Industrial Wastewater: CH_4 Emissions

- Activity data is the amount of organically degradable material in the wastewater (TOW):

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

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

i : industrial sector

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

W_i : wastewater generated, m^3/t product

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

Domestic Wastewater: N_2O Emissions

• Indirect N_2O emissions from wastewater effluent discharged into aquatic environments

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

N_2O Emissions : N_2O emissions in inventory year, kg N_2O/yr

$N_{EFFLUENT}$: nitrogen in the effluent discharged to aquatic environments, kg N/yr

$EF_{EFFLUENT}$: emission factor for N_2O emissions from discharged to wastewater, kg N_2O-N/kg N

44/28 : conversion of kg N_2O-N into kg N_2O.

Domestic Wastewater: N_2O Emissions

- Total N in the effluent

$$N_{EFFLUENT} = (P \bullet PROTEIN \bullet F_{NPR} \bullet F_{NON-CON} \bullet F_{IND-COM}) - N_{SLUDGE}$$

$N_{EFFLUENT}$: total annual amount of nitrogen in the wastewater effluent, kg N/yr

P : human population

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

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

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

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

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

Domestic Wastewater: N_2O Emissions

- Emissions from advanced centralised wastewater treatment plants

$$N_2O_{PLANTS} = P \bullet T_{PLANT} \bullet F_{IND-COM} \bullet EF_{PLANT}$$

N_2O_{PLANTS} : total N_2O emissions from plants in inventory year, kg N_2O/yr

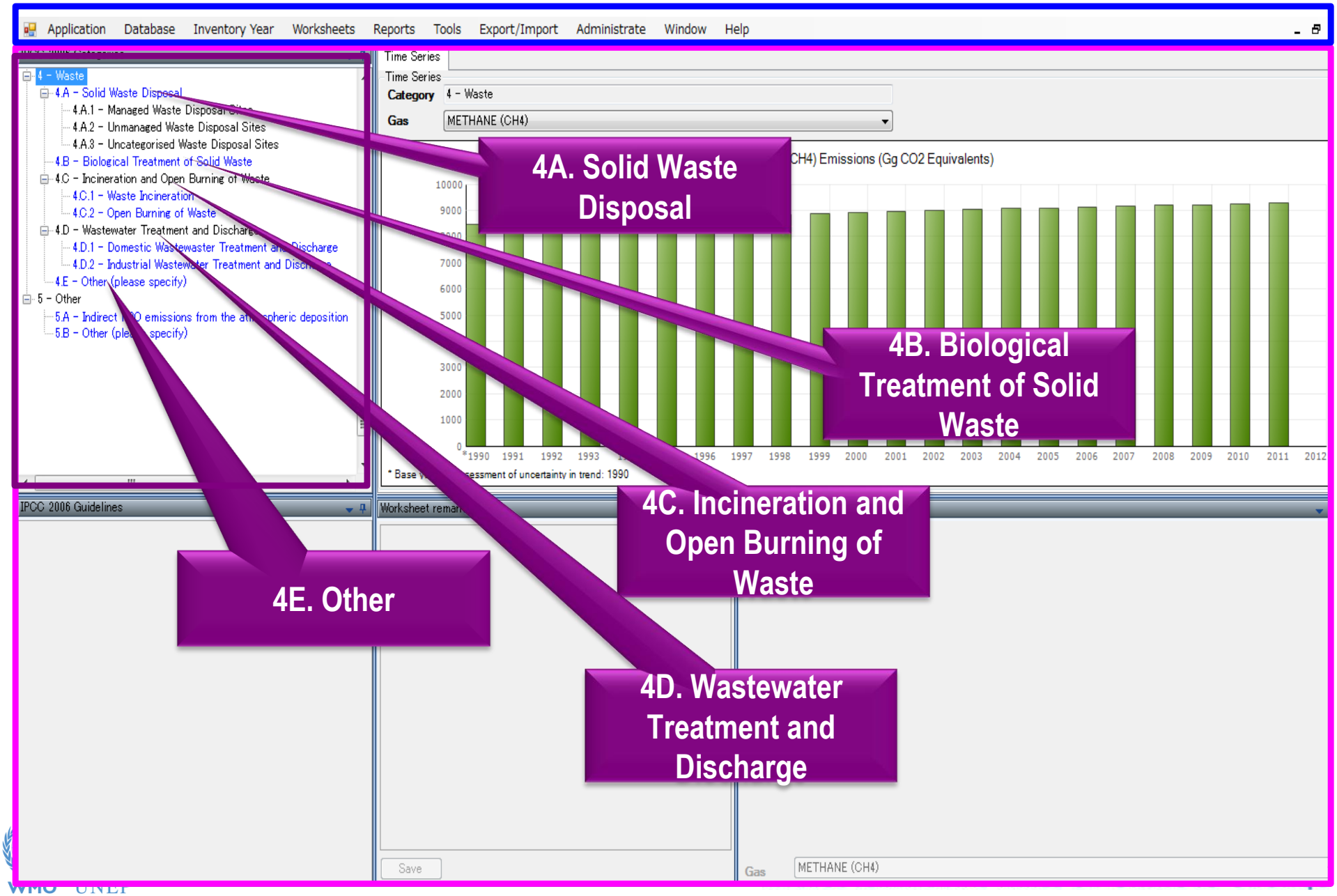
P : human population

T_{PLANT} : degree of utilization of modern, centralized WWT plants, %

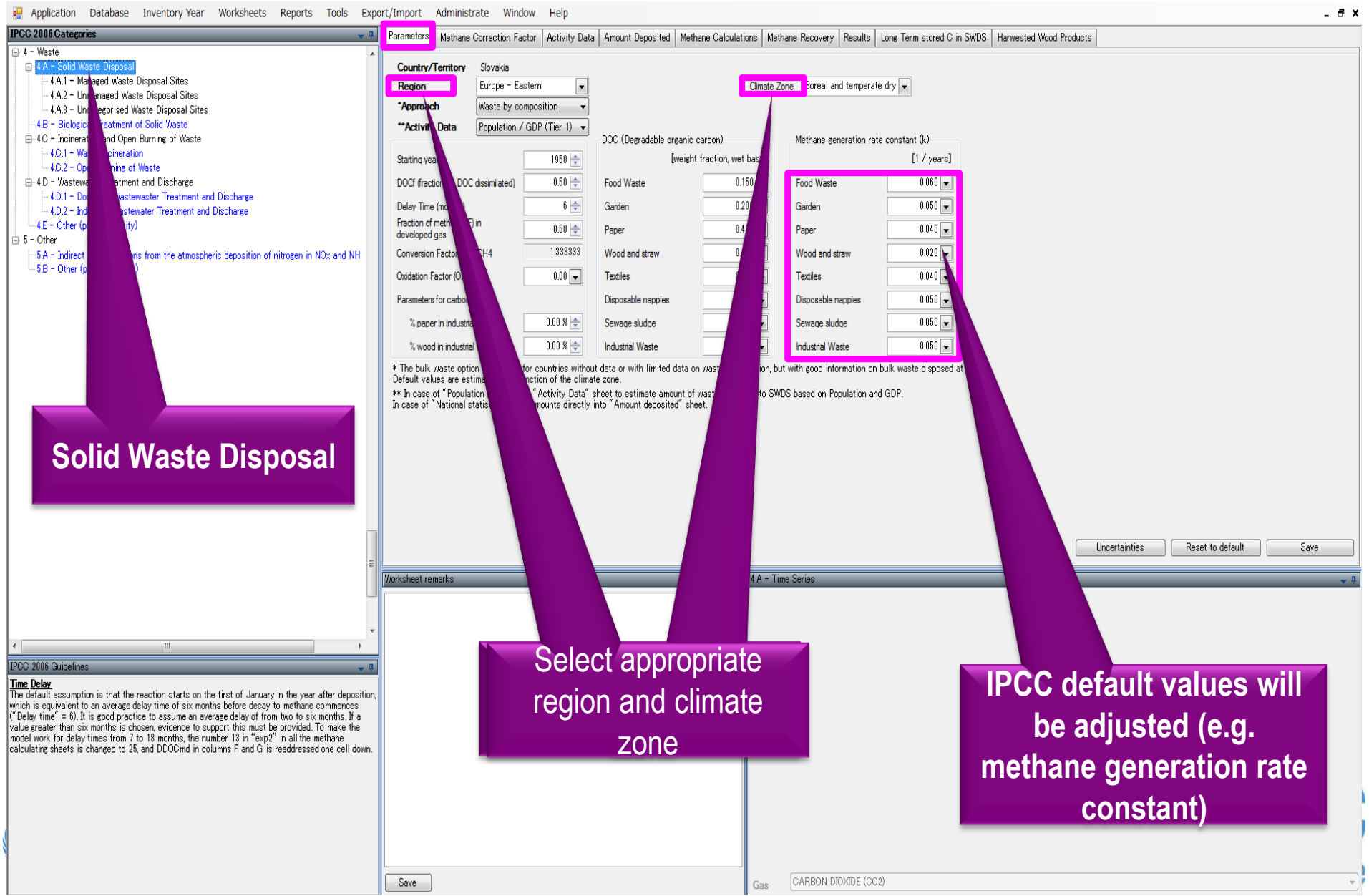
$F_{IND-COMM}$: fraction of industrial and commercial co-discharged protein (default = 1.25)

