IPCC estimation methods and tiers

Session 2: IPCC Guidelines and Importance of Ground Data Collection for adequate estimation of methane emission

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IPCC Guidelines (IPCC estimation methods):
Principles, Tiered Approach, Default data, etc

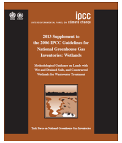
National GHG Inventory under the Paris Agreement

- Developing Country Parties must prepare and submit their national GHG inventories every 2 years as integral part of biennial transparency report (BTR)
- Annual estimates of all anthropogenic emissions and removals of greenhous gases (GHGs) taking place within national territory and offshore areas over which the country has jurisdiction
  - GHGs to be included in national GHG inventories under the Paris Agreement are
    - ✓ CO_2 , CH_4 , N_2O , HFCs , PFCs , SF_6 , NF_3
- Essential element of enhanced transparency framework (ETF)
  - Provides a fundamental basis of nationally determined contribution (NDC)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2[(1)]	CH_4	N_2O	HFCs	PFCs	SF_6	Unspecified mix of HFCs and PFCs	NF_3	Total
	CO_2 equivalent (kt)								
Total (net emissions)[(1)]	1245764.48	36099.86	22667.43	31776.63	3280.06	2165.76		1360.96	1343115.17
1. Energy	1250301.61	2484.74	6712.35						1259498.70
A. Fuel combustion (sectoral approach)	1249822.05	1667.77	6712.26						1258202.08
1. Energy industries	566643.99	293.16	2631.43						569568.59
2. Manufacturing industries and construction	338129.90	493.13	1854.26						340477.29
3. Transport	215803.65	169.55	1974.04						217947.24
4. Other sectors	129244.52	711.93	252.52						130208.96
5. Other	NO	NO	NO						NO
B. Fugitive emissions from fuels	479.56	816.97	0.09						1296.62
1. Solid fuels	0.49	533.12	NO,NE						533.61
2. Oil and natural gas	479.07	283.85	0.09						763.01
C. CO_2 transport and storage	NE,NO								NE,NO
2. Industrial processes and product use	46551.39	46.38	1748.15	31776.63	3280.06	2165.76		1360.96	86929.33
A. Mineral industry	35111.89								35111.89
B. Chemical industry	4757.48	28.13	1389.13	147.44	110.80	92.80		1229.80	7755.57
C. Metal industry	6300.60	18.26	NO	1.29	9.59	159.60			6489.34
D. Non-energy products from fuels and solvent use	299.09	NO	NO						299.09
E. Electronic Industry				111.61	1631.36	351.31		131.16	2225.44
F. Product uses as ODS substitutes				31516.29	1517.95				33034.24
G. Other product manufacture and use			359.02		10.36	1562.06			1931.44
H. Other	82.33	NO	NO						82.33
3. Agriculture	531.74	27958.38	11040.64						39530.76
A. Enteric fermentation		7400.57							7400.57
B. Manure management		2411.31	4543.48						6954.79
C. Rice cultivation		18077.30							18077.30
D. Agricultural soils		NO	6475.78						6475.78
E. Prescribed burning of savannas		NO	NO						NO
F. Field burning of agricultural residues		69.20	21.39						90.59
G. Liming	369.97								369.97
H. Urea application	161.77								161.77
I. Other carbon-containing fertilizers	NO								NO
J. Other		NO	NO						NO
4. Land use, land-use change and forestry[(1)]	-64926.94	57.79	209.36						-64659.80
A. Forest land	-68162.38	3.99	132.34						-68026.05
B. Cropland	3651.84	51.57	26.13						3729.54

IPCC Guidelines for National GHG Inventories

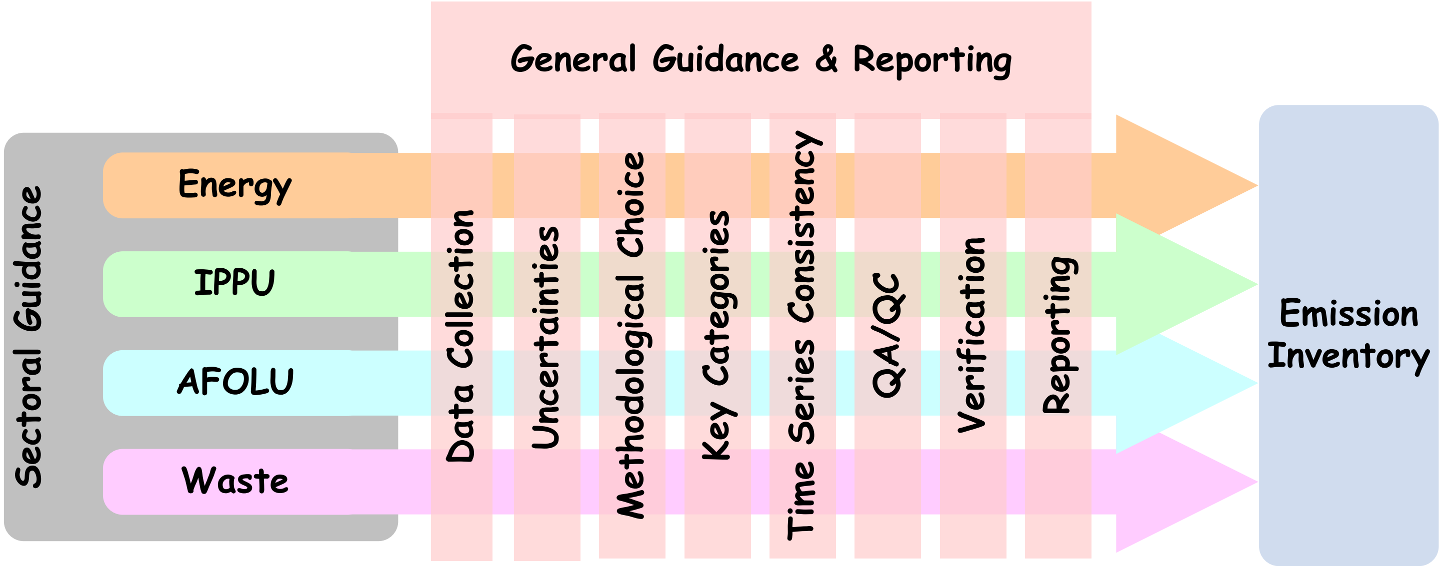
- For inventory compilation, the Parties to the Paris Agreement:
  - Shall use the 2006 IPCC Guidelines for National Greenhouse Gas Inventories
    https://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html
  - Are encouraged to use the 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (Wetlands Supplement)
    https://www.ipcc-nggip.iges.or.jp/public/wetlands/index.html
  - May use on a voluntary basis the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2019 Refinement)
    https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html



Importance of IPCC estimation methods

- IPCC Guidelines (IPCC estimation methods) are primarily for compilation of national GHG inventories, particularly under the UNFCCC and Paris Agreement.
- They also provide a fundamental basis for other GHG emission reporting/accounting schemes at various levels, such as:
  - GHG inventory reporting at a municipality level
    - ✓ e.g. Global Protocol for Community-Scale Greenhouse Gas Inventories (GPC)
  - GHG inventory reporting/accounting at a corporate level
    - ✓ e.g., The Greenhouse Gas Protocol - A Corporate Accounting and Reporting Standard
  - Emission trading scheme
    - ✓ e.g., EU-ETS
- Also important to develop a methane reduction roadmap in the context of the Global Methane Pledge.

