Main Contents of 2006 IPCC GL. Vol.5 Waste Sector

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First National Training of Trainers Seminar
on Development of a PNG Comprehensive GHG Emission Inventory Framework to Support First BRT Submission

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1. Introduction

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   - 2.2 Biological treatment of solid waste
   - 2.3 Incineration and open burning of waste
   - 2.4 Wastewater treatment and discharge

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※ Contents referred to 'The 6th GHG Inventory System training Workshop' learning materials created by IPCC TFI TSU.

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1. Introduction

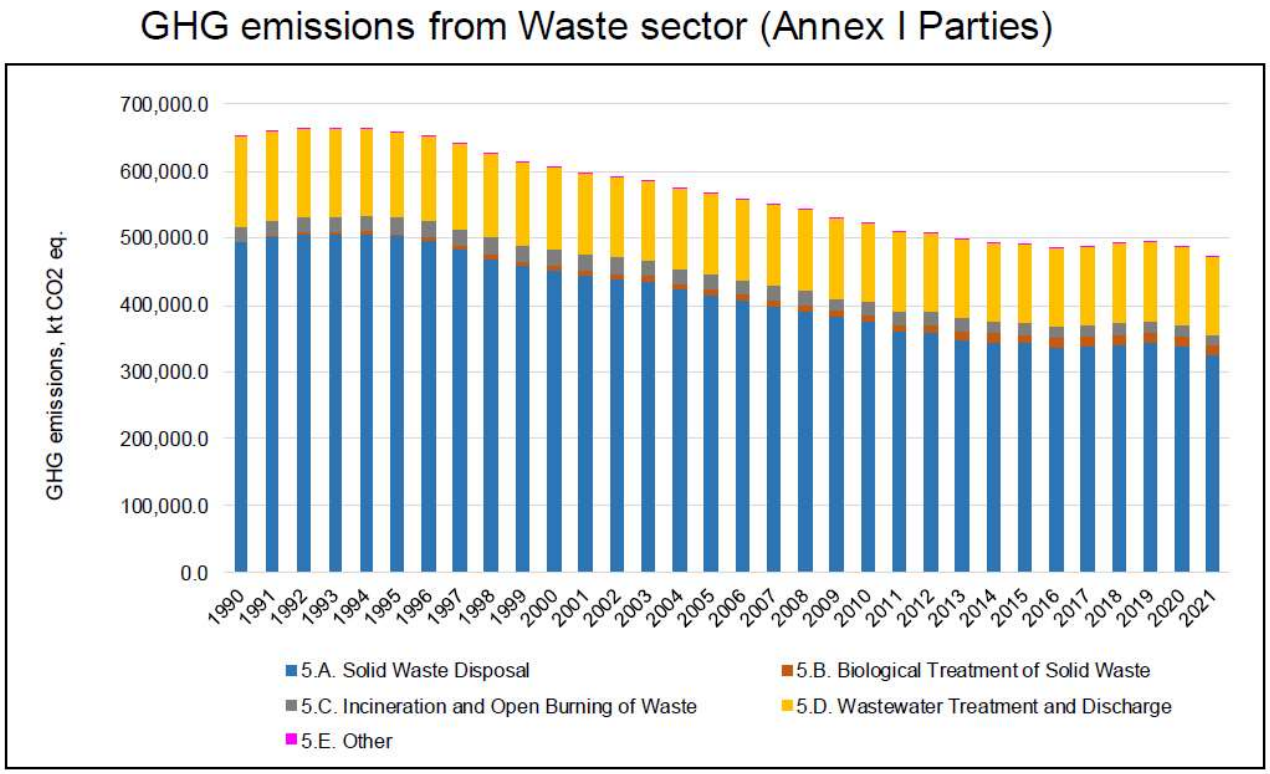
- Volume 5 (Waste) provides methodological guidance for estimation of CO_2, CH_4 and N_2O emissions from following categories:
  - Solid waste disposal
  - Biological treatment of solid waste
  - Incineration and open burning of waste
  - Wastewater treatment and discharge

- Typically, CH_4 emissions from solid waste disposal sites (SWDS) are the largest source in Waste sector.

- Biogenic CO_2 emissions are not included in Waste sector
  - Any net changes in carbon stock of biogenic origin is covered under AFOLU sector

- All greenhouse gas (GHG) emissions from waste-to-energy should be estimated and reported under Energy sector.

