United Nations
Climate Change

UNFCCC BTR REVIEW TRAINING: COURSE B

TECHNICAL REVIEW OF NATIONAL INVENTORY REPORTS OF ANTHROPOGENIC EMISSIONS BY SOURCES AND REMOVALS BY SINKS OF GHG

SUB COURSE B6: WASTE SECTOR

FIRST EDITION
September 2023

GHG Inventory Review Training Course

Waste Sector

United Nations Framework Convention on Climate Change

Abbreviations and acronyms

2019 Refinement to the 2006 IPCC Guidelines	*2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*
2006 IPCC Guidelines	*2006 IPCC Guidelines for National Greenhouse Gas Inventories*
AD	activity data
BOD	biochemical oxygen demand
BTR	biennial transparency report
CH_4	methane
CO_2	carbon dioxide
CO_2 eq	carbon dioxide equivalent
COD	chemical oxygen demand
CRT	common reporting table
DOC	degradable organic carbon
EF	emission factor
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	statistical database of the Food and Agriculture Organization of the United Nations
FOD	first-order decay
GDP	gross domestic product
GHG	greenhouse gas
GWP	global warming potential
IE	included elsewhere
IEF	implied emission factor
IPCC	Intergovernmental Panel on Climate Change
IW	industrial waste
LandGEM	Landfill Gas Emissions Model
LULUCF	land use, land-use change and forestry
MBT	mechanical biological treatment
MCF	methane correction factor
MPGs	modalities, procedures and guidelines for the transparency framework for action and support referred to in Article 13 of the Paris Agreement, set out in the annex to decision 18/CMA.1
MSW	municipal solid waste
N_2O	nitrous oxide
NA	not applicable

NCV	net calorific value
NE	not estimated
NID	national inventory document
NIR	national inventory report
NMVOC	non-methane volatile organic compound
NO	not occurring
NO_X	nitrogen oxides
QA/QC	quality assurance/quality control
SO_2	sulfur dioxide
SWDS	solid waste disposal site
TACCC	transparency, accuracy, completeness, consistency and comparability
TERR	technical expert review report
TERT	technical expert review team
TOW	total organic waste
Wetlands Supplement	*2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*
WWTP	wastewater treatment plant

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Lesson 1: Introduction

1. Overview and learning objectives

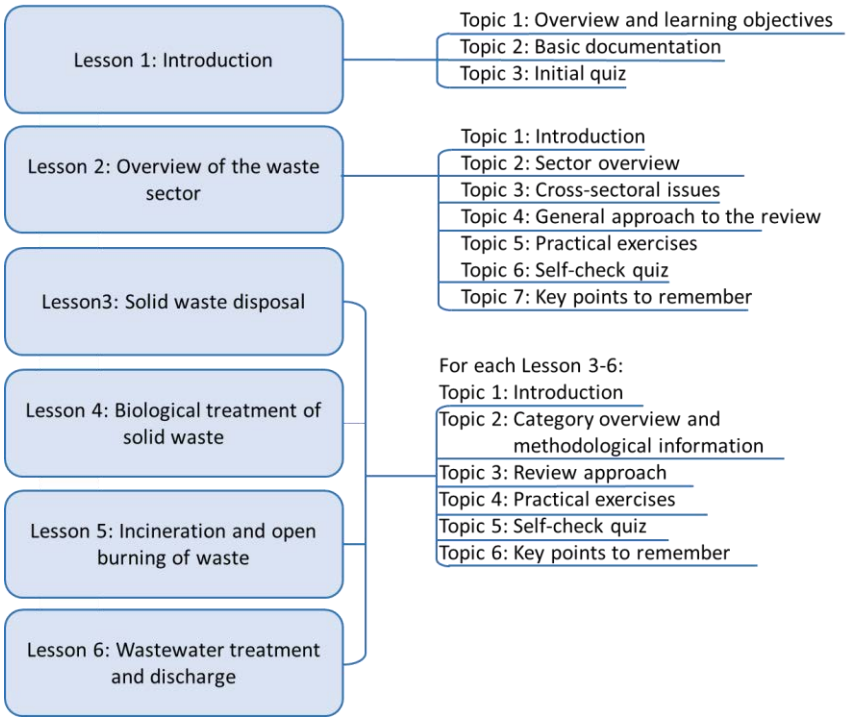
Welcome to the online training programme for the technical review of the national GHG inventory. This course will provide you with an understanding of the key actions and elements of the technical review of national inventories for the waste sector. For inventory purposes the waste sector is organized in four categories:

- Solid waste disposal (category 5.A);
- Biological treatment of solid waste (category 5.B);
- Incineration and open burning of waste (category 5.C);
- Wastewater treatment and discharge (category 5.D)

1.1. Course coverage

The course consists of six lessons, reflecting the structure of the waste sector as shown in the figure 1.1 below. Each lesson provides examples illustrating how theory is implemented in practice and includes exercises and quizzes to help you in evaluating your knowledge.

A. Figure 1.1: Outline of the waste course



1.2. Learning objectives

The overall course provides you with the background information you will need to become an efficient member of a technical expert review team (TERT). Completing the course will advance your skills, in the sense that you will:

- Enhance your overall knowledge of the methodologies used to quantify GHG emissions from waste;
- Enhance your knowledge on issues that impact emissions of more than one subsector (cross-cutting issues);
- Be able to successfully prepare for the review, assess the quality of the emission inventory and report your findings in the review report.

This first lesson provides information on the basic background documentation for the review of the waste sector emission estimates and an initial quiz that will test your knowledge of the 2006 IPCC Guidelines.

1.3. Expected time needed to complete lesson 1

- For readers with experience in GHG emission inventories: 1 hour
- For readers with less experience in GHG inventories: 2–3 hours

2. Basic documentation

2.1. Reference documentation under the enhanced transparency framework under the Paris Agreement

The main guidance and overarching principles related to the technical expert review of national GHG inventories according to the MPGs set out in the annex to decision 18/CMA.1 are discussed in the "General guidance and cross-cutting issue" course (lesson 1, topic 2, and lesson 2, topic 3). You can download decision 18/CMA.1 at https://unfccc.int/documents/193408.

In this lesson you will learn more about reporting on the waste sector in the NID, the outline of which is contained in annex V to decision 5/CMA.3 (https://unfccc.int/documents/460951). Annex I to the same decision contains a link to the CRTs (https://unfccc.int/documents/311076)

2.2. Methodological background

Volume 5 of the 2006 IPCC Guidelines provides the specific methodological guidance for the development of a national GHG inventory of the waste sector.

General cross-cutting issues on data collection, methodological choice, time-series consistency and QA/QC are covered in volume 1 of the 2006 IPCC Guidelines and discussed in more detail in the "General guidance and cross-cutting issue" course. However, in this course, some information will be repeated, whenever relevant for review of the waste sector.

Download all chapters of volume 5 of the 2006 IPCC Guidelines (www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html) before starting lessons 2–5. As a reviewer, you will make intensive use of volume 5 of the 2006 IPCC Guidelines; having your own copy allows you to mark parts of the Guidelines that you consider important. You can also add your own comments to the text. Depending on your personal preferences, you might decide to print out a hard copy or to keep your personal set of marked-up PDFs.

All chapters of volume 1 (www.ipcc-nggip.iges.or.jp/public/2006gl/vol1.html) should also be downloaded. This volume is important but less frequently used. We advise you to only print the paragraphs that are relevant as you encounter them during this course or during your future activities as a reviewer

Download an example of the CRT from https://unfccc.int/documents/311076

During the course we will refer many times to the 2006 IPCC Guidelines and CRTs, and therefore it is suggested that you have them to hand and consult them as necessary.

Note that in addition to the originally published English version of the 2006 IPCC Guidelines there are five other language versions (Arabic, Chinese, French, Russian and Spanish); however, the corrections (corrigenda) are mainly made in the English version, hence you are recommended to consult the English version when drawing any final conclusions during your assessments of GHG inventory information.

Note that technical knowledge of methodologies in the 2006 IPCC Guidelines is a prerequisite to taking part in the "General guidance and cross-cutting issues" course and this waste sector course. These courses have been devised for technical expert reviewers of national GHG inventories who would like to become expert reviewers under the ETF. Therefore, this course does not replace the need to be familiar with methods and guidance reported as good practice in the 2006 IPCC Guidelines.

3. Initial quiz to test knowledge of the 2006 IPCC Guidelines

This initial quiz tests your knowledge of the 2006 IPCC Guidelines. If you feel that you are not experienced enough in this field but you are still interested in becoming an expert reviewer, you will need to make an extra effort to study the methodological guidance in the 2006 IPCC Guidelines for the waste sector and the relevant materials in volume 1 of these guidelines, in addition to studying this course.

After answering each question, you can consult the correct answer and the corresponding explanation at the end of this section. For further information, a reference to the corresponding section(s) of the 2006 IPCC Guidelines is also provided.

Question 1

A tier 1 estimate of CH_4 emissions from solid waste disposal is based on:

A. The IPCC FOD method provided by the 2006 IPCC Guidelines and country-specific information on waste generation and composition
B. The IPCC FOD method provided by the 2006 IPCC Guidelines and default AD and parameters
C. A country-specific method to quantify CH_4 emissions
D. Any combination of A, B and C, depending on regional circumstances

Question 2

During the composting process, most solid organic materials are converted to CO_2, which is subsequently released. Part of the organic material might decompose under anaerobic conditions and this results in CH_4 emissions.

Which of the following statements is true?

A. Emissions of CO_2 need to be quantified and included in the inventory. Emissions from CH_4 can be disregarded because emissions are generally insignificant
B. Emissions of CH_4 need to be quantified. CO_2 emissions can be disregarded, since CO_2 is from a biogenic origin
C. Both CO_2 emissions and CH_4 emissions need to be quantified and included in the inventory
D. Both CO_2 and CH_4 can be disregarded in the inventory

Question 3

A dry climate (with less precipitation than evaporation) will _____ the methanogenic processes in solid waste disposal sites, in contrast to a wet climate (with excess precipitation).

A. Accelerate
B. Decelerate
C. Stop
D. Have no influence on

Question 4

A Party calculates CH_4 emissions from composting, assuming the default CH_4 EF from the 2006 IPCC Guidelines. What CH_4 EF (on a wet weight basis) could be used by the Party?

A. 10 kg/t
B. 4 g/t
C. 4 kg/t
D. 10 g/t

Question 5

Another Party calculates CH_4 emissions from composting, assuming a country-specific CH_4 EF. What information is appropriate as a justification of this country-specific EF?

A. Country-specific data, published in peer-reviewed journals, with the additional justification that measurements are performed at representative composting installations
B. CH_4 EFs from another country, with the additional justification that the composting installations in this other country are similar to the installations of the Party
C. An EF from the OECD Emission Factor Database
D. A and B
E. A, B and C

Question 6

Which international organization provides data on protein supply/consumption that can be used in the estimation of N_2O emissions from domestic wastewater treatment and discharge?

A. FAO
B. Eurostat
C. International Energy Agency
D. World Bank

Question 7

Which of the parameters COD or BOD will have a higher numerical value for the same wastewater sample?

A. COD
B. BOD
C. They are equal
D. They have no numerical values

Question 8

Which parameters are used in the quantification of CO_2 emissions from incineration of municipal solid waste, with known fractions of paper, wood and plastics?

A. WF_j, dm_j, MCF, CF_j, FCF_j, OF_j
B. SW_i, dm_j, MCF, CF_j, FCF_j, OF_j
C. SW_i, dm_j, CF_j, FCF_j, OF_j
D. WF_j, dm_j, CF_j, FCF_j, OF_j

Question 9

A Party has produced emissions estimates for waste disposed of at solid waste disposal sites from 1985 onwards, using the IPCC waste model which is based on the FOD method from the 2006 IPCC guidelines. For the quantification of CH_4 emissions for 2005, this Party should use historical data since which year?

A. 1955
B. 1985
C. 2004
D. 2005

Question 10

AD on open burning can be based on which of the following?

A. The fraction of the population whose waste is not collected
B. The fraction of the population whose waste is collected and partially burned at open dumps
C. The rural population
D. A, B and C

Question 11

Which of the following correctly completes the sentence?
Open burning of waste on unmanaged SWDS

A. Does not affect CH_4 emissions from SWDS, as reported under category 5.A
B. Reduces CH_4 emissions from SWDS, as reported under category 5.A
C. Completely reduces CH_4 emissions from SWDS, as reported under category 5.A
D. Does not result in N_2O emissions

Question 12

Which of the following correctly completes the sentence?
Uncollected domestic wastewater can be

A. Discharged into a river
B. Treated in open pits or latrines
C. Treated in a wastewater treatment plant
D. A and B
E. A, B and C

3.1. Answers to initial quiz

Question 1
The correct answer is B.
The estimations of the tier 1 methods are based on the IPCC FOD method using mainly default AD and default parameters. This method assumes that the degradable organic component "DOC" in waste decays slowly over a few decades, during which CH_4 and CO_2 are formed. If conditions are constant, the rate of CH_4 production depends solely on the amount of carbon remaining in the waste. As a result, emissions of CH_4 from waste deposited in a disposal site are highest in the first few years after deposition then gradually decline as the degradable carbon in the waste is consumed by the bacteria responsible for the decay.

Please note that only a few reviewers will be able to answer such a question without consulting the 2006 IPCC Guidelines.

To learn more, consult the 2006 IPCC Guidelines (vol. 5, chap. 3, pp.3.6 and 3.7).

Question 2
The correct answer is B.
CO_2 from composting is of biogenic origin and not taken into account in the national total emissions. Composting does result in CH_4 emissions and needs to be quantified. For this purpose, default CH_4 EFs are provided in the 2006 IPCC Guidelines (vol. 5, chap. 4, table 4.1, p.4.6).
To learn more, consult the 2006 IPCC Guidelines (vol. 5, chap. 4, pp.4.4–4.6).

Question 3
The correct answer is B.
Decreased precipitation will decelerate the activity of methanogenic bacteria because it results in a reduced moisture content in the waste which inhibits metabolic processes. Increased precipitation generally enhances the effect of methanogenic bacteria. This is also reflected in the default CH_4 generation rates set out in the 2006 IPCC Guidelines (vol. 5, chap. 3, table 3.3, p.3.17): k values in a boreal and temperate wet climate (e.g. 0.09 y^{-1} for bulk waste) are higher than k values in a boreal and temperate dry climate (0.05 y^{-1} for bulk waste). For a tropical wet climate the default value for bulk waste is 0.17 y^{-1} and for a tropical dry climate 0.065 y^{-1}.
To learn more, consult the 2006 IPCC Guidelines (vol. 5, chap. 3, pp.3.15–3.18).

Question 4
The correct answer is C.
The 2006 IPCC Guidelines provide default CH_4 EFs to calculate CH_4 emissions. Table 4.1 (vol. 5, chap. 4) provides default values for composting. The CH_4 EF (on a wet weight basis) is 4 g/kg waste treated, which is the same as 4 kg/t.
To learn more, consult the 2006 IPCC Guidelines (vol. 5, chap. 4, table 4.1, p.4.6).

Question 5

The correct answer is D.

The 2006 IPCC Guidelines (vol. 1, chap. 2, pp.2.12–2.14) provide guidance on EFs. Table 2.2 (p. 2.13) indicates that the material mentioned in answers A and B are potential sources for a country-specific EF, on the condition that justification is provided that the EFs are determined at composting installations that are representative of the Party's composting plants. EFs from the OECD Emission Factor Database are mentioned (in table 2.2) as being useful for cross-checking, but may not be representative of composting installations of the Party. If a Party decides to use the EF from the OECD Emission Factor Database, additional justification is required.

To learn more, consult the 2006 IPCC Guidelines (vol. 1, chap. 2, pp.2.12–2.14 and table 2.2 in particular).

Question 6

The correct answer is A.