IPCC estimation methods - Basic Principle



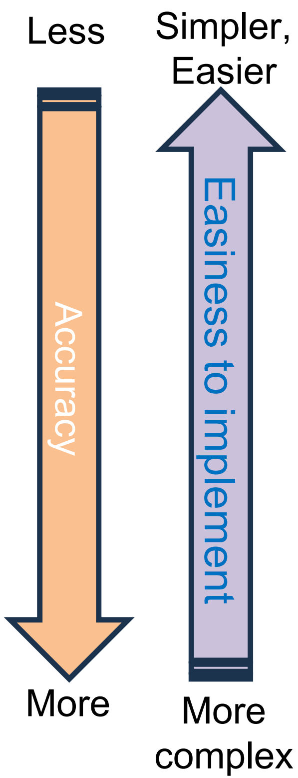
Source: Primer for 2006 IPCC Guidelines (http://www.ipcc-nggip.iges.or.jp/support/support.html)

- IPCC estimation methods are intended to ensure that greenhouse gas inventories are accurate in the sense that they are systematically neither over- nor underestimates so far as can be judged, and that uncertainties are reduced so far as practicable.

IPCC estimation methods– Tiered approach

- A "tier" represents a level of methodological complexity.
- Usually three tiers are provided for estimation of emissions from each source category & gas.
  - Tier 1 = basic method
  - Tier 2 = intermediate
  - Tier 3 = most demanding in terms of complexity and data requirements
- Tiers 2 and 3 are sometimes referred to as higher tier methods and are generally considered to be more accurate.

Example: Methods for estimating CH_4 and N_2O from road vehicles



Tier 1

EQUATION 3.2.3
TIER 1 EMISSIONS OF CH_4 AND N_2O

$$Emission = \sum_a [Fuel_a \bullet EF_a]$$

Tier 2

EQUATION 3.2.4
TIER 2 EMISSIONS OF CH_4 AND N_2O

$$Emission = \sum_{a,b,c} [Fuel_{a,b,c} \bullet EF_{a,b,c}]$$

Tier 3

EQUATION 3.2.5
TIER 3 EMISSIONS OF CH_4 AND N_2O

$$Emission = \sum_{a,b,c,d} [Distance_{a,b,c,d} \bullet EF_{a,b,c,d}] + \sum_{a,b,c,d} C_{a,b,c,d}$$

Emission = emission of CH4 or N2O (kg)
EF = emission factor (kg/TJ or kg/km)
Fuel = fuel consumed (TJ)
Distance = distance travelled during thermally stabilized engine operation phase for a given mobile source activity (km)
C = emissions during warm-up phase (cold start) (kg)

a = fuel type (e.g., diesel, gasoline, natural gas)
b = vehicle type
c = emission control technology (such as uncontrolled, catalytic converter, etc.)
d = operating conditions (e.g., urban or rural road type, climate, or other environmental factors)

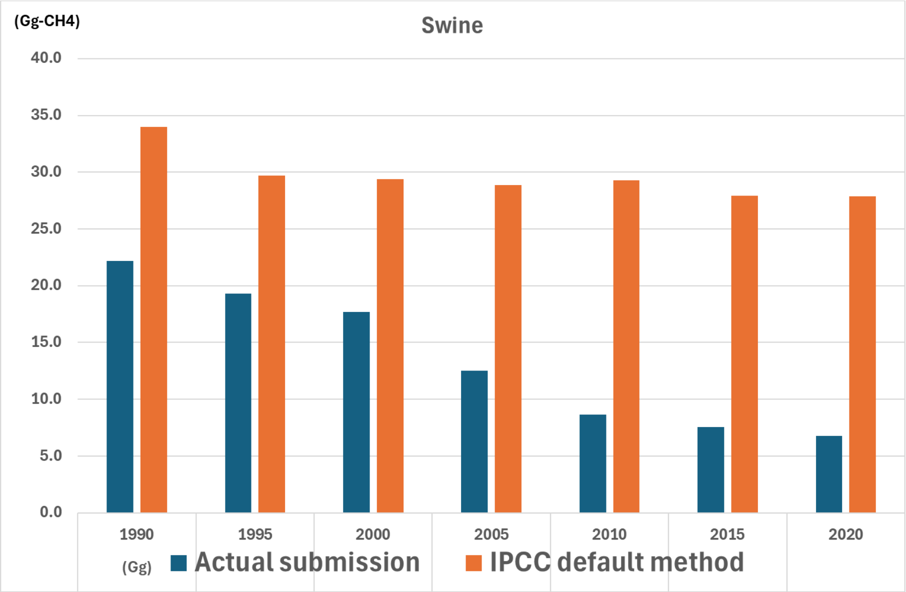
Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 3 of Vol.2

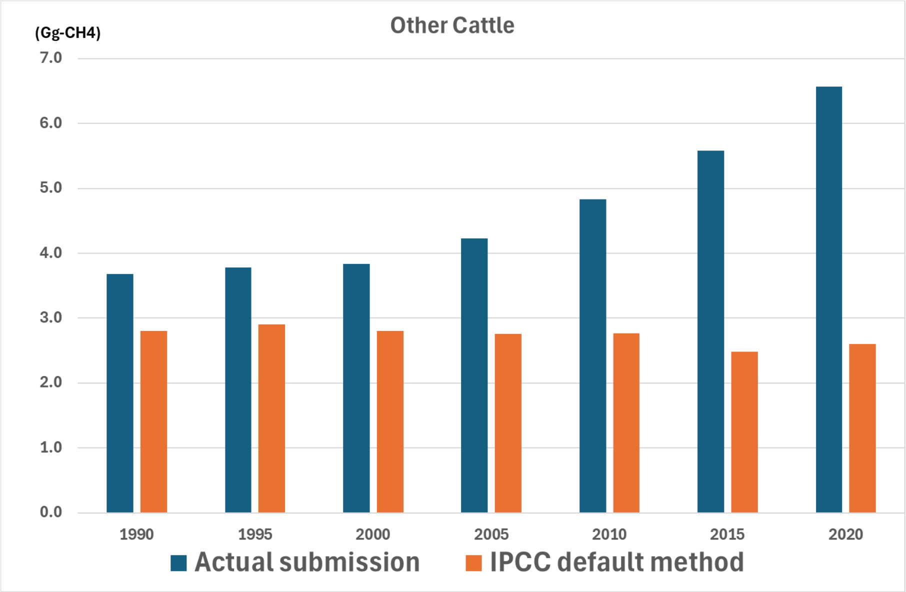
IPCC default data vs. local data

- IPCC Guidelines provide "default" values of emission factors and other parameters for all source/sink categories. (= IPCC default data)
- In principle, it is better to use local data (country-specific, site-specific, plant-specific, etc). If and where such local data are not easily available, IPCC default data may be used as a last resort.
- Tier 1 methods rely heavily on default data. Default data are also used in Tie 2 methods for some categories, particularly where the Tier 2 equations are complex with many parameters required.