1. Introduction



Source: https://di.unfccc.int/ghg_profile_annex1

The emissions from Solid Waste Disposal account for 69-77% of Waste sector emissions followed by emissions from Wastewater Treatment and Discharge (19-24%)

2.1 Solid Waste Disposal

- Disposal of municipal, industrial and other solid waste produces significant amounts of CH_4. Decomposition of organic components in waste under anaerobic environment

- Waste disposal practices vary in placement of waste and management of the site, etc.
  - Methane correction factor (MCF) accounts for the fact that unmanaged SWDS produce less CH_4 from a given amount of waste than anaerobic managed SWDS.

- Methodology for estimating CH_4 emissions from SWDS is based on First Order Decay (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, NOx and CO)
  - A simple spreadsheet model (IPCC Waste Model) is provided to assist countries in using the FOD method.

2.1 Solid Waste Disposal: CH_4 Emissions

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

CH_4 Emissions	=	CH_4 emitted in year *T*, Gg
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 is generated as a result of degradation of organic material under anaerobic conditions. Part of CH_4 generated is oxidized in the cover of SWDS, or can be recovered for energy of flaring.

2.1 Solid Waste Disposal: CH_4 Emissions

EQUATION 3.6
CH_4 GENERATED FROM DECAYED DDOCm

$$CH_4\ generated_T = DDOCm\ decomp_T \bullet F \bullet 16/12$$

Where:

CH_4 $generated_T$	=	amount of CH_4 generated from decomposable material
DDOCm $decomp_T$	=	DDOCm decomposed in year *T*, Gg
F	=	fraction of CH_4, by volume, in generated landfill gas (fraction)
16/12	=	molecular weight ratio CH_4/C (ratio)

- The amount of CH_4 formed from decomposable material is found by multiplying the CH_4 fraction in generated landfill gas and the CH_4/C molecular weight ratio

2.1 Solid Waste Disposal: CH_4 Emissions

EQUATION 3.2
DECOMPOSABLE DOC FROM WASTE DISPOSAL DATA

$$DDOCm = W \bullet DOC \bullet DOC_f \bullet MCF$$

Where:

DDOCm	=	mass of decomposable DOC deposited, Gg
W	=	mass of waste deposited, Gg
DOC	=	degradable organic carbon in the year of deposition, fraction, Gg C/Gg waste
DOC_f	=	fraction of DOC that can decompose (fraction)
MCF	=	CH_4 correction factor for aerobic decomposition in the year of deposition (fraction)

- DDOCm is the part of the organic carbon that will degrade under the anaerobic conditions in SWDS.

2.1 Solid Waste Disposal: IPCC Default EFs

TABLE 2.4
DEFAULT DRY MATTER CONTENT, DOC CONTENT, TOTAL CARBON CONTENT AND FOSSIL CARBON FRACTION OF DIFFERENT MSW COMPONENTS

MSW component	Dry matter content in % of wet weight [1]	DOC content in % of wet waste		DOC content in % of dry waste		Total carbon content in % of dry weight		Fossil carbon fraction in % of total carbon	
	Default	Default	Range	Default	Range [2]	Default	Range	Default	Range
Paper/cardboard	90	40	36 - 45	44	40 - 50	46	42 - 50	1	0 - 5
Textiles [3]	80	24	20 - 40	30	25 - 50	50	25 - 50	20	0 - 50
Food waste	40	15	8 - 20	38	20 - 50	38	20 - 50	-	-
Wood	85 [4]	43	39 - 46	50	46 - 54	50	46 - 54	-	-
Garden and Park waste	40	20	18 - 22	49	45 - 55	49	45 - 55	0	0
Nappies	40	24	18 - 32	60	44 - 80	70	54 - 90	10	10
Rubber and Leather	84	(39) [5]	(39) [5]	(47) [5]	(47) [5]	67	67	20	20
Plastics	100	-	-	-	-	75	67 - 85	100	95 - 100
Metal [6]	100	-	-	-	-	NA	NA	NA	NA
Glass [6]	100	-	-	-	-	NA	NA	NA	NA
Other, inert waste	90	-	-	-	-	3	0 - 5	100	50 - 100

[1] The moisture content given here applies to the specific waste types before they enter the collection and treatment. In samples taken from collected waste or from e.g., SWDS the moisture content of each waste type will vary by moisture of co-existing waste and weather during handling.