The 2006 IPCC Guidelines (vol. 5, chap. 6, section 6.3.1.3) provides information on choice of AD to estimate N_2O emissions from domestic wastewater treatment and discharge. Page 6.25 specifies that "per capita protein generation consists of intake (consumption), which is available from the Food and Agriculture Organization (FAO, 2004)."

To learn more, consult the 2006 IPCC Guidelines (vol. 5, chap. 6, section 6.3.1.3, p.6.25). Please note that the FAO statistics no longer provide protein consumption data but instead provide protein supply data. The 2019 Refinement (vol. 5. chap. 6, Table 6.10A (New)) provides default factors to calculate protein consumption as a fraction of protein supply.

Question 7

The correct answer is A.

The BOD concentration indicates only the amount of carbon that is aerobically biodegradable. The standard measurement for BOD is a 5-day test, denoted as BOD_5. The term 'BOD' in the 2006 IPCC Guidelines refers to BOD_5. The COD measures the total material available for chemical oxidation (both biodegradable and non-biodegradable).

To learn more, consult the 2006 IPCC Guidelines (vol. 5, chap. 6, p.6.7).

Question 8

The correct answer is D.

The 2006 IPCC Guidelines (vol. 5, chap. 5, p 5.7) provide two equations to quantify CO_2 emissions from the incineration of waste: equation 5.1 and 5.2. According to the text, just above equation 5.2, for MSW it is good practice to calculate the CO_2 emissions on the basis of waste composition (i.e. waste types/material such as paper, wood, plastics) in the waste incinerated. Equation 5.2 uses the parameters from answer D.

To learn more, consult the 2006 IPCC Guidelines (vol. 5, chap. 5, section 5.2.1, pp.5.6–5.8).

Question 9

The correct answer is A.

The IPCC methodology for estimating CH_4 emissions from SWDS is based on the FOD method from the 2006 IPCC Guidelines (vol. 5, chap. 3, p.3.6). According to the Guidelines (p.3.12), it requires data on solid waste disposal (amounts and composition) that are collected by default for 50 years. To calculate emissions in 2005, waste disposed since 1955 should be taken into account. In most cases this information is not available and historical AD have to be estimated.

To learn more, consult the 2006 IPCC Guidelines (vol. 5, chap. 3, pp.3.6 and 3.12).

Question 10

The correct answer is D.

According to the 2006 IPCC Guidelines (vol. 5, chap. 5, p.5.16), in a developed country, P_{frac} can be assumed to be the rural population for a rough estimate (i.e. answer C). In a developing country, mainly in urban areas, P_{frac} can be roughly estimated as being the sum of population whose waste is not collected by collection structures and population whose waste is collected and disposed in open dumps that are burned (i.e. answer A and B).

To learn more, consult the 2006 IPCC Guidelines (vol. 5, chap. 5, p.5.16).

Question 11

The correct answer is B.

This is a cross-sectoral issue and several considerations are relevant:

Waste that is burned is no longer available to generate CH_4 via methanogenesis of organic material. The 2006 IPCC Guidelines (vol. 5, chap. 3, p.3.12) indicate that when open burning takes place at SWDS, the amount of waste available for decay should be adjusted in the calculation of CH_4 emissions from SWDS.

However, combustion of waste in open burning is incomplete and therefore not all CH_4 generation is avoided. The 2006 IPCC Guidelines (vol. 5, chap. 5, pp.5.11 and 5.16) indicate that when a substantial quantity of waste is burned in open dumps, a relatively large part is left unburned. So upon open burning, part of the waste that is not oxidized generates CH_4 emissions which should be quantified.

Overall CH_4-emissions from SWDS are reduced, but CH4 emissions due to the incomplete combustion of the waste in open burnings still occur. In addition, upon open burning N_2O emissions will occur and need to be also quantified (2006 IPCC Guidelines, vol. 5, chap. 5, pp.5.13–5.15). .

To learn more, consult the 2006 IPCC Guidelines (vol. 5, chap. 3, p 3.12; chap. 5, p.5.11 and 5.16; and chap. 5, pp.5.13–5.15).

Question 12

The correct answer is D.

The 2006 IPCC Guidelines (vol. 5, chap. 6, figure 6.1, p.6.7, and table 6.1, p.6.8) provide an overview of types of treatment and discharge systems. Uncollected wastewater can be treated in open pits and latrines or can be discharged into a river without prior treatment. Treatment in wastewater treatment plants occurs only after collection of wastewater in a sewer system.

To learn more, consult the 2006 IPCC Guidelines (vol. 6, chap. 6, pp.6.7–6.8).

Lesson 2: Overview of the waste sector

1. Introduction

This lesson discusses emissions generated from the treatment of waste and assumes that the reader has prior knowledge of the 2006 IPCC Guidelines, volume 5, chapters 1 and 2.

The lesson consists of seven topics:

Topic 1: Introduction
Topic 2: Sector overview
Topic 3: Cross-sectoral issues
Topic 4: Overall review approach
Topic 5: Practical exercises
Topic 6: Self-check quiz
Topic 6: Key points to remember

1.1. Learning objectives

At the end of this lesson, you should be able to:

- Identify the most important categories and gases emitted in the waste sector;
- Identify key areas to watch out for when reviewing the waste sector, in particular possible double counting or omission of emissions in the reporting;
- Understand how to apply the general assessment of cross-cutting issues in the review of the waste sector.

1.2. Expected time needed to complete lesson 2

- For readers with experience in GHG emission inventories: 2–4 hours
- For readers with less experience in GHG inventories: 4–8 hours

2. Sector overview

2.1. Categories in the waste sector

The waste sector consists of four categories, each of which is divided into subcategories. In addition, a fifth category, 'other' can be used whenever country-specific activities occur within the waste sector that are not covered by the first four categories but do generate GHG emissions.

Table 2.1 summarizes the major waste sector categories, the chapters of the 2006 IPCC Guidelines that provide the methodologies to estimate the GHG emissions and the CRT for reporting the emissions for each category. Lessons 3 to 6 describe the four categories in more detail.

Table 2.1. The categories of the waste sector

	Category	GHG	2006 IPCC Guidelines reference	Common reporting table	Lesson for the category
5.A	*Solid waste disposal*	CH_4	Vol. 5, chaps. 2 and 3	CRT 5.A	3
5.B	*Biological treatment of solid waste*	CH_4, N_2O	Vol. 5, chaps. 2 and 4	CRT 5.B	4
5.C	*Incineration and open burning of waste*	CO_2, CH_4, N_2O	Vol. 5, chaps. 2 and 5	CRT 5.C	5
5.D	*Wastewater treatment and discharge*	CH_4, N_2O	Vol. 5, chaps. 2 and 6	CRT 5.D	6

- The organization of categories and subcategories in the CRTs is the mandatory structure for reporting emissions under the waste sector.
- The chapters in the NID and the CRTs closely follow the sector split of the 2006 IPCC Guidelines.
- CO_2 emissions may occur from activities under all categories. However, when CO_2 comes from a biogenic source (e.g anaerobic digestion of organic waste) it is not included in the national totals. However, when the CO_2 comes from a non-biogenic source (e.g. for waste incineration, part of the CO_2 comes from a fossil source) these emissions should be included in the inventory.
- Waste management may also result in emissions of precursor gases: carbon monoxide, NO_X, NMVOCs and SO_2. There are no specific methodologies suggested for each of them provided in the 2006 IPCC Guidelines, but rather references to the available methodologies in the EMEP/CORINAIR Emission Inventory Guidebook (see 2006 IPCC Guidelines, vol. 1, chap. 7). Parties should provide estimates for these gases, if relevant.
- Paragraph 28 of decision 5/CMA.3 indicates that Parties may use on a voluntary basis the 2019 Refinement to the 2006 IPCC Guidelines. Please note that it provides some amendments and new methodologies for the waste sector, as specified in the lessons for each of the categories.

Box: CO_2 from biogenic carbon

According to the 2006 IPCC Guidelines (vol. 1, chap. 1, p.1.6) CO_2 emissions resulting from the combustion or biodegradation of biogenic material (e.g. food waste, wood and paper) are not included in national total emissions. This is because the carbon is of biogenic origin and is captured from the atmosphere due to the growth of plants and trees. Thus, over the relatively short product lifespan (e.g. of the food, wood and paper) from growth to decay, there are no net CO_2 emissions. Any imbalance between carbon fixation and CO_2 emissions at the end-of-life of the product, results in carbon stock change in living biomass and this is accounted for under the LULUCF sector.

CO_2 emissions due to incineration and open burning of materials containing fossil carbon are included in the national total emissions (category 5.C). Such materials are unlikely to biodegrade in the conditions present in SWDS, installations for biological treatment and in wastewater. As a result,

category 5.A (SWDS), 5.B (biological treatment of solid waste) or 5.D (wastewater treatment and discharge) have negligible CO_2 emissions of a fossil nature and therefore Parties are not required to report these emissions.

Box: Precursor gases

Precursor gases do not contribute directly to global warming. However, through atmospheric reaction, they do affect concentrations of other gases in the atmosphere that do affect global warming. Carbon monoxide, NO_X and NMVOCs contribute to the formation of ozone; in addition, NO_X plays an important role in the earth nitrogen cycle, which generates N_2O; SO_2 emissions result in sulfate particles, which also play a role in climate change.

Box: Category descriptions

5.A solid waste disposal: under this category the main activities are related to managed, unmanaged or uncategorized SWDS (often referred to as landfilling and/or open dumping). The main sources of emissions are MSW (household waste, garden and park waste, commercial/institutional waste), industrial waste and sludge. For many Parties, solid waste disposal will be the largest category in the waste sector and most Parties report these emissions as a key category.

5.B biological treatment of solid waste: (composting or anaerobic digestion) results in emissions of CH_4 and N_2O. Owing to the relatively small amounts of solid waste currently treated biologically and the relatively low EFs, in most cases biological treatment of solid waste is not a key category.

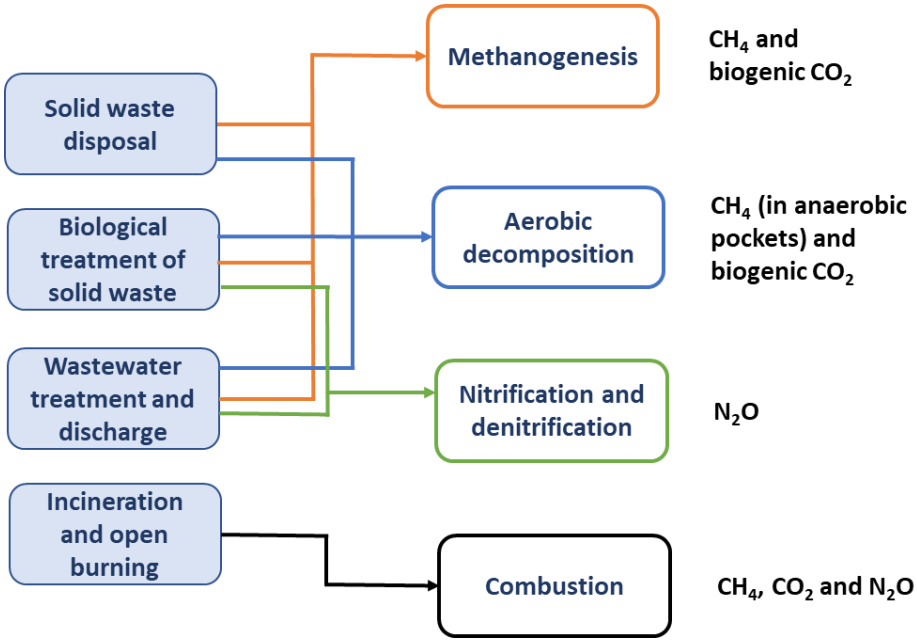
5.C incineration and open burning of waste: incineration of waste results in emissions of CO_2, CH_4 and N_2O. Waste incineration without energy recovery is reported under waste. When waste is incinerated with energy recovery, emissions are reported under the energy sector. Incineration and open burning of waste can be a key category when large amounts of waste are incinerated without energy recovery or open burned.

5.D wastewater treatment and discharge: wastewater treatment and discharge results in emissions of CH_4 and N_2O. Wastewater treatment and discharge can be a key category when a large amount of wastewater is treated in well-managed wastewater anaerobic plants.

2.2. Relevant processes in the waste sector

Waste materials generally consist of biogenic (rice husk, dead leaves, waste food, sewage, sludge, etc.) and non-biogenic (several types of plastics waste, lard oil, etc.) materials. During waste treatment and disposal, biological and chemical processes occur that result in GHG emissions. The main processes relevant for each of the categories covered in the sector are summarized in figure 2.1 For further information on each of the processes click the relevant box in the figure.

B. Figure 2.1: Relevant processes in the waste sector



Box: Processes in the waste sector

Methanogenesis

Biodegradation of organic wastes (such as food wastes, garden wastes, paper and wood) by bacteria under anaerobic conditions is often referred to as methanogenesis. The product of methanogenesis is a mixture of CH_4 and CO_2. Methanogenesis is inhibited by oxygen and only occurs under strict anaerobic conditions (no oxygen present).

Methanogenesis is of importance for CH_4 emissions from categories 5.A solid waste disposal, 5.B biological treatment of solid waste and 5.D wastewater treatment and discharge.

Aerobic decomposition

Aerobic decomposition is the biodegradation of organic wastes by bacteria in the presence of oxygen. The final product is CO_2. When conditions are not 100 per cent aerobic, methanogenesis may take place in parts that remain anaerobic.

Aerobic decomposition is relevant for categories 5.B biological treatment of solid waste and 5.D wastewater treatment and discharge. Aerobic decomposition is also important for 5.A solid waste disposal, because in unmanaged SWDS and semi-aerobic SWDS, part of the organic wastes is removed by aerobic degradation.

Nitrification and denitrification

Waste and wastewater contain nitrogen components (e.g. urea in wastewater or proteins in solid waste) and N_2O is generated as a by-product of nitrification, or as an intermediate product of denitrification. In a series of biological processes (nitrification and denitrification) most nitrogen components are converted into nitrogen gas, but a small part is emitted as N_2O. The nitrification step requires aerobic conditions, while the denitrification step generally progresses under anaerobic conditions.

Nitrification/denitrification is relevant for category 5.B biological treatment of solid waste, where composting might result in N_2O emissions. It is also relevant for 5.D wastewater treatment and discharge. In SWDS, conditions remain largely anaerobic and no nitrification occurs. Therefore, N_2O emissions from SWDS are considered to be insignificant and do not need to be reported.

Combustion

Waste is incinerated as a management practice, either in a dedicated incinerator or through open burning, mainly to reduce the amount of waste. Combustion of solid waste largely produces CO_2. Other components (including CH_4 and N_2O) are also produced, but on a mass basis in minor quantities compared with CO_2.

CH_4 emissions are a result of incomplete combustion. Factors affecting the CH_4 emissions are temperature, residence time and waste to air ratio (i.e. air volume in relation to the waste amount). The CH_4 emissions are particularly relevant for open burning, where a large fraction of carbon in the waste is not completely oxidized.

N_2O emissions are generated because of incomplete combustion of nitrogen-containing components. Modern waste incinerators have a system to reduce emissions of air pollutants. Some of the technologies used might increase N_2O emissions from incinerators.

2.3. IPCC tier approaches to estimate GHG emissions

As for all other sectors, the 2006 IPCC Guidelines provide three tier levels, or methods, for estimating GHG emissions of the sector. The relevant decision trees and tiers for each category are provided in the category-specific lessons.