IPCC default data	Local data
• Can be easily obtained from IPCC Guidelines • Do not reflect local conditions, therefore will lead to less accurate emission estimates	• Well reflect local conditions, which helps enhance the accuracy of emission estimates • Not easily available – need to be developed through measurements, experiments, or to find in literature

- Better to use higher tiers (e.g. Tier 2) with local data than to use Tier 1 with default data, because it enables:
  - More accurate estimation of emissions; and
  - More accurate reflection of emission reduction efforts in your national GHG inventory.





Comparison of estimates of CH_4 emissions from manure management in Japan between those in the actually submitted inventory and those calculated using IPCC Tier 1 methods and default data (calculated by Kiyoto Tanab

Sources of CH_4 emissions

Sources of Methane Emissions (in general)

- Energy sector
  - Fuel combustion activities
  - Fugitive emissions from coal mining and oil & natural gas systems
- Industrial Processes and Product Use (IPPU) sector
  - Chemical industry
  - Metal industry
- Agriculture sector
  - Livestock: Enteric fermentation
  - Livestock: Manure management
  - Rice cultivation
- Land Use, Land Use Change and Forestry (LULUCF) secto
  - Wetlands (including peatland)
- Waste sector
  - Solid waste disposal
  - Wastewater treatment and discharge

Significant sources of methane emissions (in FSM)

- Energy sector
  - Fuel combustion activities
  - Fugitive emissions from coal mini
- Industrial Processes and Prod
  - Chemical industry
  - Metal industry
- Agriculture sector
  - Livestock: Enteric fermentation
  - Livestock: Manure management
  - Rice cultivation
- Land Use, LandUse Change and Forestry (LULUCF) secto
  - Wetlands (including peatland)
- Waste sector
  - Solid waste disposal
  - Wastewater treatment and discharge

Not insignificant, as reduction of methane emissions related to diesel electric generation is included in the updated NDC submitted in October 2022.

Not insignificant, as it has some association with manure management. Measures to reduce methane emissions from both categories may be considered in an integrated manner.

Not insignificant, as this source was identified as a “key category” in NC3&BUR1 submitted in May 2023

More than 90% of methane emissions are from these two sources in FSM.

Methane emission sources in FSM

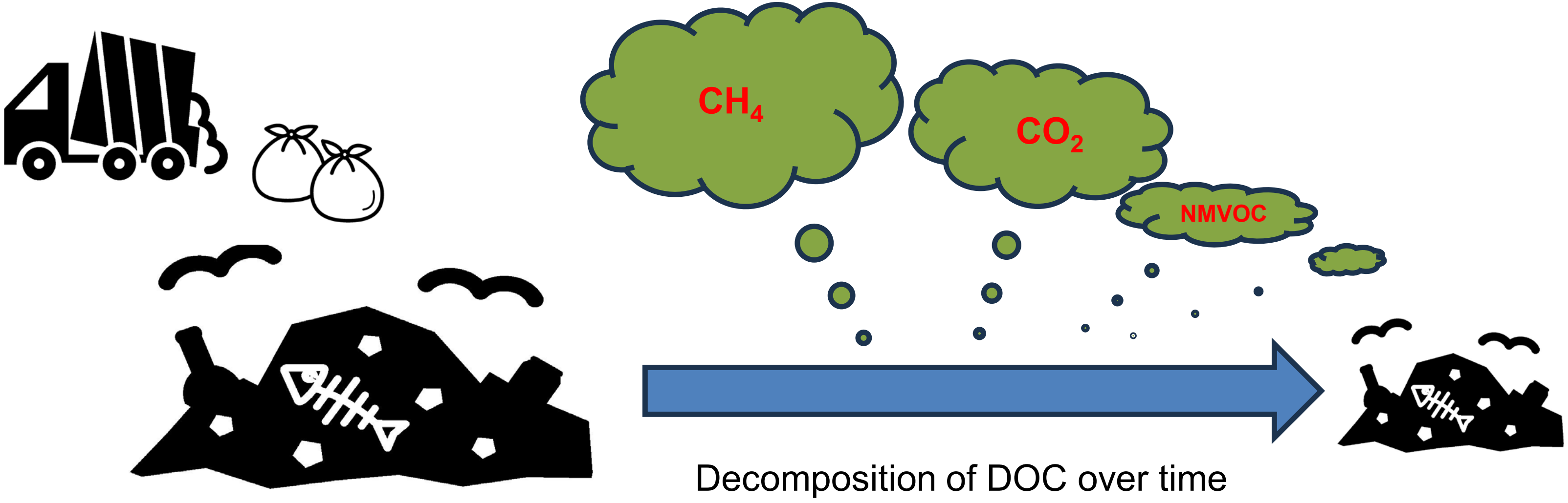
- Two major sources account for more than 90% of methane emissions
  - Livestock: Manure Management
  - Solid Waste Disposal
- It should be noted that the other sources may be also important for various reasons such as:
  - The emissions may be underestimated due to inappropriate use of IPCC methods or lack of data.
  - The emissions may greatly increase in the future due to, e.g.,
    - economic development
    - Change in policies and measures relating to food security, public hygiene, etc