[2] The range refers to the minimum and maximum data reported by Dehoust *et al*., 2002; Gangdonggu, 1997; Guendehou, 2004; JESC, 2001; Jager and Blok, 1993; Würdinger *et al*., 1997; and Zeschmar-Lahl, 2002.

[3] 40 percent of textile are assumed to be synthetic (default). Expert judgement by the authors.

[4] This value is for wood products at the end of life. Typical dry matter content of wood at the time of harvest (that is for garden and park waste) is 40 percent. Expert judgement by the authors.

[5] Natural rubbers would likely not degrade under anaerobic condition at SWDS (Tsuchii et al., 1985; Rose and Steinbüchel, 2005).

[6] Metal and glass contain some carbon of fossil origin. Combustion of significant amounts of glass or metal is not common.

2.1 Solid Waste Disposal: Choice of Methods, AD and EFs

- Methodological tiers for estimation of CH_4 emissions
  - Tier 1: Based on IPCC FOD method using mainly default activity data(AD) and default parameters
  - Tier 2: Use IPCC FOD method and some default parameters, but require good quality country-specific AD on current and historical waste disposal at SWDS
  - Tier 3: Based on the use of good quality country-specific AD and the use of either the FOD method with (1) nationally developed key parameters, or (2) measurement derived country-specific parameters.
- Key parameters include half-life, and either methane generation potential (Lo) or degradable organic carbon (DOC) content in waste and the fraction of DOC which decomposes (DOCf).
- The FOD method requires data for historical disposal of solid waste The *2006 IPCC Guidelines* provide guidance on estimation of historical waste disposal data
- Default values for AD and emission parameters are given in Chapters 2 and 3.

2.2 Biological Treatment of Solid Waste

- Composting and anaerobic digestion of organic waste (food waste, garden and park waste etc.)
  - reduced volume in the waste material
  - stabilisation of waste
  - production of biogas for energy use
  - end product can be recycled as a fertilizer or soil amendment

- Composting
  - large fraction of DOC in waste is converted to CO_2
  - CH_4 and N_2O can both be formed during composting

- Anaerobic digestion
  - Biogas (CH_4 and CO_2)
  - N_2O is assumed to be negligible

2.2 Biological Treatment of Solid Waste: CH_4 Emissions

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

Where:

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 = 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

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2.2 Biological Treatment of Solid Waste: N_2O Emissions

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

Where:

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

i = composting or anaerobic digestion

2.2 Biological Treatment of Solid Waste: IPCC Default EFs

TABLE 4.1
DEFAULT EMISSION FACTORS FOR CH_4 AND N_2O EMISSIONS FROM BIOLOGICAL TREATMENT OF WASTE

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

Sources: Arnold, M.(2005) Personal communication; Beck-Friis (2002); Detzel *et al.* (2003); Petersen *et al.* 1998; Hellebrand 1998; Hogg, D. (2002); Vesterinen (1996).
Note: Default emission factors for CH_4 for anaerobic digestion already account for CH_4 recovery.

2.2 Biological Treatment of Solid Waste: Choice of Methods, AD & EFs

- Methodological tiers for estimation of CH_4 and N_2O emissions
  - Tier 1: Uses IPCC default EFs
  - Tier 2: Country-specific EFs based on representative measurements are used
  - Tier 3: Based on facility or site-specific measurements data (on-line or periodic)

- Regional default values for AD and EFs are given in Chapters 2 and 4

- It is good practice that countries use national, annually or periodically collected data, where available
  - National statistics
  - Data from municipal or regional authorities responsible for waste management, or from waste management companies.

2.3 Incineration and Open Burning of Waste

- Waste incineration: combustion of solid and liquid waste in controlled incineration facilities.

- Open burning of waste: combustion of solid waste in open-air or in open dumps. It also can include uncontrolled incineration devices.

- Incineration and open burning of waste are sources of GHG emissions including CO_2, CH_4 and N_2O
  - Emissions from waste incineration without energy recovery are reported in Waste Sector
  - Emissions from incineration with energy recovery are reported in Energy Sector

2.3 Incineration and Open Burning of Waste: CO_2 Emissions

- Based on the total amount of waste combusted:

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

Where:

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 specified as follows: MSW: municipal solid waste (if not estimated using Equation 5.2), ISW: industrial solid waste, SS: sewage sludge, HW: hazardous waste, CW: clinical waste, others (that must be specified)

Estimation of the 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.