At a general level, when reviewing the choice of method, keep in mind the following:

- Paragraph 21 of the MPGs states that each Party shall use methods from the 2006 IPCC Guidelines (or any subsequent versions or refinement agreed upon by the Conference of the Parties). Each Party should make every effort to use a recommended method (tier level) for key categories in accordance with those IPCC Guidelines. As a reviewer, you must assess whether a Party has followed the recommendations and decision trees from the 2006 IPCC Guidelines and its choice of methods and parameters.
- Paragraph 23 of the MPGs states that a Party may be unable to adopt a higher-tier method for a particular key category owing to lack of resources. In such cases, the Party may use a tier 1 approach, and shall clearly document why the methodological choice was not in line with the corresponding decision tree of the 2006 IPCC Guidelines. The Party should prioritize for future improvement any key categories for which the good practice method elaborated in the Guidelines cannot be used. Hence, as a reviewer, you must seek out any explanatory information that clarifies why the methodological choice was not in line with the corresponding decision tree of the 2006 IPCC Guidelines.
- Paragraph 28 of decision 5/CMA.3 notes that Parties may use on a voluntary basis the 2019 Refinement to the 2006 IPCC Guidelines (2019 IPCC refinement). Hence, as a reviewer you must be aware of the improvements undertaken in the 2019 IPCC Refinement. Guidance to quantify waste generation, composition and management data for solid waste under the 2019 Refinement can be found here.[1] Below it is an overview of the main changes between the 2006 IPCC Guidelines and the 2019 Refinement to the 2006 IPCC Guidelines.

Main changes for waste generation, composition and management data for solid waste in the 2019 Refinement to the 2006 IPCC Guidelines

The 2019 Refinement to the 2006 IPCC Guidelines (vol. 5, chap. 2) provide an update of per capita generation of MSW and its management by region in an updated table 2.1. In this updated table, more regions are distinguished in Asia, Africa and Oceania than in table 2.1 in the 2006 IPCC Guidelines. An updated table 2 .3 provides improved information on the composition of MSW. In addition, the 2019 Refinement to the 2006 IPCC Guidelines provides a new table 2.4 with default values of carbon content, nitrogen content and DOC for sludges from both domestic and industrial wastewater treatment plants.

The 2019 refinement also provides an updated annex 2A.1 (vol. 5, chap. 2) with waste generation and management data for a large number of countries and the regional averages on the basis of the new regional defaults. These data are compared with the values in the Revised 1996 IPCC Guidelines and the 2006 IPCC Guidelines, as follow:

- For Parties that use either default MSW generation data from annex 2A.1 or the MSW default composition from table 2.3, the implementation of the 2019 Refinement will

[1] https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_2_Ch02_Waste_Data.pdf

affect emissions from solid waste disposal (5.A) and incineration and open burning (5.C). For biological treatment of waste (5.B), effects will be limited, because the regions where (according to the new table 2.1) a substantial amount of MSW is composted are those with country-specific information on biological treatment of solid waste.

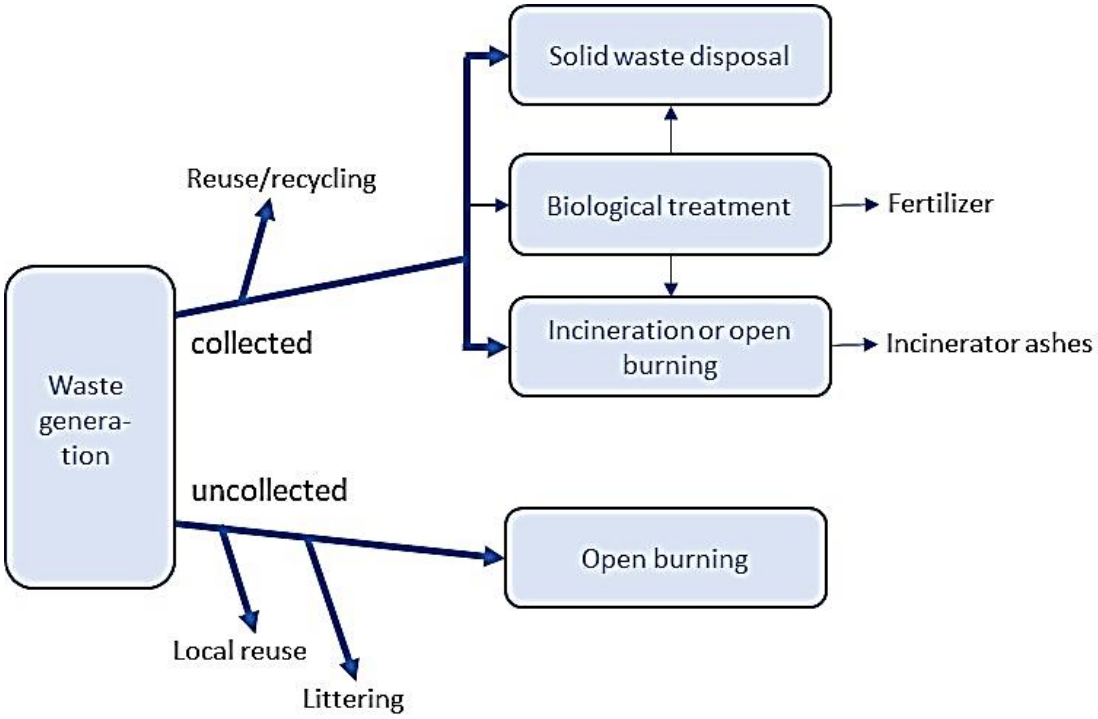
- Both the per capita MSW generation and the composition of MSW from the 2019 Refinement are default values for 2010, where the defaults from the 2006 IPCC Guidelines refer to 2000.
- Annex 2A.1 provides useful information if you, as a reviewer, wish to evaluate country-specific per capita waste generation with the waste generation of other countries in the same region.

2.4. Solid waste generation and management practices

The specific methodologies to quantify emissions from for the waste sector is summarized in lessons 3 to 6 (categories 5.A to 5.D). However, there are cross categories elements for categories 5.A solid waste disposal, 5.B biological treatment, and 5.C incineration and open burning of waste: the solid waste generation is the common basis for AD to estimate emissions; and the types and composition of waste and the waste management practices (e.g collection, reuse/recycling, solid waste disposal on land, biological and other treatments as well as incineration and open burning of waste) will have an impact on the amount of solid waste treated under each of the categories, as showed in figure 2.3 below.

As a reviewer, you need to understand how the AD for solid waste can be impacted by these management practices and by the type and composition of waste, since they are at the basis for the quantification and review of AD and emissions under categories 5.A, 5.B and 5.C. Please see “Box: Waste generation and management” below for more information.

C. Figure 2.2: Waste generation and management



In developed countries, waste generated by most of the urban population and a significant part of the rural population will be collected and treated via state-of-the-art technologies (managed SWDS or incinerators). In developing countries, large parts of the waste might remain uncollected. Part of this waste might be open burned. Collected waste might still be treated in unmanaged SWDS, where open burning might also take place.

Most Parties (developed and developing) will have waste policies in place, which affect all of the above-mentioned activities. Waste policies generally aim at:

- Decreasing waste generation;
- Increasing the fraction of waste collected;
- Increase recycling and reuse;
- Increase the amount of waste treated in managed SWDS or incineration plants.

Waste management activities are interlinked. For example, a change in waste collection or an increase in incinerator capacity has an impact on the amount of waste disposed in SWDS. The AD used for emission estimates need to be consistent across categories in the waste sector:

- Same assumptions on waste generation and collection;
- Same assumptions on treatment (fraction of waste landfilled; fraction incinerated; fraction open burned);

- Same assumptions on waste composition (organic and fossil carbon content).

Due to implementation of waste policies, significant shifts in waste treatment options can be expected in the time frame of one or two decades. The effect of waste policies will be reflected by changes in the composition and on the amount of waste treated under categories 5.A, 5.B and 5.C.

To learn more about how AD can be impacted by waste management practices and type and composition of wastes, see chapter 2 of volume 5 of the 2006 IPCC Guidelines. The next items 2.5-2.7 will provide more detail on these cross categories elements

Box: Waste generation and management

Generation is the amount of waste, as disposed of by its source (a household, a shop or an office, an industry).

Part of the waste generated is **collected** by a municipal waste treatment company. Specific wastes might be collected separately, allowing the reuse of, for example, metals, plastics, paper or green wastes.

Collected waste might be subject to **reuse/recycling** (e.g. manual separation of materials fit for reuse, metals and plastics), **manual pretreatment** (manual sorting of reusable materials from waste), mechanical pretreatment (separation of paper, plastics and metals using equipment such as sieves, wind sifters or magnets) or **biological pretreatment** (composting or anaerobic digestion of waste). Reuse and recycling affect the amount of waste to be treated and its composition.

Ultimately solid waste is **treated** by disposal in an SWDS, incineration/burning or composting/digestion.

2.5. Types of waste

For quantification of emissions from waste, it is good practice to account for all types of solid waste (2006 IPCC Guidelines, vol. 5, chap 2, p. 2.4): households, offices, shops, markets, restaurants, public institutions, industrial installations, water works and sewage facilities, construction and demolition sites, and agricultural activities.

For some types of waste, such as sludge, hazardous waste or clinical waste, there is a common understanding among Parties with respect to definitions. Sludge, for example, is the residue of wastewater treatment; the definitions of the other wastes are reflected by the definition in the 2006 IPCC Guidelines (vol. 5, chap. 2, p.2.2.4).

There are no generally agreed definitions for municipal solid waste and industrial waste.

Municipal solid waste (MSW) is typically defined as waste as collected by municipalities or other local authorities (see also the 2006 IPCC Guidelines, vol. 5, chap. 2, p.2.5). It consists of waste of various sources, such as households, commercial and institutional wastes

(shops and offices) and municipal cleaning services. It may also include demolition wastes or sludge from a municipal wastewater treatment plant or local industries.

The term household waste is not used in the 2006 IPCC Guidelines, but might be used by some Parties in their NID. It might be defined as waste, as collected at households, excluding commercial and institutional wastes. Household waste, however, might also be used as a synonym for MSW, so it might contain commercial and institutional waste.

Industrial solid waste refers to waste from industries (see also 2006 IPCC Guidelines, vol. 5, chap. 2, p.2.8).

- Industrial waste is used by some Parties for larger industries, which operate their own SWDS to dispose their wastes. Often this refers to mining or construction wastes.
- Industrial solid waste might be co-disposed with MSW on the same SWDS. Depending on the quality of local waste registration, and whether separate statistics on industrial waste co-disposed might or might not be available. In the latter case, industrial waste would be included in MSW statistics.

2.6. Amount of solid waste

Most developed countries have high-quality statistics on waste generation, reuse and treatment for recent years. However, this information may not be available for earlier years in the time series. Developing countries might not have high-quality statistics even for more recent years. To estimate waste generation and treatment, Parties might:

1. Estimate AD, based on information from studies in the past;
2. Estimate missing historical AD by extrapolating more recent data;
3. Estimate MSW amounts, using default waste generation and disposal data from the 2006 IPCC Guidelines (vol. 5, chap. 2, table 2.1 for MSW). Table 2.2 provides an overview of industrial waste generation in selected countries.

Box: Methods to estimate waste generation and disposal

Use of studies

Most Parties use different types of studies to characterize different historical time periods of waste generation and disposal. Information from a single region/city is often extrapolated to the entire country. Examples of studies: an old city study on the capacity of the waste collection (number of truck-loads per week); estimates of the volume of waste in place of a specific SWDS; feasibility studies for construction of a MSW incinerator, starting from a known regional waste generation.

Ideally a Party should use studies from the Party itself, but where this is not possible studies from countries with similar conditions may be considered.

When a time series is reconstructed, using different sources of information, time-series consistency is important. This is described in topic 4 in this lesson.

Extrapolation of more recent data

For solid waste disposal, the 2016 IPCC Guidelines (vol. 5, chap. 3, p.3.12) provide guidance for the extrapolation of AD, using as drivers GDP or other economic indicators and/or the urban population or the part of the population whose waste is collected. Since waste generation data need to be consistent over categories 5.A, 5.B and 5.C, this guidance can be considered valid for these waste categories.

Use of IPCC defaults

Regional default values for MSW generation and disposal treatment can be found in the 2006 IPCC Guidelines (vol. 5, chap. 2, table 2.1 for generation rate and fraction disposed in SWDS, and table 2.3 for waste composition). For industrial waste, default data can be found in table 2.2, although this is mostly for developed countries, with the exception of the defaults presented for China, Israel, the Republic of Korea and Singapore.

The values in table 2.1 of the 2006 IPCC Guidelines (vol. 5, chap. 2) refer to the population whose waste is collected. In many countries, especially developing countries, this encompasses only the urban population.

The values in table 2.1 are applicable to 2000. Waste generation per capita for subsequent or earlier years can be estimated using the guidance on how to estimate historical emissions from SWDS (extrapolation, interpolation) in the 2006 IPCC Guidelines (vol. 5, chap. 3, section 3.2.2).

Quantification of emissions from SWDS (category 5.A) requires a longer times series (over 50 years), than the emissions from the other categories (back to 1990, unless a developing country applies flexibility in accordance with para. 57 of the MPGs, in which case a more recent year may be used). The extrapolation of AD for category 5.A is further elaborated in lesson 3. The flexibility provisions are explained in the "General guidance and cross-cutting issues" course.

2.7. Waste composition

The composition of waste is relevant to estimating emissions of categories 5.A and 5.C.

The composition of MSW can be determined from sorting analyses. In a sorting analysis, a sample of waste is divided into fractions such as food waste, garden and park waste, paper, wood, plastic, metals, etc., after which the content of each fraction is weighed. Depending on the laboratory performing the analysis, a slightly different definition of fractions can be reported (e.g. organic waste instead of food waste and garden waste). When no information is available, the 2006 IPCC Guidelines provides a default composition for MSW (vol. 5, chap. 6, table 2.3).

Using this composition of MSW, the amount of degradable organic carbon can be calculated for use in the quantification of CH_4 emissions from SWDS, as explained in lesson 3. The same composition can be used to quantify the fossil carbon content in MSW for quantification of CO_2 emissions from incineration and open burning, as explained in lesson 5.

Industrial waste, hazardous waste and clinical waste are not characterized by their fraction of food waste, paper, etc. Instead, the 2006 IPCC Guidelines (vol. 5, chap. 2) provide information on the total carbon content, degradable organic carbon and fossil carbon content of these waste streams in tables 2.5 and 2.6.

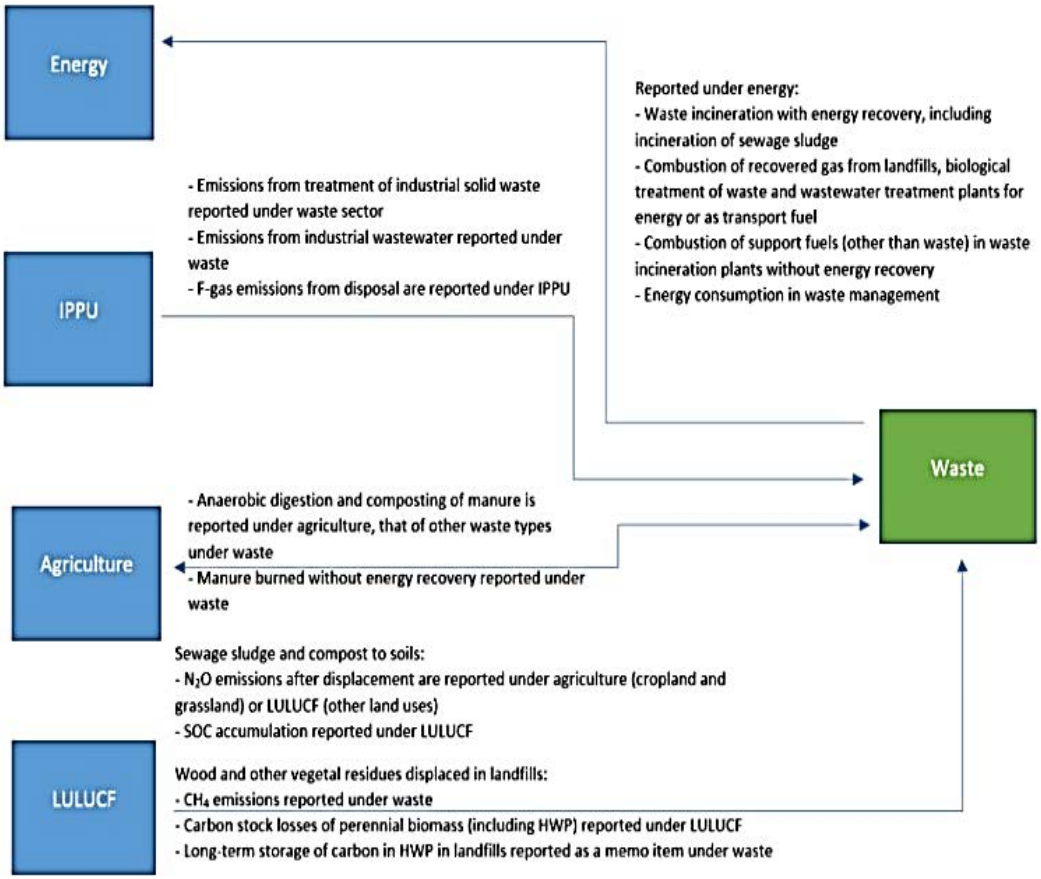
3. Cross-sectoral issues

3.1. Linkage in reporting emissions from waste and other inventory sectors

There are a number of linkages between the waste sector and the other inventory sectors as shown in figure 2.3. Familiarizing yourself with these linkages will allow you to understand how to review AD reported under these sectors in order to make sure that emissions are not omitted or double counted.