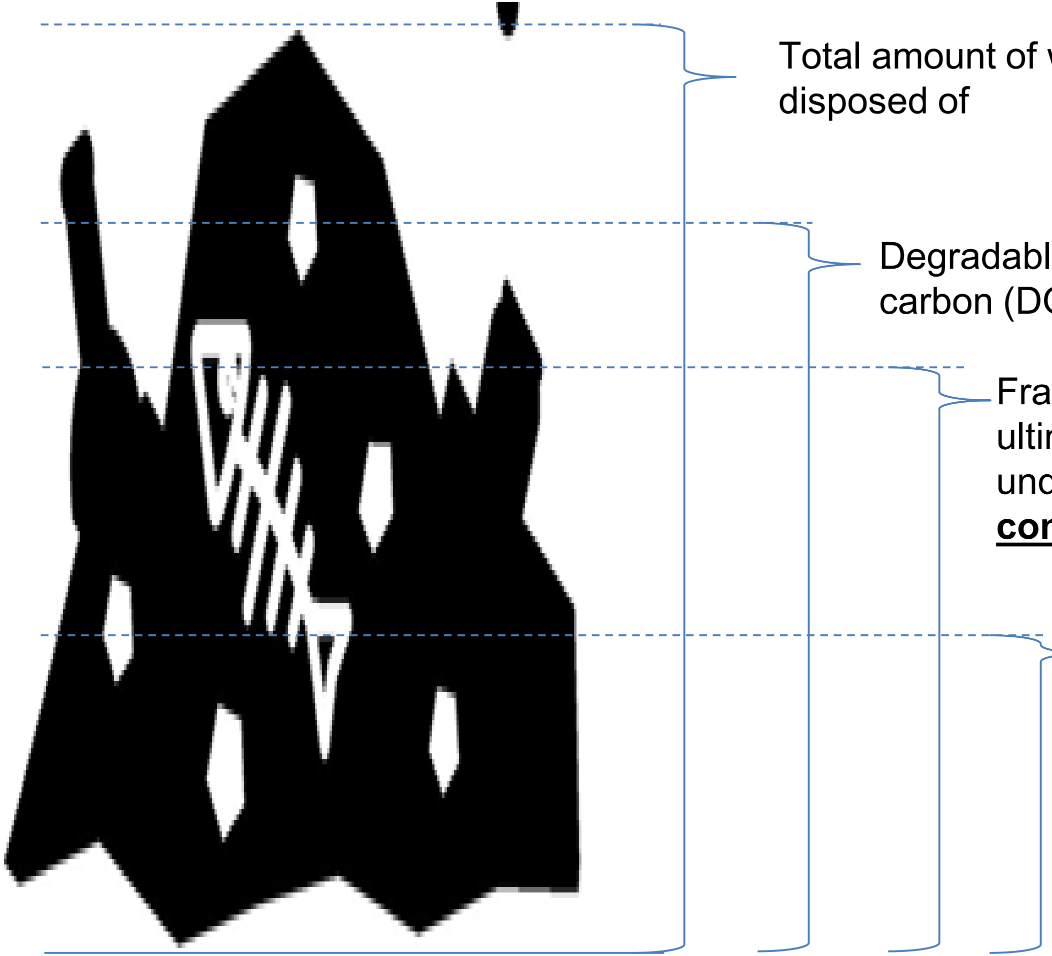
Method and data required to estimate CH4 emissions from Solid Waste Disposal

Methane emissions from Solid Waste Disposal

- Tier 1: Based on the IPCC FOD method using mainly default activity data and default parameters.
- Tier 2: Use the IPCC FOD method and some default parameters, but require good quality country-specific activity data on current and historical waste disposal at SWDS. Historical waste disposal data for 10 years or more should be based on country-specific statistics, surveys or other similar sources. Data are needed on amounts disposed at the SWDS.
- Tier 3: Use the FOD method with (1) nationally developed key parameters, or (2) measurement derived country-specific parameters. Alternatively, use country-specific methods that are of equal or higher quality.

- Treatment and disposal of municipal, industrial and other solid waste produces significant amount of methane (CH_4) with other gases such as CO_2, non-methane volatile organic compounds (NMVOC) through decomposition of degradable organic component (= degradable organic carbon: DOC) in the waste.





Total amount of waste disposed of

Degradable organic carbon (DOC)

Fraction of DOC that is ultimately degraded under **anaerobic conditions** (DOCf);

Part of DOC that actually decomposes under anaerobic conditions **depending on waste management practices at the disposal sites** – represented by "methane correction factor (MCF)";

Various factors affect decomposition and landfill gas generation

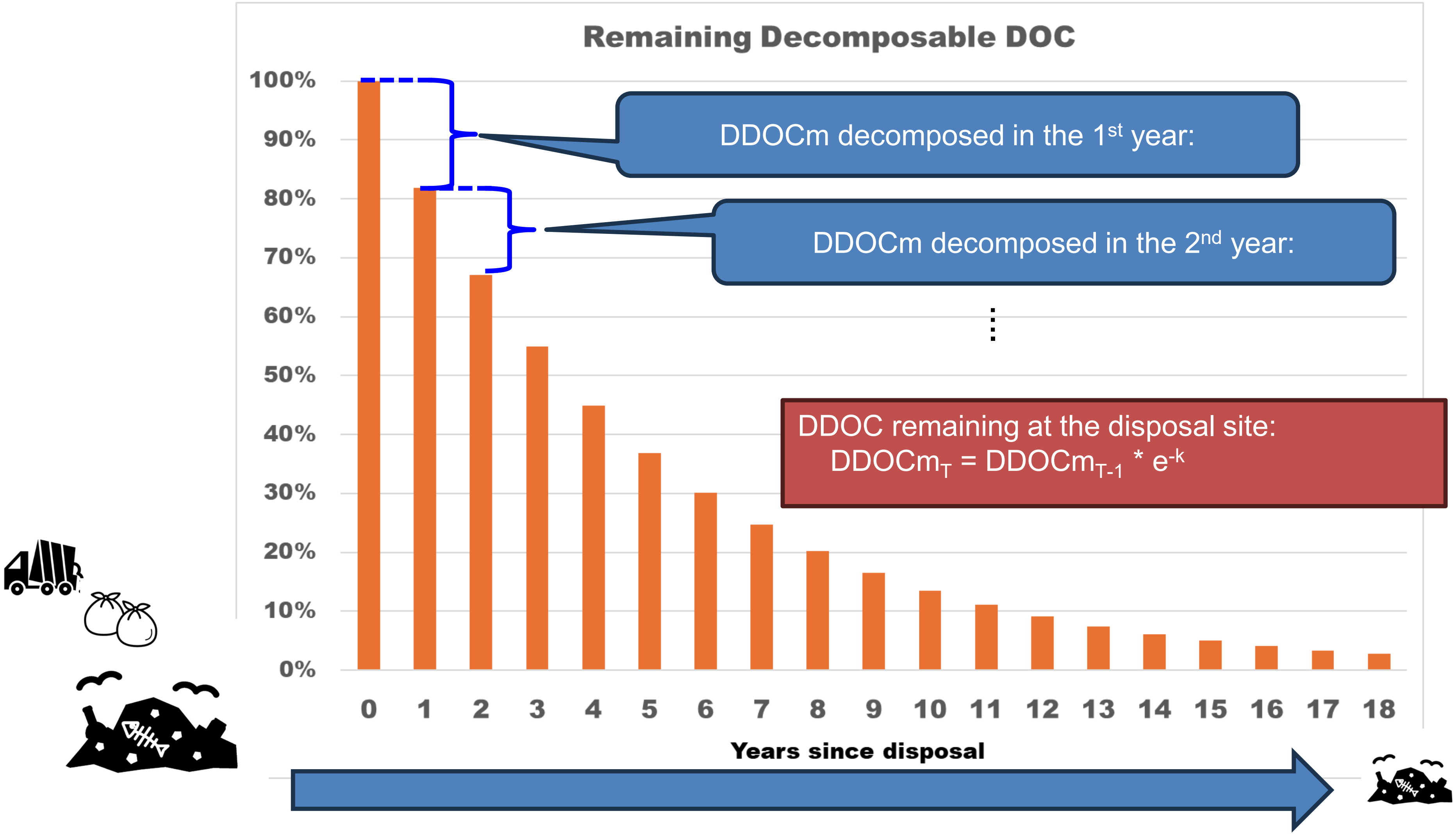
Landfill gas (including CH4) generated

Decomposable DOC (DDOCm)

The fractions mentioned above are different by type/material of waste.