2.3 Incineration and Open Burning of Waste: CO_2 Emissions

EQUATION 5.2
CO_2 EMISSION ESTIMATE BASED ON THE MSW COMPOSITION

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

Where:

CO_2 Emissions	=	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
with:	$\sum_j WF_j = 1$	
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.

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2.3 Incineration and Open Burning of Waste: CO_2 Emissions

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

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

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2.3 Incineration and Open Burning of Waste: IPCC Default EFs

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

Parameters	Management practice	MSW	Industrial Waste (%)	Clinical Waste (%)	Sewage Sludge (%) Note 4	Fossil liquid waste (%) Note 5
Dry matter content in % of wet weight		see Note 1	NA	NA	NA	NA
Total carbon content in % of dry weight		see Note 1	50	60	40 – 50	80
Fossil carbon fraction in % of total carbon content		see Note 2	90	40	0	100
Oxidation factor in % of carbon input	incineration	100	100	100	100	100
	Open- burning (see Note 3)	58	NO	NO	NO	NO

NA: Not Available, NO: Not Occurring

Note 1: Use default data from Table 2.4 in Section 2.3 Waste composition and equation 5.8 (for dry matter), Equation 5.9 (for carbon content) and Equation 5.10 (for fossil carbon fraction).

Note 2: Default data by industry type is given in Table 2.5 in Section 2.3 Waste composition. For estimation of emissions, use equations mentioned in Note 1.

Note 3: When waste is open-burned, refuse weight is reduced by approximately 49 to 67 percent (US-EPA, 1997, p.79). A default value of 58 percent is suggested.

Note 4: See Section 2.3.2 Sludge in Chapter 2.

Note 5: The total carbon content of fossil liquid waste is provided in percent of wet weight and not in percent of dry weight (GIO, 2005).

References: *GPG2000* (IPCC, 2000), Lead Authors of the *2006 Guidelines*, Expert judgement.

TABLE 2.4
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Food waste	40	15	8 - 20	38	20 - 50	38	20 - 50	-	-
Wood	85 [4]	43	39 - 46	50	46 - 54	50	46 - 54	-	-
Garden and Park waste	40	20	18 - 22	49	45 - 55	49	45 - 55	0	0
Nappies	40	24	18 - 32	60	44 - 80	70	54 - 90	10	10
Rubber and Leather	84	(39) [5]	(39) [5]	(47) [5]	(47) [5]	67	67	20	20
Plastics	100	-	-	-	-	75	67 - 85	100	95 - 100
Metal [6]	100	-	-	-	-	NA	NA	NA	NA
Glass [6]	100	-	-	-	-	NA	NA	NA	NA
Other, inert waste	90	-	-	-	-	3	0 - 5	100	50 - 100

[1] The moisture content given here applies to the specific waste types before they enter the collection and treatment. In samples taken from collected waste or from e.g., SWDS the moisture content of each waste type will vary by moisture of co-existing waste and weather during handling.

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[6] Metal and glass contain some carbon of fossil origin. Combustion of significant amounts of glass or metal is not common.

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2.3 Incineration and Open Burning of Waste: N_2O Emissions

EQUATION 5.5

N_2O EMISSION ESTIMATE BASED ON THE WASTE INPUT TO THE INCINERATORS

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

Where:

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, specified as follows:

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

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2.3 Incineration and Open Burning of Waste: CH_4 Emissions

EQUATION 5.4
CH_4 EMISSION ESTIMATE BASED ON THE TOTAL AMOUNT OF WASTE COMBUSTED

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

Where:

CH_4 Emissions	=	CH_4 emissions in inventory year, Gg/yr
IW_i	=	amount of solid waste of type *i* incinerated or open-burned, Gg/yr
EF_i	=	aggregate CH_4 emission factor, kg CH_4/Gg of waste
10^{-6}	=	conversion factor from kilogram to gigagram
i	=	category or type of waste incinerated/open-burned, specified as follows: MSW: municipal solid waste, ISW: industrial solid waste, HW: hazardous waste, CW: clinical waste, SS: sewage sludge, others (that must be specified)

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2.4 Wastewater Treatment and Discharge

- Wastewater (domestic and industrial) may be treated on site (uncollected), sewered to a centralized plant (collected) or disposed untreated.
  - Treatment and discharge systems can differ between countries and can also differ for rural and urban users

- Treatment and disposal of wastewater produce GHGs such as CO_2, CH_4 and N_2O
  - CO_2 is of biogenic origin and not included

- Sludge produced in wastewater treatment is treated further. GHG emissions from sludge sent to landfills, incinerated or used in agriculture are not included in this category.