A cross-sectoral issue relevant to all categories under the waste sector (5.A-5.D) is that when landfill gas, biogas from anaerobic digestion or wastewater treatment plants and incineration of waste are recovered and used for energy purposes, their emissions are reported under the energy sector. Most of the cross-sectoral issues in the waste sector are relevant for only one inventory category and they will be discussed in the relevant lesson on the specific category (lesson 3, 4, 5 or 6).

D. Figure 2.3: Overview of main linkages of the waste sector with other inventory sectors

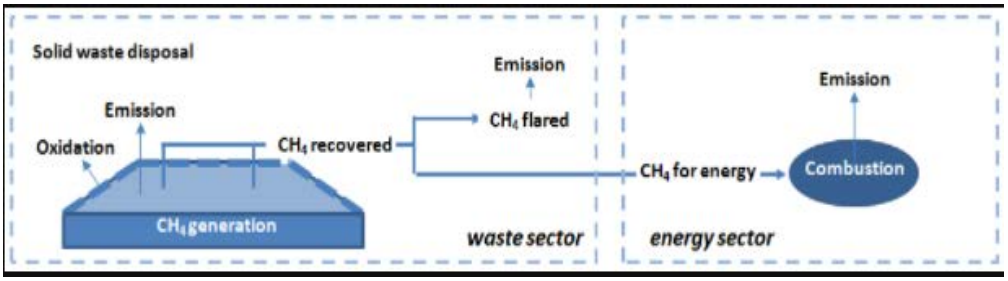


Box: CH_4 utilization and flaring

CH_4 recovered and flared is reported under the waste sector. When the CH_4 recovered is used to produce energy (electricity, heat or used as fuel in the transport sector), the emissions should be reported under the energy sector under the related category.

Figure 2.5 explains this further for a SWDS. The SWDS is located on the left. CH_4 is recovered, using vertical wells and flared or combusted to be used for energy. The dashed box on the left indicates the associated emissions to be reported under the waste sector and that on the right indicates the emissions to be reported under the energy sector.

Figure 2.5: Reporting of emissions due to utilization and flaring of recovered CH_4



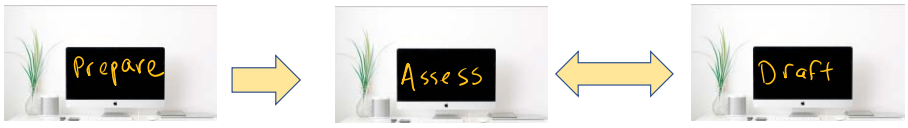
Emissions from flaring are considered insignificant and good practice in the waste sector does not require their estimation. However, if a Party wishes to do so, these emissions should be reported under the waste sector.

4. General approach to the review

4.1. Overall approach

The approach to reviewing the sector is consistent with that presented and practised in the “General guidance and cross-cutting issues ” course. The main phases of the review are preparation, assessment and drafting. In the review process there will also be a substantial amount of communication with multiple actors: the Party, your lead reviewer, fellow reviewers in the TERT and UNFCCC staff.

E. Figure 2.4. The main phases of the review



	Prepare	Assess	Draft
Before review week	• Refresh knowledge of 2006 IPCC Guidelines, latest decisions and lead reviewers' conclusions • Read submission (CRT and NID) • Identify previous recommendations and encouragements • Familiarize self with latest review tools	• Evaluate whether Party addressed findings contained in previous review report • Detailed analysis of submission against TACCC principles, including AD, EF and parameters, beginning with key categories and using review tools to facilitate work • Assess institutional arrangements for sector • Assess other cross-cutting issues (QA/QC, uncertainty, time-series consistency, recalculations, planned improvements) • If relevant, identify possible capacity-building needs • Discuss questions and issues with expert team, as needed	• Draft preliminary questions, and follow-up questions as necessary • Begin drafting review report based on findings
During review week	• All preparations should be done prior to the review week		• Finalize questions to Party early in week • Draft assessment of implementation of previous recommendations • Draft new recommendations/ encouragements, as appropriate • Fully complete first draft of your report, responding to comments from team • If relevant, consult with Party to draft capacity-building needs
After review week			• Finalize draft report • Respond to UNFCCC and Party comments

4.2. Preparation

Before the review week, familiarize yourself with:

- The information provided by the secretariat relevant for the review, for example, refreshing your knowledge of the UNFCCC reporting and review requirements, the 2006 IPCC Guidelines and review tools and other supporting materials;
- The Party's submission, including the NID and the CRTs:
    - The NID describes emissions from waste in chapter 7 according to the agreed outline. However, other sections (e.g. chapters 1, 2, 9 and 10 and the annexes) would contain additional information relevant for the waste sector, so be sure to go through them. You may also need to check the reporting on some cross-sectoral issues in other sectors (e.g. in energy and agriculture);
    - The CRTs starting with CRT 5 are used to report the information on the waste sector, with tables 5.A–5.D providing detailed information on the subcategories, including AD and IEFs, and CRT 5 providing only summary emission information. The CRTs also contains the general information required for your assessment of the sector in its summary and cross-cutting tables (CRT summary 1-3 and CRT 6-10);
- The NID may refer to additional documents which provide further information. Check in good time whether such documentation is relevant and can actually be found. If relevant documentation cannot be found, as part of your initial questions, request the Party to provide the information so that you have them available at the start of the review week;
- Only applicable, when a Party was already reviewed earlier. The findings of previous reviews are documented in a review report (TERR). As a reviewer you need to evaluate the follow-up by the Party of all unresolved recommendations from the previous review report during the assessment stage.

Box: Implied emission factors

IEFs are part of the sectoral background data tables of the CRTs. They are calculated values showing the ratio between the reported emissions and the AD. IEFs allow comparison across Parties and in some cases comparison with the default EFs. When emissions are estimated by multiplying AD and a default EF, the IEF would be equal to the default EF.

4.3. Assess

As a reviewer you need to assess the quality of the Party's submission. The "General guidance and cross-cutting issues" course gives a thorough description of all your activities during the review. Click on each subject below to find a brief recapitulation of activities:

- Conclude whether the Party addressed findings from the previous TERR;
- Make a detailed analysis of the submission against TACCC principles;
- Evaluate institutional arrangements for the waste sector;
- Evaluate other cross-cutting issues for the waste sector:
    - QA/QC;
    - Uncertainty;
    - Time-series consistency;
    - Recalculations;
    - Planned improvements;
- Identify possible capacity-building needs for the waste sector.

When concluding on issues, please be aware of the flexibility provisions a Party needs in the light of its capacities. The "General guidance and cross-cutting issues" course (lesson 3) provides more information on flexibilities. A summary of flexibility provisions from this course can be found here: https://unfccc.int/resource/tet/bw/bw2-01_flexibility.pdf

Box: Details of assessment

Evaluation of previous recommendations in the TERR

This is only applicable when the Party has undergone a previous review. The TERR from the previous review contains recommendations made by the previous TERT for the waste sector. For each recommendation you need to evaluate whether the recommendation was resolved to your satisfaction. For this you should read the entire original issue in the previous TERR, the evaluation done by the previous TERT and maybe raise questions to have full clarity on the issue and how the Party resolved it. Your conclusion on each recommendation will be part of the new TERR.

Analysis of TACCC principles

The GHG inventory should be prepared and reported following the good practice provided in the 2006 IPCC Guidelines. Good practice consists of a set of methodological principles, actions and

procedures intended to ensure that GHG inventories are accurate and that uncertainties are reduced as far as possible.

The concept of good practice is also broadly understood as a set of principles geared to improving the quality of inventories over time. These principles are intended to promote the TACCC principles (transparency, accuracy, completeness, consistency and comparability). For each category of the waste sector in lessons 3–6, questions prompt you to review whether TACCC principles have been properly implemented in given scenarios.

Institutional arrangements

To enable planning and managing the GHG inventory process on a permanent basis, the Party needs to put institutional arrangements in place. National inventory arrangements can vary by Party depending on their national circumstances and preferences, and change over time.

For waste, each Party needs to:

- Report on its inventory preparation process, including division of responsibilities of the participating institutions;
- Report on its archiving of all information used and developed, including EFs, AD, documentation on generating and aggregating data, QA/QC procedures, review results and planned improvements;
- Undertake and report on the key category analysis, data-collection procedures, QA/QC activities, uncertainty analysis and the improvement plan, which are strongly linked to the institutional arrangements and the functions of developing, managing and improving the national inventory.

For more information on assessing institutional arrangements, see the “General guidance and cross-cutting issues” course, lesson 8.

QA/QC

Each Party must elaborate an inventory QA/QC plan, including information on the inventory agency responsible for implementing QA/QC. In addition, each Party must implement and provide information on general inventory QC procedures in accordance with its QA/QC plan and the 2006 IPCC Guidelines. Those developing country Parties that need flexibility in the light of their capacities with respect to these provisions are instead encouraged to do so.

Parties should apply category-specific QC procedures for key categories and for those individual categories in which significant methodological changes and/or data revisions have occurred. In addition, Parties should implement QA procedures by conducting a basic expert peer review of their inventories.

For each waste sector category, there has to be a paragraph in the NID describing QA/QC procedures. As a reviewer, you need to check that QA/QC has sufficient substance for the key categories and whether the reporting suggest that the QA/QC procedures are well implemented.

For more general information on QA/QC, see the “General guidance and cross-cutting issues” course, lessons 3 and 8.

Uncertainty

For each category, the NID should contain a paragraph with an uncertainty analysis for the entire time series. Such an uncertainty analysis is one of the building blocks for planning future improvements of the inventory. As a reviewer, you need to evaluate the integrity of the uncertainty analysis for each category. Relevant checks may include:

- Has the Party performed and reported an uncertainty analysis in accordance with the provisions of the MPGs and the technical guidance in the 2006 IPCC Guidelines for at least the starting year, the latest reporting year and the trend?
- If the Party is one of those developing country Parties that need flexibility in the light of their capacities with respect to this provision, has it provided, at a minimum, a qualitative discussion of uncertainty for key categories?
- Have the uncertainties of the data used for all source and sink categories been reported, including the methods and assumptions used?
- Does the Party consider the results of the uncertainty analysis in targeting future inventory improvements? If so, how?

For more general information, see the "General guidance and cross-cutting issues" course, lesson 7.

Time-series consistency

All emission estimates in a time series should be estimated consistently, which means that, as far as possible, the time series should be calculated using the same method and data sources for all years. Where the same data sources or methods cannot be applied for the entire time series, Parties should use methods from the 2006 IPCC Guidelines to estimate missing values due to lack of data.

As a reviewer, you may:

- Check for significant discontinuities in the time series of AD, EFs or emissions or removals for each category (including subcategories);
- Check if the Party explains how it ensures time-series consistency;
- When the Party has not used the same methodology or the same data source throughout the time series, check the Party's explanation of how it has ensured time-series consistency.

For more detailed information, see the "General guidance and cross-cutting issues" course, lesson 7.

Recalculations

Parties can recalculate emissions for a number of reasons: update AD or EF because available data have changed; apply a higher-tier methodology; the technical capacity of the team for preparing the inventory increased and they are able to collect or use new data, implement new approaches, etc.. CRT 8 allows a quick check of whether any recalculations were performed for the waste sector. If emissions are recalculated for a specific category, this needs to be explained in a paragraph in the NID. As a reviewer you need to evaluate:

- Whether the new AD or EF or method applied by the Party is in accordance with the 2006 IPCC Guidelines;
- The accuracy and transparency of the recalculation;
- The justification of the recalculation;
- The effect of the recalculation on time-series consistency.

For more detailed information on how to review recalculations, see the "General guidance and cross-cutting issues" course, lesson 7.

Planned improvements

For each category, the NID should provide information on planned improvements. Those developing country Parties that need flexibility in the light of their capacities are also encouraged to highlight the areas of improvement that are related to the flexibility provisions used. As a reviewer you need to evaluate progress in the implementation of the planned improvements.

Capacity-building

When reviewing the submission of a developing country Party, you need to pay particular attention to its national capabilities and circumstances. Your findings and recommendations in the review report need to provide practical guidance to the Party, to help it to manage its limited resources and prioritize improvements.

For those countries just beginning to develop a GHG inventory, many of the efforts may be related to improving institutional arrangements for data collection, inventory preparation and data management, so that Parties are able to build a robust and sustainable system.

As you identify areas of improvement for Parties from developing countries, you should work closely with them to identify specific capacity-building needs that would be highlighted in the TERR to support them in their improvement efforts.

4.4. Draft

The outputs of the review consist of a series of documents completed at different stages of your work. As a member of the TERT responsible for the review of the GHG inventory, you will provide your contributions to a larger report covering all elements of the BTR review. Note that as a reviewer and TERT member you will be responsible for drafting:

- Questions to the Party for your sector;
- Areas for improvement and capacity-building needs related to your sector;
- Relevant sections in the TERR.

Detailed guidance on how to draft questions and findings is provided in the "General guidance and cross-cutting issues" course, lesson 6.

Box: Details of drafting

Draft questions

In the process of your preparations and assessment, you will need to draft questions to the Party to seek clarification prior to the review week (preliminary questions). Your questions should be clear so that the Party understands the exact nature of the issue you identified and should not be judgmental.

You will send preliminary questions to the lead reviewers and the secretariat (review officers) for consideration, after which they forward the questions to the Party.

It is very important that you prepare your questions in advance of the review week and in line with the review schedule and deadlines communicated to you by the lead reviewers and review officers. This provides the Party with sufficient time to consider the questions and provide responses. It also allows you to send follow-up questions, as needed, prior to the review or in the first or second day of the review week.

General guidance on how to draft clarification questions to a Party under review is presented in appendix lesson 2-1 (https://unfccc.int/resource/tet/bw/bw2-01_app_2.1.pdf).

Draft improvements

At the end of the review week, the TERT will prepare a list of reporting areas identified for improvement based on the TERT assessment of the GHG inventory submission against the reporting requirements. The list contains preliminary recommendations (for 'shall' reporting provisions) and encouragements (for 'non-shall' provisions).

A key role you will have as a reviewer is to work with developing country Parties to identify capacity-building needs that will help the countries to improve their reporting over time. This preliminary list of capacity-building needs, when developed, would be included with the draft areas of improvement to the Party at the end of the review week.

Draft the technical expert review report

The TERR is the main output of the review process and is produced under the collective responsibility of the TERT; it covers all areas of the review of the BTR.