First Order Decay (FOD) method

- Decomposition of DDOCm continues over many years.
- To estimate annual emissions of CH_4, it is necessary to know the amount of DDOCm decomposed in each year.
- The 2006 IPCC Guidelines suggest the First Order Decay (FOD) method--- which is built on an exponential factor that describes the fraction of degradable material which each year is degraded into CH_4 and CO_2.
  - Overall decomposition process can be approximated by first order kinetics.



Remaining Decomposable DOC
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
DDOCm decomposed in the 1st year:
DDOCm decomposed in the 2nd year:
DDOC remaining at the disposal site:
$DDOCm_T = DDOCm_{T-1} * e^{-k}$
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Years since disposal

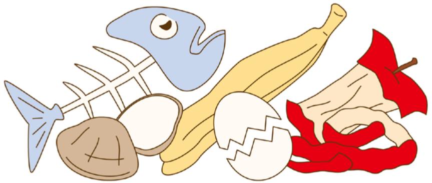
- Half-lives (time taken for the DOCm in waste to decay to half its initial mass) for different types of waste vary from a few years to several decades or longer.

$$DDOCm_T = DDOCm_{T-1} * e^{-k}$$

This reaction constant k depends on various factors, particularly waste type.

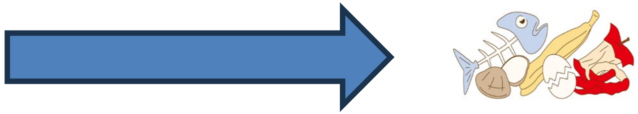
Wood waste

Slow decomposition



Food waste

Rapid decomposition



Waste deposited into the site in Year 0

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)

EQUATION 3.4
DDOCm ACCUMULATED IN THE SWDS AT THE END OF YEAR T

$$DDOCma_T = DDOCmd_T + \left(DDOCma_{T-1} \bullet e^{-k}\right)$$

EQUATION 3.5
DDOCm DECOMPOSED AT THE END OF YEAR T

$$DDOCm\ decomp_T = DDOCma_{T-1} \bullet \left(1 - e^{-k}\right)$$

Where:

T = inventory year

$DDOCma_T$ = DDOCm accumulated in the SWDS at the end of year *T*, Gg

$DDOCma_{T-1}$ = DDOCm accumulated in the SWDS at the end of year (*T*-1), Gg

$DDOCmd_T$ = DDOCm deposited into the SWDS in year *T*, Gg

DDOCm $decomp_T$ = DDOCm decomposed in the SWDS in year *T*, Gg

k = reaction constant, $k = \ln(2)/t_{1/2}$ (y^{-1})

$t_{1/2}$ = half-life time (y)

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)

- Mass of CH_4 generated should be calculated for each of different waste types using Equations 3.2– 3.6 above, and then should be summed up.

EQUATION 3.1
CH_4 EMISSION FROM SWDS

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

Where:

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)

Data necessary to collect

Type of data	Note
Amount of waste generated	**Municipal solid waste**: can be estimated as the product of the per capita waste generation rate (tonnes/capita/yr) for each waste component and population (capita). **Industrial waste**: No default data for FSM. The data should to the extent possible be collected by industry types.
Fraction of waste disposed to solid waste disposal sites	Alternatively, the amount of waste disposed to solid waste disposal sites may be directly obtained from surveys at each disposal site.
Waste composition	Regional default values are available in the 2019 Refinement (Vol.5, Chapter 2). However, it is advisable to obtain country-specific (or site-specific) data.

Data necessary to collect

Type of data	Note
Degradable Organic Carbon (DOC)	Default values for each waste type are available in the 2006 IPCC Guidelines (Vol.5, Chapter 2) and the 2019 Refinement(Vol.5, Chapter 2). However, it is advisable to obtain country-specific data.
Fraction of Degradable Organic Carbon Decomposed (DOCf)	Recommended default values are available in the 2019 Refinement (Vol.5, Chapter 3, Table 3.0 (New)).
Methane Correction Factor (MCF)	Default values for different types of disposal sites are available in the 2019 Refinement (Vol.5, Chapter 3, Table 3.1 (Updated)). It is important to appropriately classify each disposal site in the country by type of site.
Fraction of CH_4 in generated Landfill Gas (F)	The IPCC default value for the fraction of CH_4 in landfill gas (0.5) may be used.

Data necessary to collect

Type of data	Note
Methane Recovery (R)	CH_4 recovery should be reported only when references documenting the amount of CH_4 recovery are available. In the absence of such references, R should be zero. (Default value is zero.)
Oxidation Factor (OX)	The oxidation factor (OX) reflects the amount of CH_4 from SWDS that is oxidised in the soil or other material covering the waste. Default values are available in the 2019 Refinement (Vol.5, Chapter 3,Table 3.2).
half-life ($t_{1/2}$) or reaction constant (k)	It is important to use appropriate values for each waste type, taking other factors (e.g. temperature, moisture) into account. Default values are available in the 2019 Refinement (Vol.5, Chapter 3,Table 3.3).

Waste composition

- Regional default values are available in the 2019 Refinement (Vol.5, Chapter 2, see below). However, it is advisable to obtain country-specific (or site-specific) data.

TABLE 2.3 (UPDATED)
MSW COMPOSITION DATA BY PERCENT – REGIONAL DEFAULTS

Region	Food waste	Garden waste	Paper /cardboard	Wood	Textiles	Nappies	Rubber /Leather	Plastic	Metal	Glass	Other
Asia											
Central Asia	30.0	1.4	24.7	2.5	3.5	0	0	8.4	0.8	5.9	23.0
Eastern Asia	40.3	0.0	20.4	2.1	1.0	0.0	0.0	6.5	2.7	4.3	22.9
South-Eastern Asia	49.9	1.0	11.2	0.8	0.4	0.0	0.0	10.2	4.2	3.7	18.6
Southern Asia	66.1	0.0	9.2	0.0	1.2	0.0	0.4	7.0	0.9	1.5	13.9
Western Asia	42.2	3.2	15.3	0.8	3.0	0.4	0.3	17.2	2.5	3.4	11.8
Africa											
Northern Africa	50.4	0.0	12.1	0.0	5.8	0.0	0.0	13.8	4.4	3.3	[illegible]
Eastern Africa	44.4	6.9	10.4	0.5	3.0	0.0	0.4	8.0	2.6	2.1	[illegible]
Middle Africa	28.4	0	8	0	1.3	0	0	7.1	1.4	1.1	52.7

2019 Refinement, Vol.5, Chapter 2, Table 2.3 (Updated)

Degradable Organic Carbon (DOC)

- Although default values are available, the use of country-specific values is encouraged if data are available. Country-specific values can be obtained by performing waste generation studies, sampling at disposal sites combined with analysis of the degradable carbon content within the country.

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

2006 IPCC Guidelines, Vol.5, Chapter 2, Table 2.4

Methane Correction Factor (MCF)

- The MCF accounts for the fact that unmanaged solid waste disposal sites (SWDS) produce less CH4 from a given amount of waste than anaerobic managed SWDS.
- Quite important to appropriately classify each disposal site in the country by type of site.