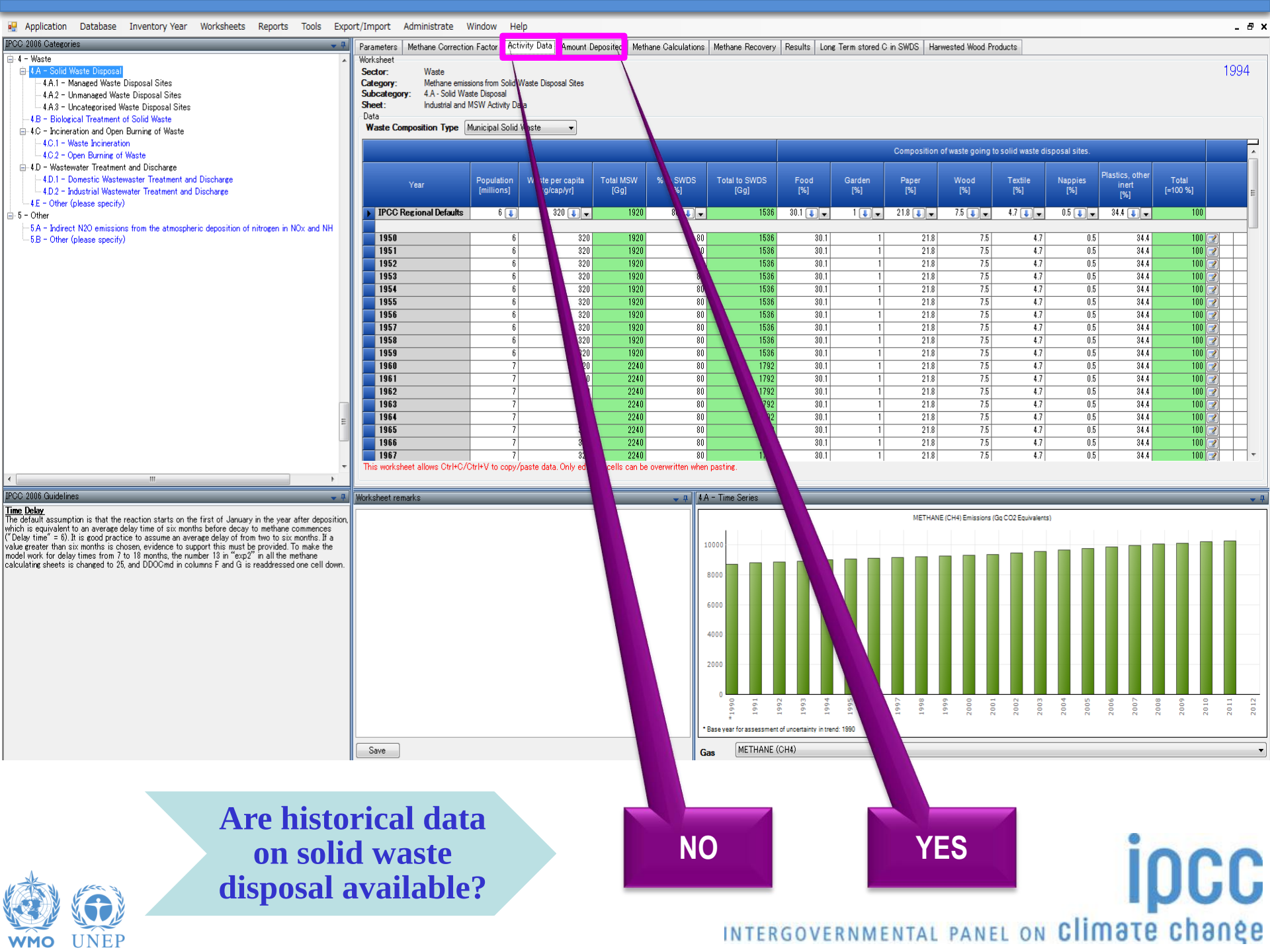
EF_{PLANT} : emission factor, 3.2 g N_2O/person/year