You will be expected to have a robust first draft of your part of the report at the end of the review week to be communicated to the Party.

When assessing a previous recommendation, your draft will contain the status of the issue followed by the rational for your conclusion and any follow-up information received during the review (if relevant).

When you draft the new findings, make sure to start with a clear explanation of the issue, followed by any follow-up during the review week and completed with a recommendation (for 'shall' requirements) or an encouragement (for 'non-shall' requirements). Always remember that the recommendation is the only part to go to the next TERR, so it must be clear, informative and stand-alone.

An example of drafting for the TERR is provided in figure 2.5.

F. Figure 2.5: Example of a finding and conclusion in a TERR

ID#	*Finding classification*	*Description of finding with recommendation or encouragement*	*Is finding an issue/problem?[a]*
W.2	5.A Solid waste disposal on land – CH_4	The TERT noted that information regarding how the data for the amounts of waste deposited on solid waste disposal sites for the period 1950–1990 were estimated was not provided in the NID. In accordance with the 2006 IPCC Guidelines, first-order decay methods require data on solid waste disposal (amounts and composition) that are collected by default for 50 years. Countries that do not have historical statistical data, or equivalent data on solid waste disposal that go back for the whole period of 50 years or more, need to estimate these data using surrogates (extrapolation with population, economic or other drivers). During the review, the Party explained that waste deposited data had been extrapolated using surrogates (population and gross domestic product).	Yes. Transparency
		The TERT recommends that the Party provide in the NID information on how the data for the amounts of waste deposited on solid waste disposal sites for the period 1950–1990 were estimated.	
W.3	5.B.1 Composting – CH_4 and N_2O	The Party stated in the NID (p.372, footnote 357) that the data on quantities of waste composted in the period 1990–1994 had been interpolated based on rough assumptions. However, the TERT noted that additional and transparent information about these rough assumptions is not presented in the NID. During the review, the Party explained that the rough estimation consists of an approximately 5 per cent per year increase in organic and wood waste and, because there was no consistent information on the sludge and textile waste for the period 1990–1994, it remained at the level of 1995.	Yes. Transparency
		The TERT recommends that the Party provide in the NID information about the assumptions used to determine quantities of waste composted for the period 1990–1994.	

Description

Recommendation

Clear reference to NID or CRT Table

Effective communication between the TERT and the Party is key to a successful review process.

Make sure that in all communications (e.g. preparing questions to the Party or drafting text for the TERR) you make clear references to the relevant pages, chapters, paragraphs and tables in the NID, CRTs, previous TERR or 2006 IPCC Guidelines. Providing, for example, the page and/or table number when referring to the NID prevents the Party and your lead reviewer from losing valuable time in finding the relevant information.

5. Practical exercises

Below you will find two examples of Party submissions with questions to prompt you to think how you might review the information provided. The examples and exercises focus on common elements to be assessed across categories when reviewing the quality of the Party's submission (i.e. key category analysis, uncertainty analysis, QA/QC, time-series consistency, recalculations and progress in implementing improvements). Exercises linked to the review of the implemented methodologies for each of the categories are provided in the lessons for the specific category.

For each question, select an answer or draft your response. The answers are provided in a subsection below.

Note that you may detect other types of issues from the examples provided below or may wish to draft the questions or text to the TERR in a different way. The issues are selected for the purposes of the exercises covering different cross-cutting issues and to provide suggestions for possible responses. They do not cover all possible review issues for the presented examples.

When going through the examples you can refer to the relevant chapters of volumes 1 and 5 of the 2006 IPCC Guidelines. These chapters can also be used during the examination and during a real review.

You are encouraged to download all chapters of volumes 1 and 5 of the 2006 IPCC Guidelines as a PDF. This will allow you to mark up the relevant phrases and tables or add comments if you find this helpful.

5.1. Exercise 1

A Party from Central Asia prepared an overview of national waste management and treatment.

Appendix lesson 2-2 contains the relevant chapter of the NID:
https://unfccc.int/resource/tet/bw/bw2-02_app_2.2.pdf
Download here a selection of the CRTs to use in the exercise below:
https://unfccc.int/resource/tet/bw/bw2-03_Exercise_2.1.zip

Question 1.1

According to the information in the 2024 Party's submission for the year 2022 (NID and CRT), are the CH_4 emissions from solid waste disposal (5.A) a key category?

A. Yes
B. No
C. Insufficient information to answer this question

Question 1.2

In the previous TERR, you find the following finding and recommendation under W.6 related to the Party's previous submission (i.e. 2023):

"According to the NID, CH_4 emissions from solid waste disposal are a key category. However, emissions from solid waste disposal are calculated, using a tier 1 methodology, using default activity data (waste generation) from the 2006 IPCC Guidelines (vol. 5, chap. 2, table 2.1). According to the decision tree for category 5.A (2006 IPCC Guidelines, vol. 5, chap. 3, figure 3.1), when the category is key tier 2 or higher needs to be used. Tier 2 means that emissions are calculated, using good-quality country-specific activity data on current and historical waste disposal at SWDS. There are no explanations in the NID on the choice of the methodology."

During the review, the Party provided new information on waste generation. This new information consists of a literature survey of available information from national studies, which enables the Party to make an estimate of waste generation for the entire period 1950–2021. This information allows the Party to estimate CH_4 emissions using a tier 2 methodology

The TERT recommends that the Party estimate in the next NID the generation of solid waste and the CH_4 emissions from solid waste disposal, using the available country-specific information on waste generation and disposal.

What is your judgment on the status of implementation of the recommendation in the current submission under review?

A. Resolved
B. Addressing
C. Not resolved

Question 1.3

As a reviewer, you expect that a change in waste generation will result in a recalculation of CH_4 emissions from SWDS.

According to the information in the 2024 Party's submission (NID and CRTs), did the Party recalculate CH_4 emissions from SWDS? Please note that when a Party performs recalculation, the CRT 8s1 shows a comparison of the estimates between the previous and current submissions for all common years of both submissions.

A. Yes
B. No
C. Insufficient information in the submission to answer this question

Question 1.4

Do you think the information on the uncertainties in section 7.2.3 of the NID is sufficient, bearing in mind that the section in the NID is the same as in the previous submission?

A. Yes
B. No

Question 1.5

You have analysed the information provided in table 249 of the NID and noted some inconsistencies not explained in the report. An important example is the share of waste that goes to SWDS. This drops from 25 per cent in 1990 to 10 per cent in 2000, after which it slightly increases again to 12 per cent in 2010, after which a steep increase to 50 per cent is reported in 2015. In addition, the values for 2015-2020 are the same. This trend is not explained in the NID.

What question could you ask the Party regarding time series consistency?

Please submit your question to the Party here:

5.2. Exercise 2

Download here the relevant description of waste generation and treatment in the NID (chap. 7.1, starting on p.7.4) of a Party from Africa to use in the exercise: https://unfccc.int/resource/tet/bw/bw2-04_exercise_2.docx

Question 2.1

Assuming that this is the entire text provided for solid waste in the NID, do you think the waste inventory for categories 5.A (SWDS) and 5.C (open burning) is complete?

A. Yes
B. No
C. Insufficient information in the NID to answer this question

Question 2.2

Can you reproduce the amount of household waste disposed to SWDS in table 7.1 (e.g. for 2022), by using the information/assumptions reported in the NID?

A. Yes. The amount of household waste to SWDS in 2022 can be reproduced from the information in the NID and it amounts to 315 kt
B. No. The amount of household waste to SWDS in 2022 based on the information in the NID should be 224 kt.
C. No. The amount of household waste to SWDS in 2022, based on the information in the NID, should be 315,000 kt.

Question 2.3

Do the Party explain the assumption on the share of urban waste disposed in SWDS transparently?

A. Yes
B. No
C. Insufficient information in the downloads to answer this question

Question 2.4

In response to your question on justification of the assumption on urban waste to SWDS, the Party acknowledges that it does not have a proper justification.

How would you conclude on the finding of an unjustified assumption on the share of urban waste disposed in SWDS?

A. Transparency issue
B. Completeness issue
C. Accuracy issue
D. Comparability issue

5.3. Answers to practical exercises (item 5.1 and 5.2 above)

Exercise 1

Question 1.1

The correct answer is A. CRT 7 provides a summary overview of key categories. According to this summary, CH_4 emission from solid waste disposal (5.A) is a key category according to both the level and the trend assessment.

Question 1.2

The correct answer is A. The issue is resolved in the current submission since waste generation is no longer estimated using the defaults from the 2006 IPCC Guidelines and the Party is now using the available country-specific information for waste generation as required in the previous recommendation (during the review of the Party's 2023 submission). According to the current NID the allocation of the Municipal Solid Waste (MSW) to the various waste treatment techniques is done for the years 1950, 1960, 1970, 1980, 1990, 2000, 2010 and 2015. Data from 2015 is applied for 2016-2022.

For rural areas expert judgment was used to quantify waste generation for the rural population as shown in table 248 (share of the population whose waste is not collected).

Even if you find some issues with the application of the tier 2 approach and the data used in the current submission, this will be a new recommendation.

Question 1.3

The correct answer is A. CH_4 emissions for the years before the current year (i.e. 1990-2021) are recalculated. This can be seen in CRT 8s1 for the previous inventory years, which gives an overview of the recalculated data.

> Recalculations can only be made for the years, for which an estimate was provided in the previous inventory. As a result, no recalculations can be expected in the CRT for the latest years in the inventory. As a reviewer, when you want to identify recalculations in the CRT 8s1, you need to check the CRT for years before the latest year for which an estimate is made.
>
> The tools provided by the secretariat will help you to quickly identify the recalculations between the years and their magnitude and impact on the overall recalculations for the inventory.

In the CRT 2024_2021 provided for this exercise you can see that CH_4 emissions for category 5.A are recalculated. In cells I52 and J52, emissions from category 5.A in the previous submission are reported as 499 kt CO_2 eq and in the current submission as 533.71 kt CO_2 eq.

> Please note that the values in CRT 5.A and 8s1 are different since the table on recalculation presents all data in kt CO_2 eq and CRT 5.A in kt CH_4. In order to convert CH_4 emissions to CO_2 eq, the GWP values listed in table 8.A.1 of the Fifth IPCC Assessment Report shall be used in line with decision 5/CMA.3, paragraph 25, and decision 18/CMA.1, annex, paragraph 37.

The NID should contain a paragraph with an explanation on the recalculation performed by the Party, where you can check what was the reason of the recalculation (if changes in methods, EFs or AD). In the NID provided for this exercise (see item 7.2.6) the Party reported that recalculation was performed because of new and country-specific information obtained on waste generation (so, the reason for the recalculation was an updated in AD)

Question 1.4
The correct answer is A. The description in the NID is sufficient and transparent. The Party provided the combined uncertainty for the category, while specifying the individual uncertainties of the AD and parameters participating in the estimates. There is a clear reference to the method used to calculate the overall uncertainty for the category and also clear references to the sources of uncertainty of the AD and parameters used. In addition, the AD have been changed in relation to the previous submission, and this is reflected in a decrease in the estimated overall uncertainty for the category.

Question 1.5
A valid question to the Party might read:

The TERT noted the new information used for calculating waste generation and allocation of waste in chapter 7.1 of the NID. However, a major discontinuity in the share of waste that goes into SWDS is noted in table 249. This share drops from 25 per cent in 1990 to 10 per cent in 2000, after which it slightly increases again to 12 per cent in 2010, followed by a steep increase to 50 per cent in 2015 and constant share kept for 2015–2020. Could the Party explain the observed trend in allocation of waste to SWDS?

Exercise 2

Question 2.1
The correct answer is B. The description in the NID is about household waste, where the 2006 IPCC Guidelines (vol. 5, chap. 3, p. 2.4) indicate that it is good practice to account for all types of solid waste when estimating waste-related emissions in the GHG inventory. You could ask if waste from, for example, shops, offices, municipal services and industries are included in the inventory.

Question 2.2
The correct answer is A. The amount in table 7.1 can be reproduced.

Total population is 2.60 million people in 2022.

- Urban high income is 2.60*19%=0.494 million people in 2022. Per capita waste generation of this group is 51 per cent higher than the per capita rural waste generation of 0.163 t of waste per person per year, so 1.51*0.163=0.246 t per person per year. Urban-high income waste generation is 494,000 (persons) *0.246 t per person per year = 121,588 t.
- Urban low-income population can be calculated as 2.60*19%=0.884 million people in 2022. Per capita waste generation of this group is 34 per cent higher than the per capita rural waste generation of 0.163 t waste per person per year, so 1.34*0.163=0.218 t per person per year. Urban-high income waste generation is 884,000 (persons) *0.218 t per person per year = 193,083 t.

- Total urban waste generation in 2022 is 121,588 t + 193,083 = 314,671 t, which is 315 kt. According to the NID all waste generated by the urban population was sent to waste disposal sites.

Question 2.3

The correct answer is B. The assumption on waste to SWDS is clearly specified in the NID: all urban waste is sent to SWDS. However, according to the 2006 IPCC Guidelines (vol. 5, chap. 2, table 2.1), the default for fraction of MSW disposed to SWDS for Africa is 0.69. The assumption from the Party on the fraction of waste disposed to SWDS (100 per cent) differs from the IPCC default value. The 100 per cent allocation to SWDS of urban wastes is not sufficiently documented. As a reviewer, you may draft a question to the Party and ask for a clarification and documentation of the allocation used.

Question 2.4

The correct answer is C. If no country-specific information is available on the share of waste disposed in SWDS, the default value for Africa from table 2.1 (2006 IPCC Guidelines, vol. 5, chap. 2) should be used, which is 0.69. Accuracy in the 2006 IPCC Guidelines (vol. 1, chap. 1, p.1.8) is defined as “the national greenhouse gas inventory contains neither over- nor under-estimates so far as can be judged.” The current assumption that all urban waste is disposed in SWDS results in an overestimation of emissions of the category. The inventory can therefore be considered as not accurate.

6. Self-check quiz

The questions set out below will allow you to check your knowledge of the sector. Please be aware that you can use the information in the 2006 IPCC Guidelines when answering these questions.

Question 1

Which of the following elements is not part of chapter 7 in the NID?

A. QA/QC
B. Uncertainty analysis
C. Prognosis of future emissions
D. Recalculations

Question 2

Upon manual separation of MSW, the total mass of waste is reduced and its composition is affected.

A. True
B. False

Question 3

Quantification of CH_4 emissions from SWDS and CO_2 emissions due to incineration need to be quantified based on the same assumptions on waste generation, composition of waste and carbon content in waste.

A. Always true
B. Sometimes true, but not always
C. False

Question 4

You have reviewed all recalculations carried out by a Party in the waste sector on the basis of CRT 8 and the NID.

Which of the following reporting options might lead to an issue in the reporting of the recalculations in the inventory of the waste sector?

A. Detailed explanations of recalculations have not been provided in the NID
B. Recalculations have only been performed for a few years but they are linked to an AD update for these particular years
C. The information on recalculation in the NID and CRT table 8 is not consistent
D. A and C
E. A, B and C

Question 5

As a reviewer you note that the Party has not provided information on any category-specific QC procedures for the sector. How would you treat this issue in the TERR?

A. As a recommendation
B. As an encouragement

Question 6

Assuming a known rural population size, generation of MSW in rural areas can be quantified using default values in the 2006 IPCC Guidelines.

A. Always true
B. Sometimes true, but not always
C. False

6.1. Answers to self-check quiz

Question 1
The correct answer is C. The NID, chapter 7, contains additional information on key category analysis, QA/QC checks applied, uncertainties and recalculations performed for the sector. A prognosis of future emissions is not part of an inventory.

Question 2
The correct answer is A. Upon manual separation of waste, specific fractions in the waste are removed for reuse. As a result, the total mass of waste is reduced and its composition is affected. When only inorganic materials are removed (metals, plastics), the total CH_4 potential is not affected. When organic materials are removed (paper, wood), the CH_4 potential is reduced as well.