TABLE 3.1 (UPDATED)
SWDS CLASSIFICATION AND METHANE CORRECTION FACTORS (MCF)

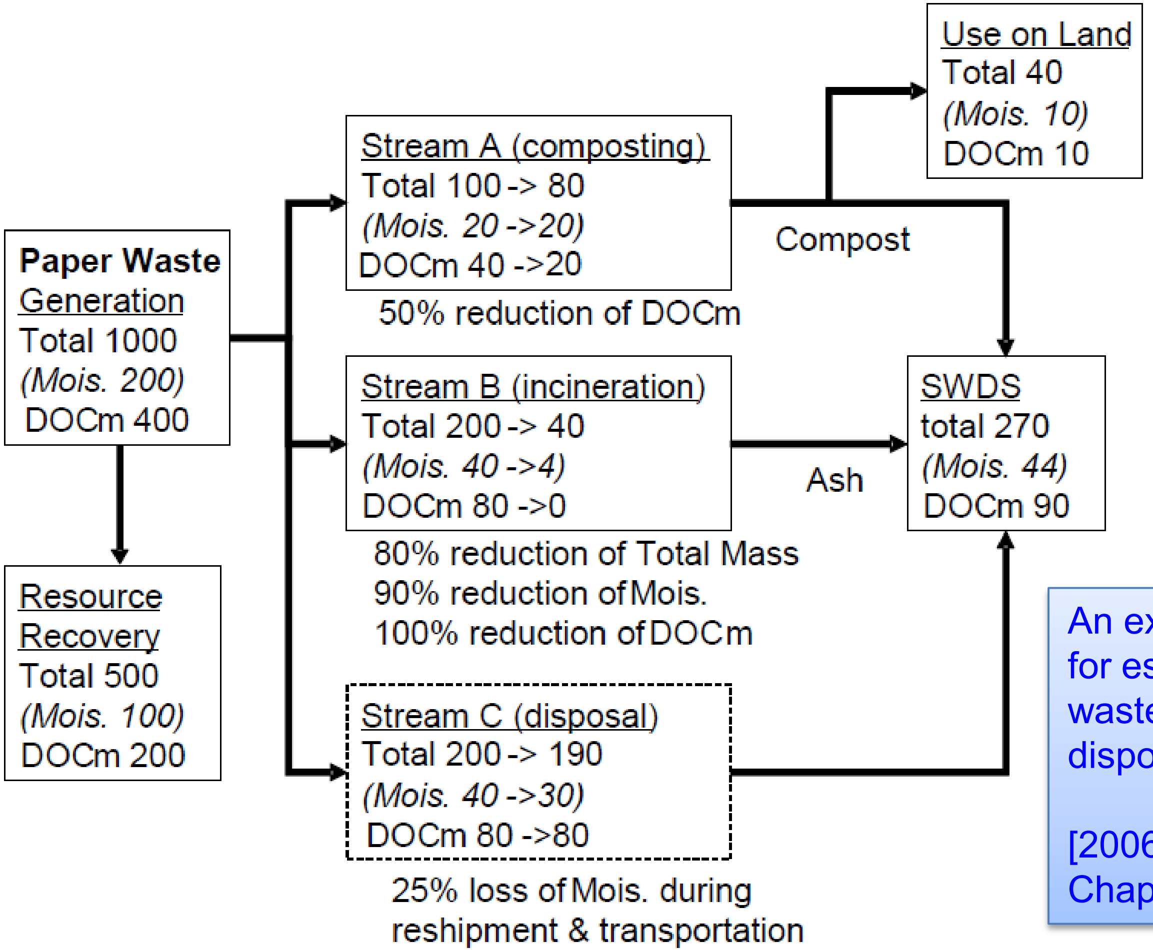
Type of Site	Methane Correction Factor (MCF) Default Values	Remarks
Managed – anaerobic	1.0[a]	These must have controlled placement of waste (i.e., waste directed to specific deposition areas, a degree of control of scavenging and a degree of control of fires) and will include at least one of the following: (i) cover material; (ii) mechanical compacting; or (iii) levelling of the waste.
Managed well – semi-aerobic	0.5[b]	When semi-aerobic managed SWDS type is managed under one of the following condition, it is regarded as well magement ; (i) permeable cover material; (ii) leachate drainage system without sunk; (iii) regulating pondage; and (iv) gas ventilation system without cap, (v) connection of leachate drainage system and gas ventilation system.
Managed poorly – semi-aerobic	0.7[c]	When semi-aerobic managed SWDS type is managed under one of the following condition, it is regarded as poor management; (i) condition of sunk of leachate

2019 Refinement, Vol.5, Chapter 3, Table 3.1 (Updated)

Waste stream analyses

- Waste treatment techniques are often applied in a chain or in parallel.
- A more accurate but data intensive approach to data collection is to follow the streams of waste from one treatment to another taking into account the changes in composition and other parameters that affect emissions.

Important to analyze the waste stream in order to grasp the overview of waste management taking place within the country so that CH_4 emissions from waste management in the country can be estimated as accurately as possible.



An example of applying the approach for estimating the amount of paper waste disposed at solid waste disposal sites (Hypothetical case)

[2006 IPCC Guidelines, Vol.5, Chapter 2, Box 2.1]

Method and data required to estimate CH_4 emissions from Livestock: Manure Management

Methane emissions from Manure Management

- Tier 1: Only requires livestock population data by animal species/category and climate region or temperature, in combination with IPCC default emission factors, to estimate emissions.
- Tier 2: Requires detailed information on animal characteristics and manure management practices, which is used to develop emission factors specific to the conditions of the country.
- Tier 3: Some countries for which livestock emissions are particularly important may wish to go beyond the Tier 2 method and develop models for country-specific methodologies or use measurement-based approaches to quantify emission factors.

Tier 2 method

EQUATION 10.22
CH_4 EMISSIONS FROM MANURE MANAGEMENT

$$CH_{4Manure} = \sum_{(T)} \frac{\left(EF_{(T)} \bullet N_{(T)}\right)}{10^6}$$

Where:

$CH_{4Manure}$ = CH_4 emissions from manure management, for a defined population, Gg CH_4 yr^{-1}

$EF_{(T)}$ = emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}

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

T = species/category of livestock

- **Country-specific emission factors should be developed through the equation on the next slide (Equation 10.23).**

EQUATION 10.23
CH_4 EMISSION FACTOR FROM MANURE MANAGEMENT

$$EF_{(T)} = \left(VS_{(T)} \bullet 365\right) \bullet \left[B_{o(T)} \bullet 0.67\, kg/m^3 \bullet \sum_{S,k} \frac{MCF_{S,k}}{100} \bullet MS_{(T,S,k)} \right]$$

Where:

$EF_{(T)}$ = annual CH_4 emission factor for livestock category *T*, kg CH_4 $animal^{-1}$ yr^{-1}

$VS_{(T)}$ = daily volatile solid excreted for livestock category *T*, kg dry matter $animal^{-1}$ day^{-1}