2.4 Wastewater Treatment and Discharge

Figure 6.1 **Wastewater treatment systems and discharge pathways**

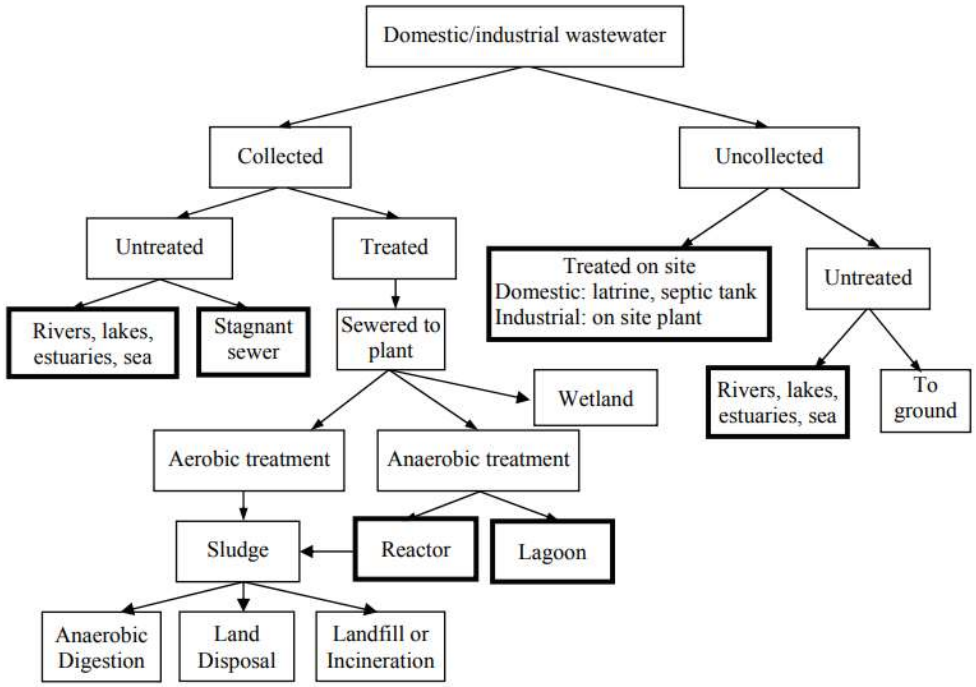

TABLE 6.1
CH_4 AND N_2O EMISSION POTENTIALS FOR WASTEWATER AND SLUDGE TREATMENT AND DISCHARGE SYSTEMS

Types of treatment and disposal				CH_4 and N_2O emission potentials
Collected	Untreated		River discharge	Stagnant, oxygen-deficient rivers and lakes may allow for anaerobic decomposition to produce CH_4. Rivers, lakes and estuaries are likely sources of N_2O.
			Sewers (closed and under ground)	Not a source of CH_4/N_2O.
			Sewers (open)	Stagnant, overloaded open collection sewers or ditches/canals are likely significant sources of CH_4.
	Treated	Aerobic treatment	Centralized aerobic wastewater treatment plants	May produce limited CH_4 from anaerobic pockets. Poorly designed or managed aerobic treatment systems produce CH_4. Advanced plants with nutrient removal (nitrification and denitrification) are small but distinct sources of N_2O.
			Sludge anaerobic treatment in centralized aerobic wastewater treatment plant	Sludge may be a significant source of CH_4 if emitted CH_4 is not recovered and flared.
			Aerobic shallow ponds	Unlikely source of CH_4/N_2O. Poorly designed or managed aerobic systems produce CH_4.
		Anaerobic treatment	Anaerobic lagoons	Likely source of CH_4. Not a source of N_2O.
			Anaerobic reactors	May be a significant source of CH_4 if emitted CH_4 is not recovered and flared.
Uncollected			Septic tanks	Frequent solids removal reduces CH_4 production.
			Open pits/Latrines	Pits/latrines are likely to produce CH_4 when temperature and retention time are favourable.
			River discharge	See above.