IPCC Inventory Software



IPCC Inventory Software: Solid Waste Disposal on Land




Application
Database
Inventory Year
Worksheets
Reports
Tools
Export/Import
Administrate
Window
Help
IPCC 2006 Categories
4 - Waste
4.A - Solid Waste Disposal
4.A.1 - Managed Waste Disposal Sites
4.A.2 - Unmanaged Waste Disposal Sites
4.A.3 - Uncategorised Waste Disposal Sites
4.B - Biological Treatment of Solid Waste
4.C - Incineration and Open Burning of Waste
4.C.1 - Waste Incineration
4.C.2 - Open Burning of Waste
4.D - Wastewater Treatment and Discharge
4.D.1 - Domestic Wastewater Treatment and Discharge
4.D.2 - Industrial Wastewater Treatment and Discharge
4.E - Other (please specify)
5 - Other
5.A - Indirect N2O emissions from the atmospheric deposition of nitrogen in NOx and NH
5.B - Other (please specify)
Parameters
Methane Correction Factor
Activity Data
Amount Deposited
Methane Calculations
Methane Recovery
Results
Long Term stored C in SWDS
Harwested Wood Products
Worksheet
Sector: Waste
Category: Methane emissions from Solid Waste Disposal Sites
Subcategory: 4.A - Solid Waste Disposal
Sheet: Industrial and MSW Activity Data
1994
Data
Waste Composition Type
Municipal Solid Waste
Composition of waste going to solid waste disposal sites.
Year
Population [millions]
Total MSW [Gg]
Total to SWDS [Gg]
Food [%]
Garden [%]
Paper [%]
Wood [%]
Textile [%]
Nappies [%]
Plastics, other inert [%]
Total [=100 %]
IPCC Regional Defaults
This worksheet allows Ctrl+C/Ctrl+V to copy/paste data. Only ed cells can be overwritten when pasting.
IPCC 2006 Guidelines
Time Delay
The default assumption is that the reaction starts on the first of January in the year after deposition, which is equivalent to an average delay time of six months before decay to methane commences ("Delay time" = 6). It is good practice to assume an average delay of from two to six months. If a value greater than six months is chosen, evidence to support this must be provided. To make the model work for delay times from 7 to 18 months, the number 18 in "exp2" in all the methane calculating sheets is changed to 25, and DDOCmd in columns F and G is readdressed one cell down.
Worksheet remarks
Save
4.A - Time Series
METHANE (CH4) Emissions (Gg CO2 Equivalents)
10000
8000
6000
4000
2000
0
1990
1991
1992
1993
1994
1995
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
* Base year for assessment of uncertainty in trend: 1990
Gas
METHANE (CH4)
Are historical data on solid waste disposal available?
NO
YES
WMO
UNEP
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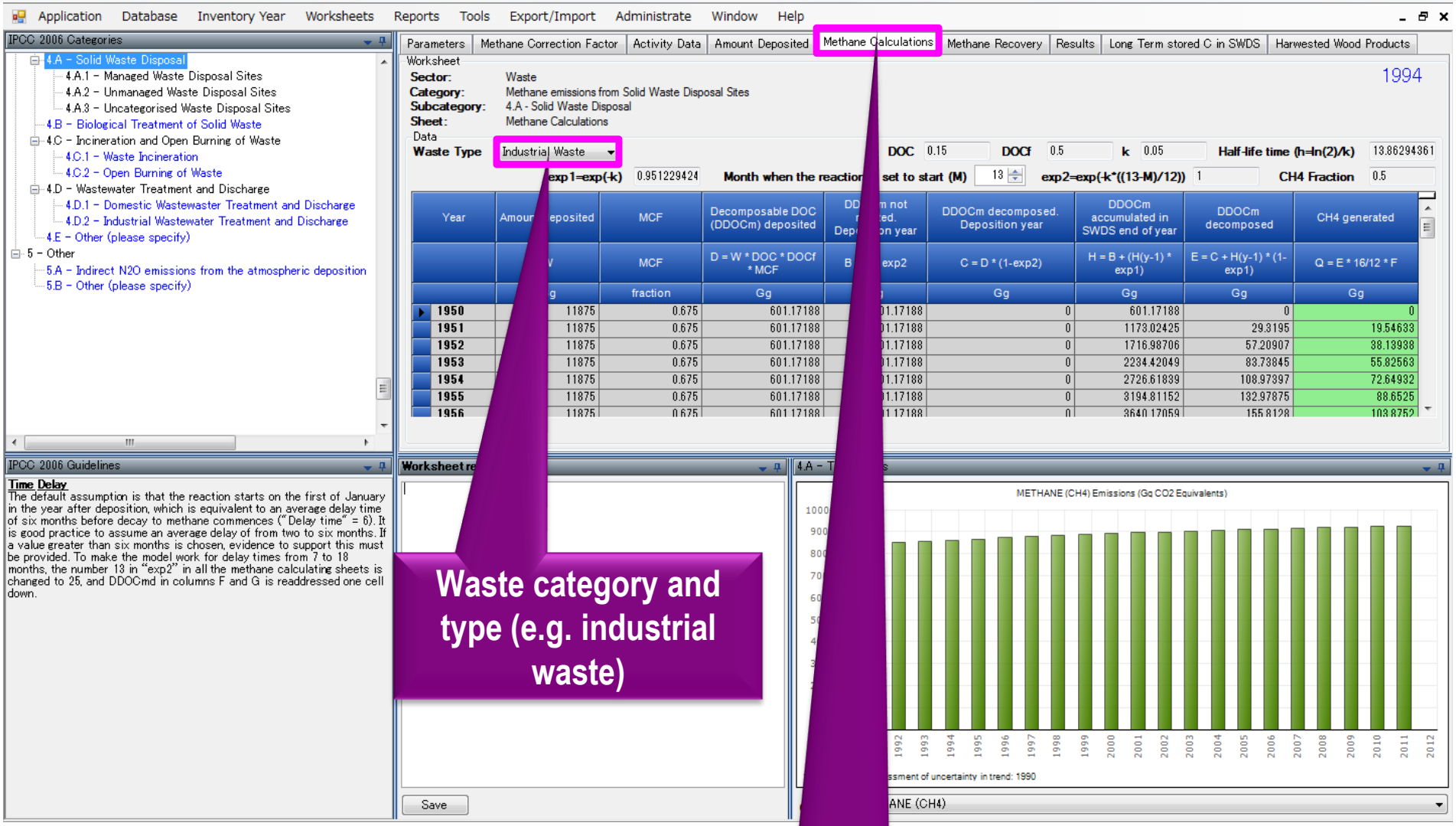