365 = basis for calculating annual VS production, days yr^{-1}

$B_{o(T)}$ = maximum methane producing capacity for manure produced by livestock category *T*, m^3 CH_4 kg^{-1} of VS excreted

0.67 = conversion factor of m^3 CH_4 to kilograms CH_4

$MCF_{(S,k)}$ = methane conversion factors for each manure management system *S* by climate region *k*, %

$MS_{(T,S,k)}$ = fraction of livestock category *T*'s manure handled using manure management system *S* in climate region *k*, dimensionless

Data necessary to collect

Manure characteristics

Type of data	Note
Daily volatile solid excreted for livestock category T (VS(T))	Can be estimated based on feed intake and digestibility, which are the variables also used to develop the Tier 2 enteric fermentation emission factors. Alternatively, it can be estimated based on laboratory measurements of livestock manure.
Maximum methane producing capacity for manure produced by livestock category T (Bo(T))	Varies by animal species and feed regimen and is a theoretical methane yield based on the amount of VS in the manure. The preferred method to obtain Bo measurement values is to use data from country-specific published sources, measured with a standardised method. It is important to standardise the Bo measurement, including the method of sampling. If country-specific Bo measurement values are not available, default values are provided in Tables 10A-4 through 10A-9 in Chapter 10, Volume 4 of the 2006 IPCC Guidelines..

Data necessary to collect

Manure management system characteristics

Type of data	Note
Methane conversion factors for each manure management system S by climate region k (MCF(S, k))	Determined for a specific manure management system and represent the degree to which Bo is achieved. The amount of methane generated by a specific manure management system is affected by the extent of anaerobic conditions present, the temperature of the system, and the retention time of organic material in the system. Default methane conversion factors (MCFs) are provided in Table 10.17 of Chapter 10, Volume 4 of the 2006 IPCC Guidelines for different manure management systems and by annual average temperatures..

Data necessary to collect

Type of data	Note
Fraction of livestock category T's manure handled using manure management system S in climate region k (MS(T, S, k))	The portion of manure managed in each manure management system must be collected for each representative animal species.
Number of head of livestock species/category T (N(T))	

Obtaining data/information on manure management systems used in the country is important.

TABLE 10.18
DEFINITIONS OF MANURE MANAGEMENT SYSTEMS

System	Definition
Pasture/Range/Paddock	The manure from pasture and range grazing animals is allowed to lie as deposited, and is not managed.
Daily spread	Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion.
Solid storage	The storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to be stacked due to the presence of a sufficient amount of bedding material or loss of moisture by evaporation.
Dry lot	A paved or unpaved open confinement area without any significant vegetative cover where accumulating manure may be removed periodically.
Liquid/Slurry	Manure is stored as excreted or with some minimal addition of water in either tanks or earthen ponds outside the animal housing, usually for periods less than one year.

Uncovered anaerobic lagoon	A type of liquid storage system designed and operated to combine waste stabilization and storage. Lagoon supernatant is usually used to remove manure from the associated confinement facilities to the lagoon. Anaerobic lagoons are designed with varying lengths of storage (up to a year or greater), depending on the climate region, the volatile solids loading rate, and other operational factors. The water from the lagoon may be recycled as flush water or used to irrigate and fertilise fields.
Pit storage below animal confinements	Collection and storage of manure usually with little or no added water typically below a slatted floor in an enclosed animal confinement facility, usually for periods less than one year.
Anaerobic digester	Animal excreta with or without straw are collected and anaerobically digested in a large containment vessel or covered lagoon. Digesters are designed and operated for waste stabilization by the microbial reduction of complex organic compounds to CO_2 and CH_4, which is captured and flared or used as a fuel.
Burned for fuel	The dung and urine are excreted on fields. The sun dried dung cakes are burned for fuel.
Cattle and Swine deep bedding	As manure accumulates, bedding is continually added to absorb moisture over a production cycle and possibly for as long as 6 to 12 months. This manure management system also is known as a bedded pack manure management system and may be combined with a dry lot or pasture.
Composting - in-vessel[a]	Composting, typically in an enclosed channel, with forced aeration and continuous mixing.
Composting - Static pile[a]	Composting in piles with forced aeration but no mixing.

Composting - Intensive windrow[a]	Composting in windrows with regular (at least daily) turning for mixing and aeration.
Composting - Passive windrow[a]	Composting in windrows with infrequent turning for mixing and aeration.
Poultry manure with litter	Similar to cattle and swine deep bedding except usually not combined with a dry lot or pasture. Typically used for all poultry breeder flocks and for the production of meat type chickens (broilers) and other fowl.
Poultry manure without litter	May be similar to open pits in enclosed animal confinement facilities or may be designed and operated to dry the manure as it accumulates. The latter is known as a high-rise manure management system and is a form of passive windrow composting when designed and operated properly.
Aerobic treatment	The biological oxidation of manure collected as a liquid with either forced or natural aeration. Natural aeration is limited to aerobic and facultative ponds and wetland systems and is due primarily to photosynthesis. Hence, these systems typically become anoxic during periods without sunlight.

[a] Composting is the biological oxidation of a solid waste including manure usually with bedding or another organic carbon source typically at thermophilic temperatures produced by microbial heat production.

Method and data required to estimate CH4 emissions from Wastewater Treatment and Discharge

Methane emissions from Wastewater Treatment and Discharge

- Tier 1: Applies default values for the emission factor and activity parameters. This method is considered good practice for countries with limited data.
- Tier 2: Follows the same method as Tier 1 but allows for incorporation of a country specific emission factor and country specific activity data.
- Tier 3: For a country with good data and advanced methodologies, a country specific method could be applied as a Tier 3 method. A more advanced country-specific method could be based on plant-specific data from large wastewater treatment facilities.

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 6.3
TOTAL ORGANICALLY DEGRADABLE MATERIAL IN DOMESTIC WASTEWATER

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

Where:

TOW	=	total organics in wastewater in inventory year, kg BOD/yr
P	=	country population in inventory year, (person)
BOD	=	country-specific per capita BOD in inventory year, g/person/day,
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.)

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.

Obtaining data/information on treatment/discharge pathways or systems used in the country is important.