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2.4 Wastewater Treatment and Discharge: CH_4 Emissions

- CH_4 production depends primarily on the amount of degradable organic material in wastewater, temperature and type of treatment system.
- Common parameters used to measure the organic component of the wastewater :
  - Biochemical Oxygen Demand (BOD): amount of carbon that is aerobically biodegradable
  - Chemical Oxygen Demand (COD): total organic material available for chemical oxidation

- Methodological tiers for estimation of CH_4 emissions:
  - Tier 1 method applies default values for EFs (Bo, MCF, etc.) and AD
  - Tier 2 method allows for incorporation of a country-specific EF and AD
  - Tier 3 method is a country-specific method with measurements or other bottom-up data

- 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
  CH_4 recovery for energy generation should be reported in the Energy Sector

2.4 Wastewater Treatment and Discharge: CH_4 Emissions

EQUATION 6.1
TOTAL CH_4 EMISSIONS FROM DOMESTIC WASTEWATER

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

Where:

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, See Table 6.5.

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

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

j = each treatment/discharge pathway or system

EF_j = emission factor, kg CH_4 / kg BOD

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

EQUATION 6.2
CH_4 EMISSION FACTOR FOR EACH DOMESTIC WASTEWATER TREATMENT/DISCHARGE PATHWAY OR SYSTEM

$$EF_j = B_o \bullet MCF_j$$

Where:

EF_j = emission factor, kg CH_4/kg BOD

j = each treatment/discharge pathway or system

B_o = maximum CH_4 producing capacity, kg CH_4/kg BOD

MCF_j = methane correction factor (fraction), See Table 6.3.

TABLE 6.2
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)

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2.4 Wastewater Treatment and Discharge: CH_4 Emissions

EQUATION 6.4
TOTAL CH_4 EMISSIONS FROM INDUSTRIAL WASTEWATER

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

Where:

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

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

i = industrial sector

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

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

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

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

EQUATION 6.6
ORGANICALLY DEGRADABLE MATERIAL IN INDUSTRIAL WASTEWATER

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

Where:

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

i = industrial sector

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

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

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

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2.4 Wastewater Treatment and Discharge: N_2O Emissions

- The N_2O emissions are associated with the degradation of nitrogen components in the wastewater (e.g., urea, nitrate and protein).

- N_2O emissions can occur as direct emissions from treatment plants or indirect emissions from wastewater after disposal of effluent into waterways, lakes or the sea.

- N_2O may be generated during
  - Nitrification: aerobic process converting ammonia and other nitrogen compounds into nitrate (NO_3-)
  - Denitrification: biological conversion of NO_3- into nitrogen gas (N_2) under anoxic environment.

- The emissions from industrial sources are believed to be insignificant compared to emissions from domestic wastewater.

2.4 Wastewater Treatment and Discharge: 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 wastewater, kg N_2O-N/kg N

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

2.4 Wastewater Treatment and Discharge: N_2O Emissions

- Total N in the effluent

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

$N_{EFFLUENT}$: 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

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2.4 Wastewater Treatment and Discharge: N_2O Emissions

- Emissions from advanced centralized 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

- To include N_2O emissions from plants, the amount of nitrogen associated with these emissions (N_{wwt}) must be subtracted from the $N_{EFFLUENT}$.

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3. Waste Data

- Collection of data is a fundamental part of inventory compilation
  - Starting point of estimation of GHG emissions/removals
  - Chapter 2 of Volume 1 gives general guidance on data collection