An alternative to manual separation is mechanical separation of waste, which is often combined with biological treatment of the residue. Biological treatment might result in CH_4 emissions.

Question 3
The correct answer is A. AD and waste composition need to be consistent across the sector. However, for CH_4 from SWDS, the organic part of the carbon content is important, since this might biodegrade. For CO_2 emissions from combustion, the fossil part of the carbon content is relevant as biogenic CO_2 emissions are not included in the totals.

Question 4
The correct answer is E. Parties shall report recalculations for the starting year and all subsequent years of the inventory time series, together with explanatory information and justifications for recalculations with an indication of relevant changes and their impact on the emission trends (MPGs, para. 43). As a reviewer, you should check in the NID and CRT 8 whether the Party provided sufficient information on why a recalculation has been conducted. If detailed explanations of recalculations have not been provided in the NID, it must be defined as failure to meet reporting requirements of the MPGs.

Paragraph 28 of the MPGs indicates that each Party shall perform recalculations in accordance with the 2006 IPCC Guidelines, ensuring that changes in emission trends are not introduced as a result of changes in methods or assumptions across the time series. In other words, recalculations should ensure the consistency of the time series. However, if the recalculation is linked only to updates of AD for separate years, for example, due to correction of mistakes or updated data for the latest year, it is possible that the recalculations do not cover all the time series.

Question 5

The correct answer is B. In line with paragraph 35 of the MPG, Parties should apply category-specific QC procedures in accordance with the 2006 IPCC Guidelines for key categories and for those individual categories in which significant methodological changes and/or data revisions have occurred. As this is not a 'shall' but a 'should' requirement, the text suggesting the Party to implement category specific QC can be an encouragement. The recommendations are reserved for the reporting requirements marked as 'shall' requirements.

Question 6

The correct answer is C. The default values in the 2006 IPCC Guidelines, volume 5, chapter 2, table 2.1, should be multiplied by the population whose waste is collected. In many countries, especially developing countries, this encompasses only the urban population (see footnote 2 to table 2.1). This means that in many countries, default values cannot be directly used for MSW generation by the rural population.

7. Key points to remember

- Volume 5 of the 2006 IPCC Guidelines provides the methodology to estimate waste sector emissions. While chapters 3 to 6 are for the specific categories, chapter 2 provides overall information on waste generation, composition and management applicable across the sector. The 2019 Refinement to the 2006 IPCC Guidelines, which provides changes and new methodologies, may be used by some Parties.
- In the Party's submission, the major elements to check for the sector are included in chapter 7 of the NID (if the outline for the NID is followed by the Party) and in CRTs starting with CRT 5. However, the cross-cutting sections of the NID and its annexes should also be checked for additional information such as key category analysis, QA/QC checks applied, uncertainties, recalculations, trend information, improvements in relation to the previous submission. The same also applies to the CRT summary tables that may provide information on recalculations, trend, key category analysis, indirect gases reported for the sector and explanations for notation key used.
- The sector should also be assessed focusing on its interlinkages with other sectors (e.g. energy and agriculture) to ensure that there are no possible omissions or double counting of emissions.
- As a reviewer, you must pay attention to the following cross-cutting areas:
    - Key category analysis;
    - Time series and recalculations;
    - Uncertainty assessment;
    - Assessment of completeness;
    - QA/QC;
    - Areas of improvements for a Party identified by the TERT, as mandated in paragraph 146(d) of the MPGs;
    - Planned improvements.
- The MPGs provide flexibility options being used in the light of a Party's capacities. As a reviewer, you must be aware of the flexibility options and check which of them are used by the developing country Parties under review, such as:
    - Key category analysis – flexibility to identify key categories using a threshold no lower than 85 per cent, in place of the 95 per cent threshold defined in the 2006 IPCC Guidelines;
    - Uncertainty assessment – flexibility to provide, at a minimum, a qualitative discussion of uncertainty for key categories;
    - Insignificant threshold – flexibility to consider an emissions category insignificant if its level of emissions is likely to be below 0.1 per cent of the national total and 1000 kt CO_2 eq, whichever is lower;
    - QA/QC – developing country Parties using flexibility are only "encouraged" to carry out QA/QC procedures;
    - Time series – flexibility to report data covering, at a minimum, the reference year/period for a Party's nationally determined contribution and a consistent annual time series from at least 2020 onwards, with the latest reporting year three years prior to the submission of the national inventory reports.

- It is good practice to account for all types of solid waste when estimating emissions. An inventory is not limited to household waste or MSW, but should include all types of waste treated.
- Definitions used in the inventory might vary between Parties. For example, sludges from centralized wastewater treatment plants might be included in MSW.
- The amount of waste treated and composition of the waste needs to be consistent among the categories. So AD are preferably based on the same or consistent data sources.
- Many Parties have waste policies in place as a result of which waste treatment and waste composition might change significantly over time. Reconstruction of the entire time series often requires combining different types of information. As a reviewer, you should ensure that the qualitative description of policies in the NID is consistent with the emission trends reported.

Lesson 3: Solid waste disposal

1. Introduction

This lesson describes the review of GHG emissions generated by solid waste disposal and assumes that the reader has prior knowledge of the 2006 IPCC Guidelines, volume 5, chapters 2 and 3.

The lesson consists of six topics:

Topic 1: Introduction
Topic 2: Category overview and methodological information
Topic 3: Review approach
Topic 4: Practical exercises
Topic 5: Self-check quiz
Topic 6: Key points to remember

1.1. Learning objectives

At the end of this lesson, you should be able to:

- Understand the key tasks to be undertaken to review a Party's reporting on solid waste disposal;
- Understand how the solid waste disposal category interlinks with other categories within the waste sector and with other sectors of the inventory;
- Identify whether a Party's reporting on solid waste disposal is consistent with the requirements in the MPGs;
- Identify issues and draft relevant recommendations in a review report for this category.

1.2. Expected time needed to complete lesson 3

- For readers with experience in GHG emission inventories: 4–8 hours
- For readers with less experience in GHG inventories: 8–12 hours

2. Category overview and methodological information

2.1. Solid waste disposal categories

Solid waste disposal is divided into three categories, as presented in the 2006 IPCC Guidelines. CH_4 emissions from these categories are reported in CRT 5.A (solid waste disposal). The 2019 refinement to the 2006 IPCC Guidelines (vol. 5, chap. 3) introduced the option to quantify emissions from active aeration. This option is already included in CRT 5.A, and as a reviewer, you should be aware of its definition and suggested methodological information for the subcategory

Table 3.1 – Solid waste disposal categories and gas emitted.

Categories		Gas emitted
5.A.1 - Managed waste disposal sites	Subcategories: 5.A.1.a – anaerobic 5.A.1.b – semi-aerobic 5.A.1.c – active aerobic	CH_4
5.A.2 - Unmanaged waste disposal sites		CH_4
5.A.3 - Uncategorized waste disposal sites		CH_4
Reported in CRT	CRT 5.A	

Please see boxes below for more information on each of the categories in tables 3.1.

CO_2 emissions from solid waste disposal, whenever they occur, are considered to be of biogenic origin and are not estimated for the category or included in the national total. No methodology is provided for N_2O emissions from SWDS as the emissions from the category are not significant.

To learn more about solid waste disposal, read chapters 2 and 3 of volume 5 of the 2006 IPCC Guidelines.

Box to table 3.1: Category 5.A.1 - managed SWDS

Managed SWDS are subdivided on the following subcategories as follows:

- 5.A.1.a - anaerobic managed SWDS that must have controlled placement of waste and one of the following: use of cover material; mechanical compaction; or waste levelling;
- 5.A.1.b - semi-aerobic SWDS that have the specific infrastructure to promote the passive aeration of waste, resulting in partially aerobic conditions. Since semi-aerobic landfills aim at minimizing anaerobic conditions and preventing the generation of CH_4, they do not have CH_4 recovery systems;
- 5.A.1.c - active-aerated SWDS that have the infrastructure for active aeration (forced by a blower) of waste. These must have controlled placement of waste and will include a leachate drainage system to avoid the blockage of air penetration, as well as cover material and an air injection or gas extraction system that prevents drying of waste.

Box to table 3.1: Category 5.A.2 - unmanaged SWDS

Unmanaged SWDS are either:

- Unmanaged – deep. These are SWDS that do not meet the criteria of managed SWDS and are on average more than 5 m deep. Shallow SWDS with an internal water table at near ground level also fall within this category. Examples are ponds, river or wetlands filled with waste; or
- Unmanaged – shallow. These are SWDS that do not meet the criteria of managed SWDS and are less than 5 m deep.

Box to table 3.1: Category 5.A.3 - uncategorized SWDS

Uncategorized SWDS are used when a country cannot categorize its SWDS in any of the other subcategories.

2.2. Methane generation and emissions from SWDS

Disposal of solid wastes in SWDS results in the generation of CH_4 in the waste and the subsequent emission of CH_4 via the surface of the SWDS.

The 2006 IPCC Guidelines use the term "solid waste disposal sites". Many countries also use the term "landfill" as a synonym and "landfill gas" for the biogas generated in SWDS. SWDS might also be referred to as "dumps" or "open dumps" in the NIDs.

Solid wastes contain biodegradable organic materials, such as food residues, paper, wood and textiles. Under anaerobic conditions, these materials are decomposed by bacteria. Since a significant part of organic material consists of carbohydrates with a composition of $C(H_2O)_n$ (in which the value of n can vary from one for simple sugars to several thousands in cellulose fibres), the overall reaction of organic material can be simplified as:

$$C(H_2O)_n \rightarrow \frac{1}{2}n\ CH_4 + \frac{1}{2}n\ CO_2$$

Or n moles of $C(H_2O)_n$ produce ½ n moles of both CH_4 and CO_2, and this explains why biogas contains approximately 50 per cent of CO_2 and 50 per cent of CH_4 by volume.

CH_4 generation requires strictly anaerobic conditions (no presence of oxygen). When an SWDS is not covered with soil, or when waste is not compacted, ambient air can enter. As a result, anaerobic conditions are prevented in the upper part of the waste and CH_4 generation is reduced. A landfill can also be engineered to have limited anaerobic conditions and reduced CH_4 generation in the waste.

CH_4 generation from solid wastes is a slow process, often taking decades to complete. As a result, CH_4 generation in SWDS in an inventory year is caused by degradation of solid wastes, disposed in the previous decades.

Once generated in the waste, CH_4 is either recovered, oxidized or emitted:

$$CH_4 \text{ generation} = CH_4 \text{ recovery} + CH_4 \text{ oxidation} + CH_4 \text{ emission}$$

So, CH_4 emissions from SWDS are reduced by:

- Recovery. Part of the CH_4 generated can be recovered from SWDS, using gas wells in the waste. The recovered CH_4 can be flared or used for energy generation;
- Oxidation. When a landfill is covered with a layer of well-aerated material, part of the CH_4 is oxidized by bacteria in this cover material. Soil is known to be active in CH_4 oxidation and might be used as cover material.

In most parts of the world, there is an increase in waste generation, as a result of increasing GDP. In addition, the share of waste collected for treatment has increased as a result of improved hygienic standards. Both trends combined result in an increasing trend in the amount of solid waste to SWDS for most parts of the world and, as a result, an increase in CH_4 emissions. In some parts of the world, however, more stringent waste policies exist that aim to reduce the amount of waste disposed.

2.3. Methods for estimating emissions

There are three methodological tiers available in the 2006 IPCC Guidelines for estimating CH_4 emissions from SWDS. A decision tree on methodology selection is provided by figure 3.1 of the 2006 IPCC Guidelines (vol. 5, chap. 3). The choice of tier used depends on whether solid waste disposal is a key category and on the data availability:

Tier 1: Calculation of emissions using the IPCC FOD method and using mainly default AD and default parameters;

Tier 2: Calculation of emissions using the IPCC FOD method and using good-quality country-specific AD on current and historical waste disposal at SWDS;

Tier 3: The use of good-quality country-specific AD (see tier 2 above) and the use of the IPCC FOD method with either: (1) nationally developed key parameters or; (2) measurement-derived country-specific parameters. The Parties may also use their own country-specific methods and models if their quality is equal to or higher than that of the IPCC waste model.

As a waste sector reviewer, you should be familiar with the decision tree in the 2006 IPCC Guidelines.

When assessing the methodology, as a reviewer you may consider the following:

- The NID and the CRTs have to include information on the IPCC tier used;
- The method used needs to be in line with the recommended methods from the appropriate decision tree in the 2006 IPCC Guidelines;
- For most Parties, category 5.A solid waste disposal is a key category, which means that a tier 2 methodology or higher is needed;
- Tiers 1 and 2 are based on the IPCC FOD method, which uses the set of equations described in annex 3A.1 (2006 IPCC Guidelines, vol. 5, chap. 3). Other models might also be described as FOD models, but use simplified equations. Such models do not qualify as IPCC FOD models.
- According to the MPGs, Parties should make every effort to use a recommended tier from the decision trees in the 2006 IPCC Guidelines. If a Party is unable to use the recommended method owing to lack of resources, it may use a tier 1 method but must clearly document the reasoning in the NID (MPGs, paras. 21 and 23).
- Paragraph 28 of decision 5/CMA.3 notes that the Parties may use on a voluntary basis the 2019 Refinement to the 2006 IPCC Guidelines. Hence, as a reviewer you must be aware of the improvements undertaken in the 2019 Refinement. Guidance to quantify emissions from SWDS can be found in the 2019 Refinement

to the 2006 IPCC Guidelines (vol. 5, chap. 3).[2] Below it is an overview of the main changes between the 2006 IPCC Guidelines and the 2019 Refinement to the 2006 IPCC Guidelines.

Main changes for solid waste disposal in the 2019 Refinement to the 2006 IPCC Guidelines

In relation to the 2006 IPCC Guidelines, the main changes in the methodology used to quantify emissions from SWDS include:

- The 2019 Refinement to the 2006 IPCC Guidelines introduce new classes of SWDS, allowing the quantification of the impact of the implementation of actively aerated SWDS (a new landfill technology, which has been implemented in some countries). At actively aerated SWDS the MCF value is reduced. Since actively aerated SWDS might be a source of N_2O, the 2019 Refinement provides some information on N_2O emissions from actively aerated SWDS in appendix 3A.1;
- An update to the default values for DOC_f (the fraction of DOC that is dissimilated) in an SWDS. In the 2006 IPCC Guidelines, DOC_f was assumed to be 0.5 for all waste fractions. In the 2019 Refinement, highly decomposable wastes are assumed to biodegrade to a larger extent (DOC_f=0.7) and less degradable waste to a lesser extent (DOC_f=0.1);
- As mentioned in lesson 2, default waste generation and composition by countries and region are also updated in the 2019 Refinement. When a Party's estimate of waste to landfill and waste composition is based on AD and/or waste composition is based on IPCC defaults, implementation of the 2019 Refinement will affect emissions from SWDS.
- To enable quantification of emissions, the 2019 Refinement provides an update of the IPCC waste model. This update has similar worksheets for the definition of input parameters and presentation of results to those of the IPCC waste model in the 2006 IPCC Guidelines.

2.4. The IPCC waste model

The IPCC methodology for estimating CH_4 emissions is based on the IPCC FOD method. FOD assumes that the degradable organic component (DOC) in waste decays slowly, taking years to decades to complete. Over this period, CH_4 and CO_2 are formed. Solid waste (e.g. MSW) that is brought into landfills accumulates over time and contributes to current CH_4 emissions. To estimate emissions from the landfills using an FOD method, information on both current and historical landfilled waste is required. The estimation of CH_4 emissions follows equation 3.1 from the 2006 IPCC Guidelines (vol. 5, chap. 3), which requires information on CH_4 generation, CH_4 recovery and CH_4 oxidation factor. To quantify CH_4 generation, a CH_4 generation model has to be used based on AD (amount of waste and waste composition) and the various model parameters.