Figure 6.2 Decision Tree for CH_4 emissions from domestic wastewater

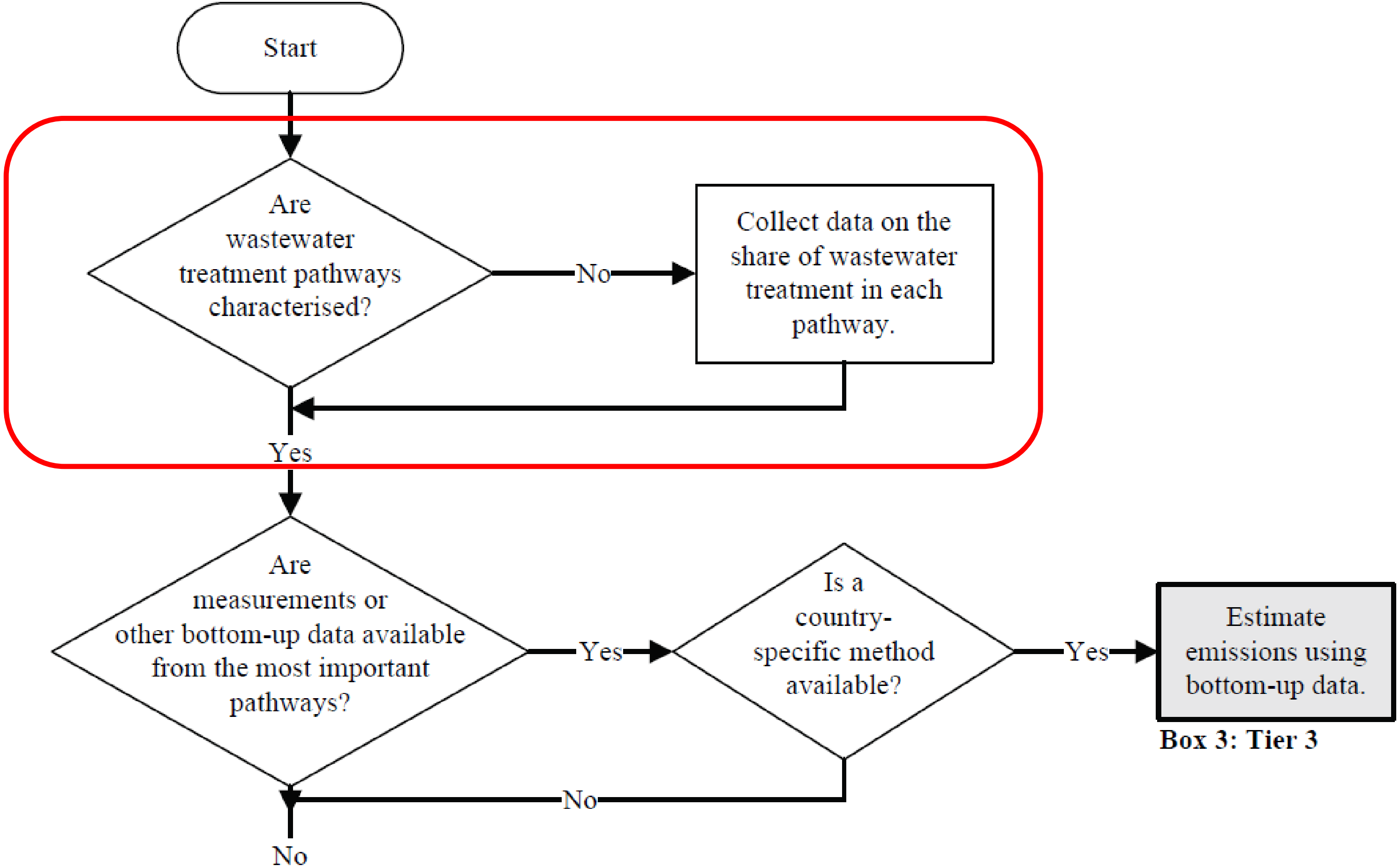
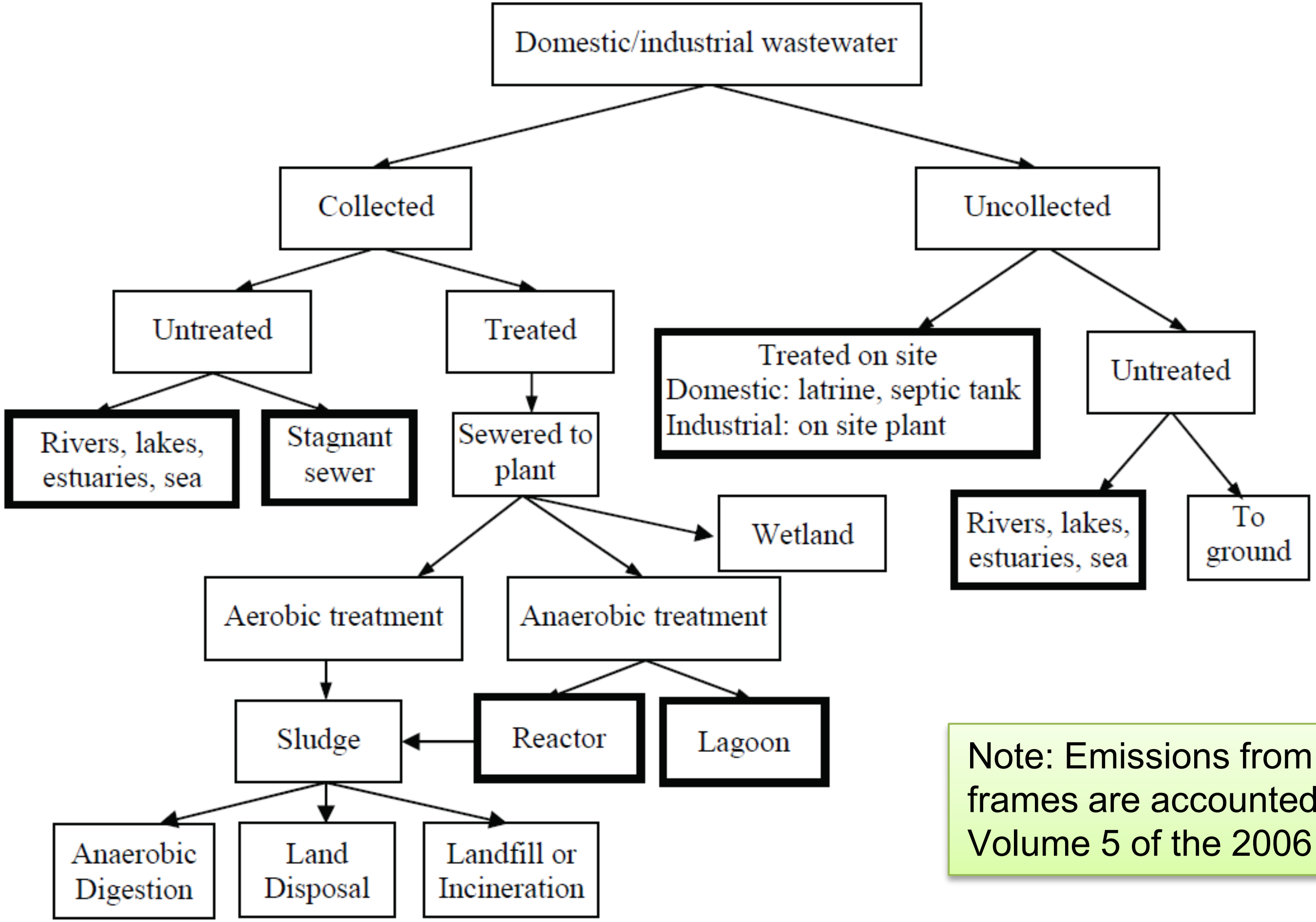


Figure 6.1 Wastewater treatment systems and discharge pathways



Note: Emissions from boxes with bold frames are accounted for in Chapter 6, Volume 5 of the 2006 IPCC Guidelines.