Waste category and type (e.g. industrial waste)

After entering parameters and activity data

Amount of CH_4 generated

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Application Database Inventory Year Worksheets Reports Tools Export/Import Administrate Window Help

IPCC 2006 Categories

- 4 – Waste
  - 4.A – Solid Waste Disposal
    - 4.A.1 – Managed Waste Disposal Sites
    - 4.A.2 – Unmanaged Waste Disposal Sites
    - 4.A.3 – Uncategorised Waste Disposal Sites
  - 4.B – Biological Treatment of Solid Waste
  - 4.C – Incineration and Open Burning of Waste
    - 4.C.1 – Waste Incineration
    - 4.C.2 – Open Burning of Waste
  - 4.D – Wastewater Treatment and Discharge
    - 4.D.1 – Domestic Wastewater Treatment and Discharge
    - 4.D.2 – Industrial Wastewater Treatment and Discharge
  - 4.E – Other (please specify)
- 5 – Other
  - 5.A – Indirect N2O emissions from the atmospheric deposition
  - 5.B – Other (please specify)

Parameters | Methane Correction Factor | Activity Data | Amount Deposited | Methane Calculations | Methane Recovery | Results | Long Term stored C in SWDS | Harwested Wood Products

Worksheet

Sector: Waste
Category: Methane emissions from Solid Waste Disposal Sites
Subcategory: 4.A - Solid Waste Disposal
Sheet: Results