[2] https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_3_Ch03_SWDS.pdf

As a waste sector review expert, you should be familiar with more details of the IPCC waste model, AD and parameters used for the method, explained in chapter 3 (Solid waste disposal) in volume 5 of the 2006 IPCC Guidelines.

There are other models for CH_4 emission estimates available, based on FOD. When using the same parameters different models should provide mostly the same outcome. This means that when the Party uses a country-specific method, you may try to estimate emissions using the IPCC model to compare the results with the Party's estimates.

Other CH_4 emission models

Some Parties have developed their own model to estimate CH_4 generation and/or emissions. A well-known example is LandGEM, developed by the United States Environmental Protection Agency, but other models are also in use. All these models are based on FOD assumptions, and the fundamentals of the models are comparable with the fundamentals of the IPCC waste model. Calculations are performed in a different spreadsheet and sometimes even in a completely different software environment.

The major difference between models is the way in which the overall CH_4 potential is determined and the definition of fractions for which an individual k value is assumed. (This k value is an indicator of the rate of CH_4 generation. The higher the k value, the faster methanogenesis proceeds.) Models can be simplified or more complicated in relation to the IPCC methodology:

- Simplified models, such as LandGEM, can be built around a default CH_4 generation potential per tonne of waste, which degrades assuming a single value of k;
- Other models are built around comprehensive databases containing detailed information on the composition of various fractions in the waste and/or assume different rates of biodegradation, which might be dependent on temperature and moisture content.

Much still remains unknown about CH_4 generation from solid waste and, as a result, there is ongoing scientific debate on which is the best approach.

2.5. Amount of waste

Category 5.A requires the quantification of CH_4 emissions from MSW and other wastes relevant for CH_4 emissions, such as sewage sludge, industrial solid waste and residues from mechanical biological treatment plants as specified in lesson 2, topic 2.

CH_4 emissions from SWDS are generated in a delayed way. As a result, waste deposited in the past is still relevant to current emissions. The 2006 IPCC Guidelines (vol. 5, chap. 3, p.3.12) indicate that the FOD method requires data on solid waste disposal by default for 50 years.

Most developed countries today have modern SWDS equipped with weighbridges. This allows the generation of high-quality information on the amount of waste deposited at SWDS and its origins (e.g. households, offices, industry) for more recent years.

For developing countries and also for developed countries in the past, per SWDS weighbridge information is generally not available. Therefore, the methods presented in lesson 2 to estimate waste generation may be used.

In many developing countries open burning of waste is common practice at SWDS. The amount of waste available for decay at SWDS should be adjusted for the amount burned.

2.6. Waste composition

The 2006 IPCC Guidelines (vol. 5, chap. 3, p.3.10) provide two options for estimating emissions: a bulk waste mode and a waste by composition mode. When waste composition is relatively stable, the two options give similar results. When rapid changes in waste composition occur, the waste by composition mode is preferred.

- When a Party has no information available on waste composition, the 2006 IPCC Guidelines (vol. 5, chap. 3, p.3.11) indicate that it is good practice to use the waste composition option in combination with the provided IPCC default data for waste composition (vol. 5, chap. 3, table 2.3).
- If a Party does have information on composition of waste landfilled, it might calculate country-specific DOC values or use the composition directly in the IPCC waste model. Composition of waste is often characterized via sorting analyses, yielding the percentages by weight of food waste, paper, wood, plastics, etc.

A combination of a sorting analysis and an assumption on DOC in fractions provides the average DOC in waste.

Box: DOC

The average DOC in waste may be calculated based on country-specific information of various fractions in waste and default values of DOC for this waste component (from table 2.4 in the 2006 IPCC Guidelines). An example of such calculation is provided below.

	A: % fraction in waste	B: DOC content in fraction	A*B
food waste	30%	15%	4.5%
paper	15%	40%	6.0%
wood	15%	43%	6.5%
inert	40%	0%	0.0%
		Average DOC in waste ⟶	**17.0%**

The composition of the waste will vary over time as a result of the implementation of waste policies (e.g. stimulation of separate collection of paper and subsequent reuse; separate collection of organic waste and subsequent composting).

To describe the effect of changes in waste composition, regular updates of DOC analyses are necessary. For newly deposited waste, this can be organized relatively easily. Historical development of DOC is less easily determined, and often relies on a small number of studies made in the past and often in a different context.

2.7. Methane recovery

As explained in the category overview, the resulting CH_4 emissions would depend on the CH_4 oxidation and recovery. The default value for CH_4 recovery is zero. CH_4 recovery should be reported only when references documenting the amount of CH_4 recovery are available. As a reviewer, note that landfill gas recovery has become more common as a measure to reduce CH_4 emissions from SWDS and more Parties will be able to report energy recovery.

When CH_4 recovery is used, it is preferably quantified, based on measurements. The 2006 IPCC Guidelines (p.3.18) provide guidance for the following estimation methods (in order of preference):

- Based on measurements of landfill gas collection and concentrations of CH_4 in the gas;
- If no gas measurements are available, recovery might be quantified based on energy production, estimating CH_4 recovery, based on electricity production;
- Based on an inventory of installed capacity of landfill gas recovery or flaring, taking into account a correction factor;
- Assuming a default collection efficiency of 20 per cent and based on the amount of CH_4 generated at landfills with landfill gas recovery.

2.8. Model parameters

The IPCC waste model uses a number of model parameters to quantify CH_4 emissions.

- MCF
- DOC_f
- k
- F
- OX

For a summary of each parameter, please see the boxes below.

Box: MCF

MCF is the CH_4 correction factor. This factor indicates that in the top of an unmanaged SWDS aerobic conditions prevail, thus reducing CH_4 generation. MCF depends on type of SWDS and default values are listed in the 2006 IPCC Guidelines (vol. 5, chap. 3, table 3.1)

As a reviewer, note that for MCF a significant research and development effort is required to develop country-specific values. Most Parties therefore will use the IPCC default values

Box: DOC_f

DOC_f is the fraction of organic material that ultimately decomposes in an SWDS. It reflects the fact that part of the organic material does not degrade under the conditions in an SWDS. The default value in the 2006 IPCC Guidelines (vol. 5, chap. 3, p.3.13) for DOC_f is 0.5.

For DOC_f a significant research and development effort is required to develop country-specific values. Most Parties therefore will use the IPCC default values. Higher-tier methods can use separate DOC_f for specific waste types. As a reviewer, note that in the 2019 Refinement to the 2006 IPCC Guidelines separate values of DOC_f for different types of waste are provided.

Box: k

k is the reaction constant for biodegradation and expresses how fast biodegradation proceeds. The higher the value of k, the faster the biodegradation. The value of k depends on type of waste and climatic conditions. Default values are listed in the 2006 IPCC Guidelines (vol. 5, chap. 3, table 3.3).

Some Parties express the rate constant of biodegradation as a half-life of biodegradation. The half-life of biodegradation is the time in which a certain amount of waste loses half of its decomposable degradable organic carbon ($DDOC_m$). The relation between k and half-life is $k=\ln(2)/t1/2$. The 2006 IPCC Guidelines (vol. 5, chap. 3, table 3.4) expresses the default values of k as a half-life (in year).

Note that a higher value of k results in a lower half-life.

Box: F

F is used for the fraction of CH_4 in landfill gas. The default value for F is 0.5. This indicates that generated landfill gas contains approximately 50 vol% CH_4. Specific components (fats and oils) might produce gases with a slightly higher CH_4 content. When waste contains a relatively large amount of such components, a somewhat higher value of F than 50 per cent can be obtained. In practice, values of F can vary between 0.5 and 0.55. Values of F below 50 vol% are unlikely.

The value of F should not be confused with the fraction of CH_4 in recovered gas, because this fraction might be increased owing to dissolution of CO_2 in the water.

Box: OX

Before being released to the atmosphere, CH_4 in a managed landfill passes through a top layer. This top layer consists of a layer of soil that has the ability to oxidize part of the CH_4.

The default values of oxidation factor (OX) (2006 IPCC Guidelines, vol. 5, chap. 3, table 3.2) are:

- 0 per cent (negligible) for managed landfills, not being covered with such aerated material, unmanaged landfills and uncategorized landfills;
- 10 per cent CH_4 oxidation for managed landfills covered with CH_4 oxidizing material.

2.9. The IPCC spreadsheet model

The 2006 IPCC Guidelines provide a spreadsheet model (in Microsoft Excel), called the IPCC waste model, developed to assist Parties in implementing FOD. Many of the reporting Parties use this model in their inventories as it can be modified and used for all tiers. This is a tool to calculate CH_4 emissions using the 2006 IPCC Guidelines method. With this model, emissions can be estimated by type of disposal site, including managed landfill (anaerobic and semi-anaerobic), unmanaged landfill (deep (>5 m depth) and shallow (<5 m depth)) and uncategorized landfill.

Review experts of the waste sector are expected to be familiar with the spreadsheet model.

To learn more on the FOD spreadsheet model and the development of the input parameters, consult volume 5, chapter 3, pages 3.10–3.12, of the 2006 IPCC Guidelines.

IPCC spreadsheet model exercises

Before moving to the next section of the lesson, some exercises using the spreadsheet model may be completed.

Download the Exercise_IPCC_Waste model exercise spreadsheet, as provided by the Party, to use in the exercise:
https://unfccc.int/resource/tet/bw/bw3-01_IPCC_Waste_Model_Exercise.xls

In addition, the NID of the Party contains the following information:

"The country of Notaname in Eastern Asia has in 2022 a population of 2.64 million inhabitants. In the last half-century the population more than doubled, from about 1 million to 2.5 million people, and the gross domestic product (GDP) increased dramatically from about $1,000 to $14,000. Along with population growth and GDP increase, waste production grew considerably, and since the early 1990s, the need to manage the landfills has become increasingly clear. In 2004, the last open dump was closed. In the 1990s, an increasing amount of attention was paid to separate collection and treatment of papers and organic wastes in the cities, and after the year 2009, two larger waste incinerators were built to deal with the waste, with a capacity of half of the current waste production of Notaname. CH_4 emissions were calculated by using a tier 2 method and by applying the IPCC FOD method."

Using the provided information, respond to the following questions, selecting one of the options provided.

Question 1

What are the 2022 CH_4 emissions, as calculated by Notaname?

A. 2.64 kt
B. 19.10 kt
C. 225.28 kt
D. 2.1 kt

Question 2

What climate conditions are assumed by the Party according to the information provided in the worksheets?

A. Dry temperate
B. Wet temperate
C. Dry tropical
D. Moist and wet tropical

Question 3

In which worksheet can you validate the assumptions on type of SWDS (managed, unmanaged)?

A. Worksheet “HWP”
B. Worksheet “Parameters”
C. Worksheet “MCF”
D. Worksheet “Activities”

Question 4

Does Notaname account for CH_4 recovery?

A. No
B. Yes, since 2006
C. Yes, since 2016
D. CH_4 recovery is irrelevant in calculating CH_4 emissions

Question 5

Notaname claims to use a tier 2 method.
Is this justified in the information reported in the worksheets and why?

A. No, the Party uses the IPCC waste model and therefore the methodology is tier 1.
B. Yes, because the Party uses a country-specific model
C. Yes, because the Party uses the IPCC FOD model with country-specific AD
D. No, the Party applies a tier 3 method because country-specific k values are applied for different fractions in the waste

2.10. Answers to IPCC spreadsheet model exercise

Question 1
The correct answer is B. The results of the IPCC waste model can be found in worksheet "Results". Column O provides the calculated CH_4 emissions in Gg and cell O87 provides the value for 2022, which is 19 Gg.

Note that one Gg equals one kt and that in the CRT, emissions are presented in kt.

Question 2
The correct answer is A. Climate conditions can be defined in the pull-down menu in worksheet "Parameters", cell C25. The climate conditions in the file as downloaded are dry temperate.

Question 3
The correct answer is C. The type of landfill can be defined in worksheet "MCF". For each year a distribution can be defined over the five landfill types, for both Municipal Solid Waste and Industrial Waste. The total for each type of waste across the 5 SWDS should add up to 100 per cent.

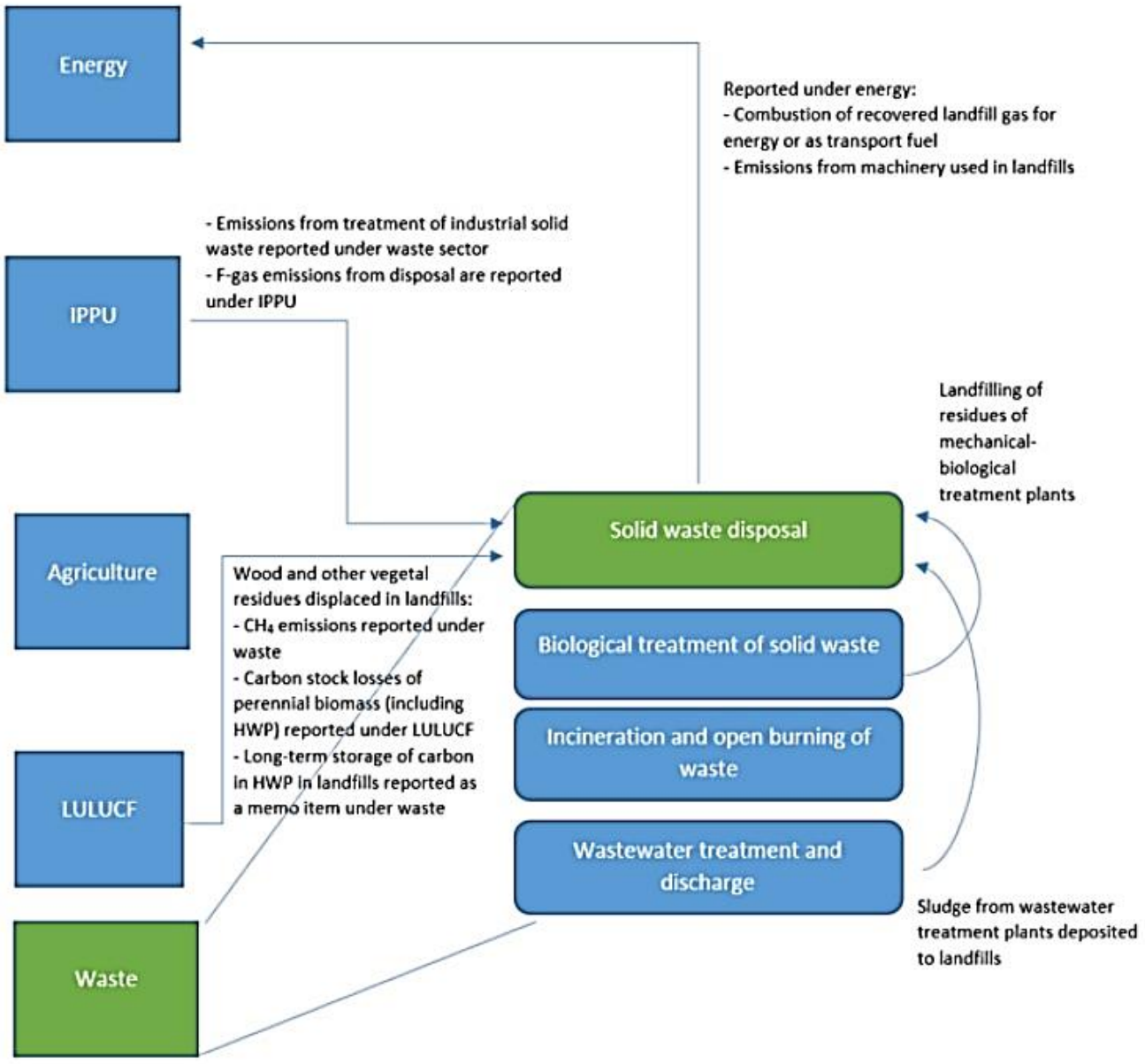
Question 4
The correct answer is B. CH_4 recovery is specified in worksheet "Recovery_OX", column C. Here it can be seen that CH_4 recovery is assumed to take place from 2006 onward. Alternatively, CH_4 recovery can also be found in worksheet "Results", column M.