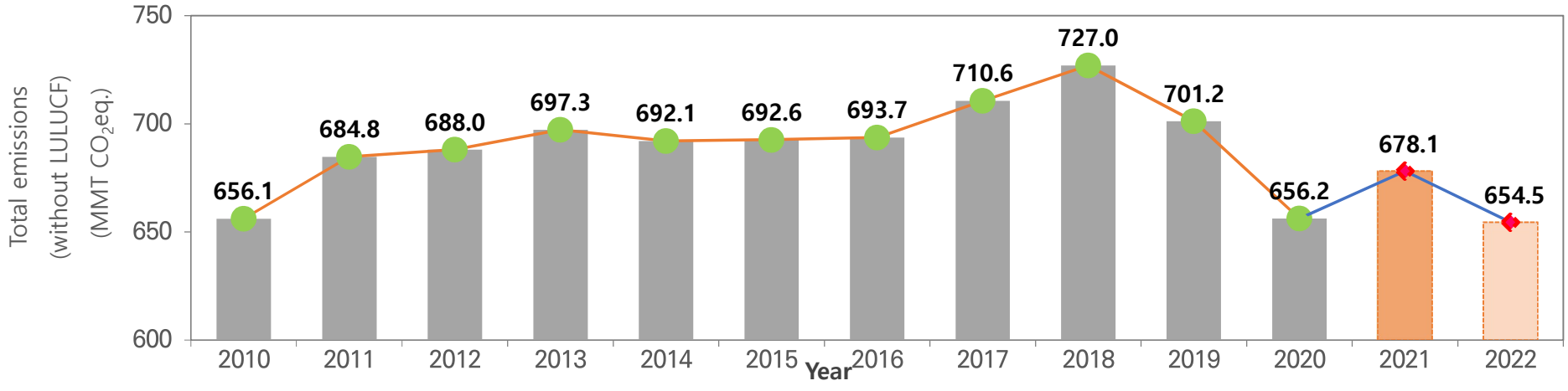
- It is preferable to use national data

- If the data is not available, IPCC default values and data from other sources can be used. However, need to assess the applicability of the data to national circumstances.
  - Chapter 2 of Volume 5 provides default data on waste generation, composition and management
  - IPCC Emission Factor Database (EFDB https://www.ipcc-nggip.iges.or.jp/EFDB/main.php) contains data from various sources with background technical information.

4. Status of Korea's GHG Inventory

654.5 MMT CO_2eq. (potential) in 2022

- 2022 Potential emissions decreased **3.5%**(23.6 MMT CO_2eq.) compared to the previous year, **9.7%** compared to 2018
- The lowest figure since 2010



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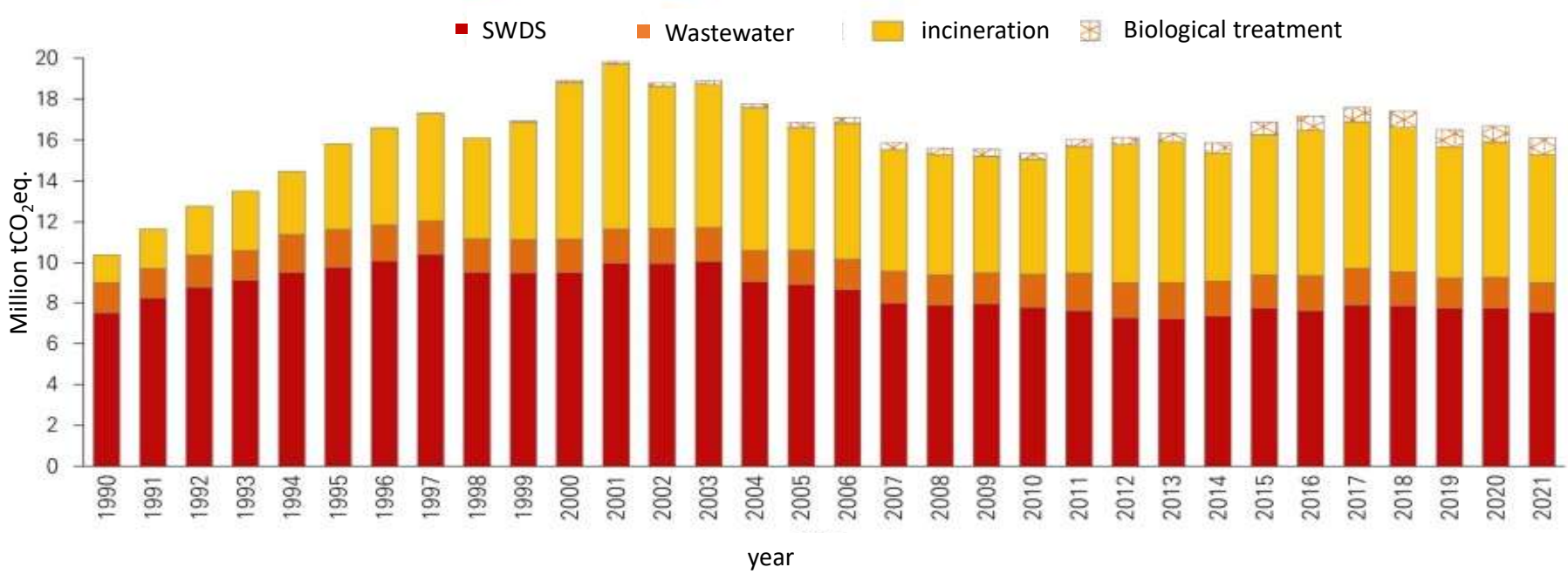
4. Status of Korea's GHG Inventory of Waste sector