1994

Data

Year	Methane generated									Methane recovery	Methane Emissions
	Food	Garden	Paper	Wood	Te…	Nappies	Sludge	Industrial	Total		
	A (Gg)	B (Gg)	C (Gg)	D (Gg)	… (Gg)	F (Gg)	G (Gg)	H (Gg)	I (Gg)	J (Gg)	M = (I–J) * (1-OX) (Gg)
1950	0	0	0	0	0	0	0	0	0	0	0
1951	0.94908	0.03521	1.23418	0.23051	0.15965	0.02113	0.13753	19.54633	22.31362	0	22.31362
1952	1.8429	0.0687	2.41997	0.45645	0.31304	0.04122	0.26836	38.13938	43.55001	0	43.55001
1953	2.68466	0.10056	3.55926	0.67793	0.46042	0.06033	0.3928	55.82563	63.76158	0	63.76158
1954	3.4774	0.13086	4.65388	0.89	0.60202	0.07852	0.51118	72.64932	82.99817	0	82.99817
1955	4.22397	0.15969	5.70558	1.10	0.73806	0.09581	0.62378	88.6525	101.30718	0	101.30718
1956	4.92707	0.18711	6.71604	1.3	0.86877	0.11227	0.73089	103.8752	118.7337	0	118.7337
1957	5.58923	0.21319	7.68688		0.99436	0.12791	0.83278	118.35548	135.32062	0	135.32062
1958	6.21282	0.238	8.61965		1.11502	0.1428	0.9297	132.12954	151.10873	0	151.10873
1959	6.8001	0.2616	9.51585		1.23095	0.15696	1.02189	145.23184	166.13681	0	166.13681
1960	7.35317	0.28405	10.37691		1.34233	0.17043	1.10958	157.69513	180.44177	0	180.44177
1961	8.03222	0.31128	11.4099		1.47596	0.18677	1.193	169.55058	194.497	0	194.497
1962	8.67172	0.33717	12.40239		1.60435	0.2023	1.27235	180.82784	207.87806	0	207.87806
1963	9.27399	0.3618	13.35596		1.7277	0.21708	1.34783	191.55509	220.61762	0	220.61762
1964	9.84118	0.38524	14.27215		1.84621	0.23114	1.41963	201.75917	232.74679	0	232.74679
1965	10.37533	0.40752	15.1524		1.96008	0.24451	1.48793	211.46559	244.29513	0	244.29513
1966	10.87839	0.42873	15.99815		2.06949	0.25724	1.55289	220.69863	255.29078	0	255.29078
1967	11.35214	0.44889	16.8107		2.1746	0.26934	1.61469	229.48136	265.76048	0	265.76048
1968	11.79831	0.46808	17.59		2.27559	0.28085	1.67347	237.83575	275.7297	0	275.7297
1969	12.21849	0.48632	18.3		2.37262	0.29179	1.72939	245.7827	285.22264	0	285.22264
1970	12.61421	0.50368	19		2.46585	0.30221	1.78258	253.34207	294.26233	0	294.26233

IPCC 2006 Guidelines

Time Delay
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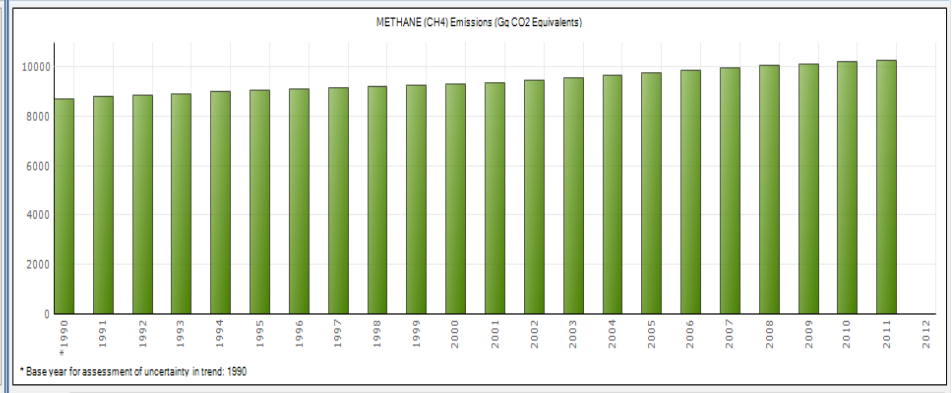
Worksheet remarks

Save

4.A – Time Series



* Base year for assessment of uncertainty in trend: 1990

Gas: METHANE (CH4)

Annual CH_4 emissions

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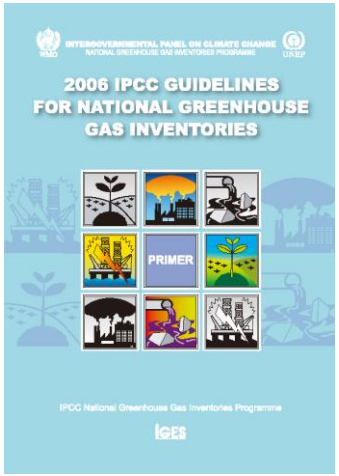
Thank you

Guidelines in all UN languages
can be downloaded from
http://www.ipcc-nggip.iges.or.jp



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