- 2021 Emissions of Waste sector accounted for **2.4%**(16.1 MMT CO_2eq.) which decreased 3.5% compared to the previous year and increased **54.9%** compared to 1990
- The peak year of the waste sector emissions of Korea was in 2001

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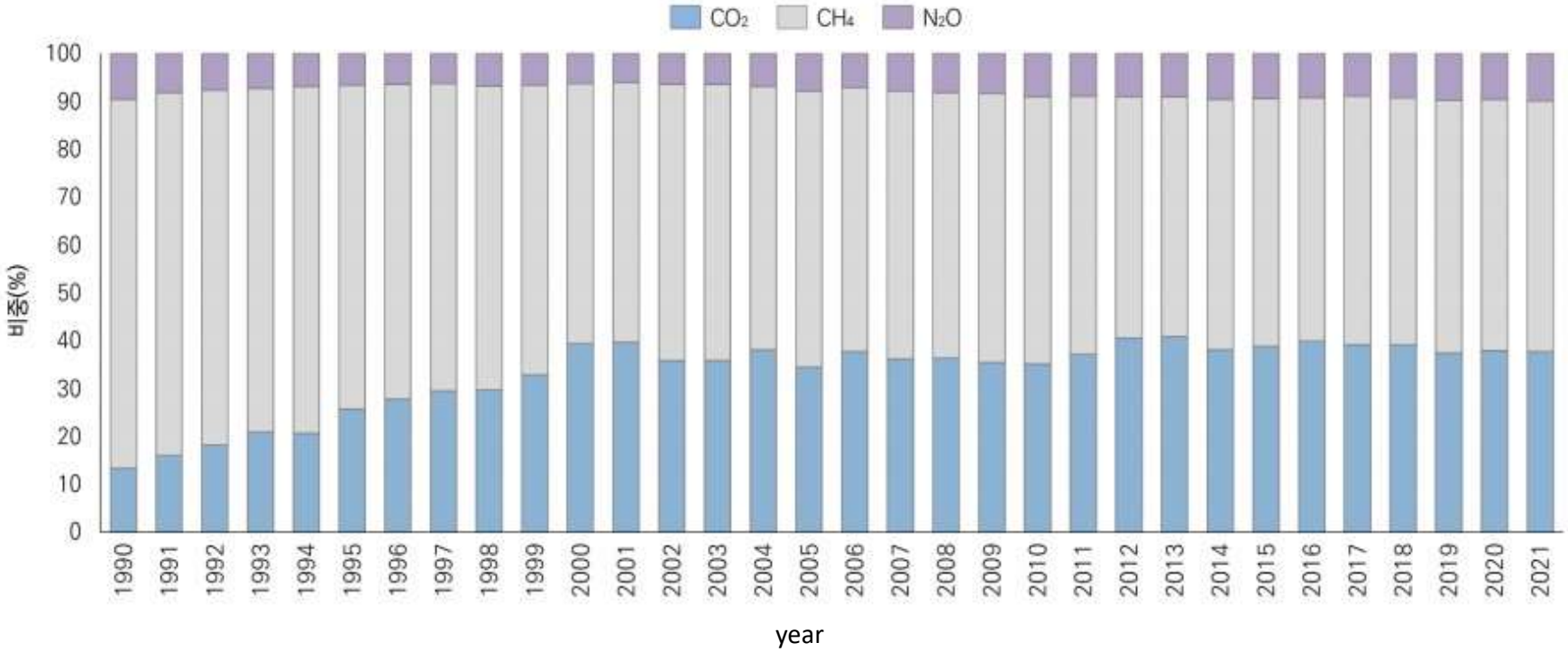
4. Status of Korea's GHG Inventory of Waste sector



- **52.4%**(8.4 MMT CO_2eq.) emissions of waste sector was from CH_4, followed by CO_2 of **37.7%**(6.1 MMT CO_2eq.), N_2O of **9.9%**(1.6 MMT CO_2eq.)

Thank you!

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and

https://www.unescap.org/our-work/environment-development

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