Question 5
The correct answer is C. The Party uses the IPCC waste model, with default model parameters for k, DOC_f and F. However, it uses country-specific information on amount of waste disposed and waste composition and distribution of waste over types of SWDS. According to the decision tree (2006 IPCC Guidelines, vol. 5, chap. 3, p.3.7) this qualifies as a tier 2 model.

2.11. Linkages between solid waste disposal and other categories and sectors

Figure 3.1 provides an overview of the main linkages between solid waste disposal and other categories and sectors. Understanding these linkages will allow you to understand cross-sectoral issues and the necessary cross-checks of AD and emissions between sectors to make sure that the emissions are not omitted or double counted.

G. Figure 3.1: Overview of main linkages of the solid waste disposal category with other sectors and categories



The following is an example of cross-sectoral linkages where you may need to consult with the expert responsible for another sector in the review:

- Emissions due to utilization of CH_4, recovered must be reported under the energy sector. This also refers to CH_4 that remains unburned in a gas engines and is emitted with the gas engines exhaust. Emissions would be reported under the energy sector category where the CH_4 is utilized.

Cross-category linkages also exist in the waste sector:

- Waste might be burned at SWDS as a way to reduce the volume of waste to be treated. This open burning of waste at SWDS is attributed to category 5.C incineration and open burning of waste. In such cases, note that open burning of waste results in a reduction in the amount of solid waste, contributing to emissions from category 5.A;
- Sludge produced at wastewater treatment plants might be disposed in SWDS. When the Party does not account for sludge removal in category 5.D (S=0 is applied in equation 6.1 from the 2006 IPCC Guidelines, vol. 5, chap. 6) all emissions due to sludge treatment and disposal are included under category 5.D. Therefore, emissions from sludge disposed in SWDS should not be accounted for under category 5.A. When the Party account for sludge removal (S>0), the amount of sludge removed under category 5.D should be consistent with the amounts of sludge used or treated in other categories: For example, sludge used as fertilizer in the agriculture sector or treated under the waste categories, 5.A, 5 B or 5.C. In such cases, emissions from sludge should be quantified, wherever sludge is treated or disposed, using the appropriate methodologies.

3. Review approach

3.1. Overview

Topic 4 in lesson 2 gives overall guidance on the review approach (prepare – assess – draft) with a reference to this particular category. This lesson focuses on aspects that are specific to solid waste disposal category. Please refer back to lesson 6 (Review process overview) of the course on general guidance and cross-cutting issues for the review of GHG inventories if you would like a refresher on the approach to conducting a GHG inventory review.

Prepare → Assess → Draft

The choice of methods and assumptions, collection of AD and selection and development of EFs are the main drivers of inventory quality. Hence, as a reviewer, you must assess and ensure that the selection of these data and the reporting, documentation and justification in the inventory submission are in accordance with the 2006 IPCC Guidelines and the requirements of MPGs and other relevant UNFCCC decisions. The specific section of the inventory submission to check for the category along with specific questions you may consider when assessing the submission are provided in the following slides, along with examples of key considerations when reviewing the category. Examples of the review steps,

follow-up communication with the Party and inputs for the review reports are provided in the case studies and practical examples.

In addition, there are several common elements to be assessed across sectors/categories when reviewing the quality of the Party's submission (i.e. uncertainty analysis, QA/QC, time-series consistency, recalculations and progress in implementing improvements). Lesson 2 of the current course provides a list of possible checks and examples of assessment of cross-cutting issues.

Box: Prepare

During this stage you obtain and familiarize yourself with all the materials needed to undertake the review. The overall preparation of the review includes the careful study of all documents that are available to inform your assessments, such as:

- Refreshing your knowledge of (i) the UNFCCC reporting and review guidelines; (ii) the 2006 IPCC Guidelines; and (iii) review tools and other supporting materials (see also lesson 2, topic 4);
- Familiarizing yourself with the Party's submission;
- Focusing on the sector under your responsibility:
    - The category-specific information contained in the Party's submission;
    - The issues for the sector in the previous review reports.

Box: Assess

During this stage you evaluate whether the recommendations of the previous review are implemented and carry out an in-depth review of the emission inventory, possibly resulting in the identification of new issues and recommendations related to the implementation of the TACCC principles. Performing the review, you might make use of the review tools as provided by the secretariat. Identify possible capacity-building needs for those Parties that need it in the light of their capacities.

Recommendations in previous TERR

One of the tasks during a review is to evaluate each recommendation in the previous TERR: whether it can be considered resolved or not resolved, or whether the Party is addressing the recommendation. The NID might include a paragraph which summarizes the status of implementation of each recommendation according to the Party. The Party may provide further information during the review. However, for each recommendation, you need to check the relevant sections or chapters in the NID and the relevant CRT to conclude whether the implementation of the recommendation and the changes to the NID and/or CRT are satisfactory to consider the recommendation as resolved.

Your conclusion on the recommendations from the previous TERR are documented in the current review report. Your conclusion has to be specific to all elements of what is recommended, making clear references to the page in the NID or to the specific CRT where improvements are made by the Party. If the issue is not yet resolved, the status should be clearly documented based on the inventory submission and any follow-up information received during the review.

Review tools provided by the secretariat

Before the review, the secretariat will make available user-friendly review tools that provide access to the secretariat's CRT database and therefore all the data submitted by Parties in their CRTs. The review tools will allow you to sort or search data according to Party, submission or inventory year, category, GHG and specific data type (e.g. emissions, AD, IEF). The review tools allow you to search for data for a particular Party or for all Parties. They will help you to discover outliers in the time series or, when comparing data across countries, allow a quick check of the magnitude of recalculations across submissions for any data point. Review tools give you quick access to data with maximum flexibility. It is often the most efficient way to find the data you are searching for while performing a review.

Box: Draft

This stage is linked to the outputs of the assessment process and drafting questions to the Party for clarification on the submission and preparing the findings on the waste sector to be included in the review report. For guidance on drafting your conclusions and recommendations from a review, refer to lesson 2. With regard to solid waste disposal, there are no special issues with drafting conclusions and recommendations. Some practical examples in drafting issues for the TERR are included in the case studies and examples included in this lesson.

3.2. Category-specific parts of a Party's submission

In the Party's submission, the main information on the quantification of emissions from solid waste disposal can be found in:

- The NID, which provides a description of the methods, AD and EFs used and the assumptions made to calculate emissions. Each NID is organized in the same way, with similar chapters. Information on solid waste disposal according to the outline of the NID will be included in chapter 7.2;
- The CRTs, which provide the numerical inventory information with calculated emissions, the AD used and back-calculated IEFs. CRT 5.A provides a summary of the results for emissions from solid waste disposal.

During the review, make sure to also check the cross-cutting information provided in CRTs 7–10, as explained in lesson 2, topic 3, as well as the cross-cutting chapters of the NID (chapters. 1, 2, 9 and 10 and annexes), which would contain additional information relevant for your assessment.

3.3. CRT 5.A

As a reviewer you must be familiar with CRT 5.A on solid waste disposal, where AD, CH_4 recovery and emissions and the resulting IEF are specified.

When reviewing CRT 5.A, consider the following:

- CRT 5.A distinguishes three categories: managed SWDS; unmanaged SWDS; and uncategorized SWDS. The category managed SWDS is subdivided into three subcategories representing the types of SWDS (anaerobic, semi-aerobic and active-aerated). Based on the existing practices, most Parties will report all of their managed waste disposed under subcategory 5.A.1.a (anaerobic);
- The 2006 IPCC Guidelines do not provide guidance for active-aerated SWDS. This type of SWDS was introduced in the 2019 Refinement to the 2006 IPCC Guidelines and guidance on quantifying its emissions is part of the 2019 Refinement;
- The CRT allow Parties to report either the total amount of waste (as bulk waste) or disaggregate the amounts of degradable fractions in the waste (report less, moderately and highly decomposable waste);
- Emissions reported are net CH_4 emissions, that is, the difference between generation and the sum of recovery and oxidation. For the IEF, the gross emissions are used (including recovery if reported);
- Methane recovery can only be specified for each subcategory and landfill type;
- The national CH_4 recovery rate for a subcategory is not specified in the CRT, but can be calculated as recovery/(emissions/(1-OX)+recovery). When a recovery rate is higher than the default recovery rate from the 2006 IPCC Guidelines (higher than 20 per cent), this means that recovery should be based on measured amounts of CH_4 recovery per site. In such a case, as a reviewer you might pay extra attention to the justification of CH_4 recovery;
- The implied emission factor (IEF) at the category level where recovery is reported is calculated as the ratio of gross emissions and amount of waste disposed. Note that emissions from SWDS are generated from waste disposed in the decades before emissions occur. So there is no direct relation between waste disposed in a year and the CH_4 emissions in that year. However, the IEF can be used to make comparisons across Parties;
- A useful check is the per capita managed waste disposal. This amount can be obtained by dividing cell C10 by the total national population (e.g. from table 5.D, cell 06). The result can be compared with the IPCC default or per capita waste generation in surrounding countries with similar waste practices;
- Another useful check is for possible unmanaged waste disposal in countries with well-developed and implemented waste policies. Large-scale disposal in unmanaged landfills is less likely here;
- A final check is for open burning of waste, when waste is deposited in unmanaged waste.

3.4. Key considerations when assessing solid waste disposal

The GHG inventory should be prepared and reported in accordance with the MPGs, following the good practice provided in the 2006 IPCC Guidelines. The fundamental principles for developing a GHG inventory, as reaffirmed by the MPGs, are transparency, accuracy, completeness, consistency and comparability (the TACCC principles). You assess the inventory for its compliance with these principles. Possible questions related to the implementation of each of the TACCC principles in the inventory for solid waste disposal can be accessed via specific questions as summarized below.

- Is the inventory sufficiently transparent?
- Is the inventory complete?
- Is the inventory consistent?
- Is the inventory comparable?
- Is the inventory accurate?

When the time comes to participate in an actual GHG inventory review, study any further review materials provided to you by the secretariat suggesting further possible checks you may want to use.

The examples provided in this lesson are not intended to provide an exclusive list of possible questions, but a starting point to stimulate your thinking. You may add or modify the questions as appropriate while conducting a review.

Box: Is the inventory sufficiently transparent?

- Is all relevant information available in the NID or in the documents referred to in the NID?
- Is the time series on amounts of waste disposed in all types of SWDS clearly described?
- Are assumptions on waste composition clear?
- Is it clear which model parameters are used?
- Does the Party recover CH_4 and, if so, does the NID clearly describe how the amount of methane recovered is quantified?

Box: Is the inventory consistent?

- Did the Party perform any recalculations and were they properly applied across the time series?
- Is the time series of AD and waste composition consistent?
    - Are there discontinuities in the time series of waste generation and disposal in SWDS?
    - Does the inventory specify the actions a Party made to ensure time-series consistency (e.g. in line with gap-filling techniques suggested by the 2006 IPCC Guidelines, vol. 1, chap. 5)?
    - Are historical data reconstructed using per capita GDP and urban population as drivers?

Many countries nowadays have good statistics on waste generation and treatment. However, quantification of CH_4 emissions from SWDS requires over 50 years of AD. Going back in time, different data sets will be used to reconstruct historical data. When AD is not available for the entire time series, the Party might extrapolate the earliest data available back in time to complete historical data.

The 2006 IPCC Guidelines (vol. 1, chap. 5) describe how to ensure a consistent time series. Guidance is given on how to combine data sets and fill up gaps in available data.

- Is the time series in AD and waste composition in line with expectation, taking into consideration the overall trend in waste generation, such as implemented waste policies across the reported time series and changes in waste treatment across the reported years (e.g. shares of biological treatment, incineration and other treatment options)?
- Is the composition of the waste disposed consistent with the composition of the waste assumed to be incinerated? When waste is open burned at SWDS, is the reduction in the amount of waste available for anaerobic decomposition at SWDS due to open burning consistent with the amount of waste considered to be open burned at SWDS in category 5.C?

Is the inventory complete?

- Does the NID explicitly mention that industrial wastes and sludge are included in the estimates?
- Is the inventory based on a time series of waste disposal, which is sufficiently long (50 years)?
- Does the NID provide information on the completeness of the inventory for the category and justify any “NE” notation key used?

Is the inventory comparable?

- Does the NID include only information on household waste or MSW, or does it also describe disposal of other wastes such as sludge or industrial waste?
- When disposal of sludge is included, is the amount of TOW removed with this sludge (S) considered in the calculation of emissions from wastewater treatment? Does the emission inventory only include waste from the part of the population whose waste is collected (or urban population)?

Is the inventory accurate?

- Is the methodology appropriate? Note that for most Parties, solid waste disposal is a key category and tier 2 or higher is required. The methodological tier should be in agreement with the decision tree in figure 3.1 in the 2006 IPCC Guidelines (see topic 2, under methodological information, as well as paragraphs 21–23 of the MPGs).
- Is the CH_4 emission model accurate?
    - Does the Party use country-specific values for DOC? Does the Party periodically update its assumptions on DOC to reflect changes in waste composition?
    - Does the Party use the correct default values for the model parameters (MCF, DOC_f, k, F and OX)?
    - When a Party uses country-specific model parameters, are they properly justified?
    - When a Party uses a tier 3 model, is the model clearly described and properly justified?

The justification of country-specific model parameters or a tier 3 model can be very technical and beyond your expertise as a reviewer. Be aware that it may as well be beyond the expertise of the Party's inventory team. In reviewing a tier 3 method or model, you might evaluate the transparency of the presentation of the method and whether the Party's QA/QC process for determining a country-specific model parameter is adequate; for example, does the Party critically discuss whether the tier 3 model results in an estimate of higher quality than that produced using the IPCC waste model? Did the Party try to compare the two models and discuss the outcomes?

- For larger countries, does the Party distinguish between regions?
    - When the country has regions with different climatic conditions;
    - When AD from one region cannot be used to estimate activities in another region, the 2006 IPCC Guidelines (vol. 5, chap. 2, p.2.6) encourage Parties to use region-specific data to the extent possible.

Higher temperatures and excess precipitation enhance biodegradation of waste and CH_4 generation and emissions. For various climate zones, the IPCC recommends different default values of k (2006 IPCC Guidelines, vol. 5, chap. 3, table 3.3).

- Is the amount of CH_4 recovered based on actual measurements of CH_4 recovered at individual sites? The 2006 IPCC Guidelines (vol. 5, chap. 3, p.3.18) give guidance on CH_4 recovery (utilization and flaring).
    - Does the inventory describe the process of collecting recovery data? For example, are collection data measured by the landfill operator reported to the authorities and subsequently compiled by the inventory team? Is energy produced?

- It is indicated in the 4th bullet point in section 3.8 of the 2006 IPCC Guidelines (vol. 5, chap. 3, p.3.28) that an inventory of known recovery facilities is desirable. Does an inventory compiler have such an inventory available?

Box: Evaluation of higher-tier models

It is not the responsibility of the TERT to judge the application by a Party of a model or tier 3 method, including country-specific approaches, but the TERT should review whether input and output data and parameters of the model or tier 3 method have been reported transparently and accurately and are consistent across the time series.

The review of models can be deemed to have been transparently and well documented in the NID when the information provided covers the following:

(i) Reasons for selecting the particular model;
(ii) If an existing model is being used and adapted: area of application of the original model and how it has been adapted (description of why and how the model was adapted for conditions outside the originally intended domain of application);
(iii) Main equations/processes;
(iv) Material assumptions (important assumptions made in developing and applying the model);
(v) Domain of application of the model (description of the range of conditions for which the model has been developed to apply);
(vi) How the model parameters were estimated;
(vii) Description of key inputs and outputs;
(viii) Details of calibration and evaluation using calibration data and independent data;
(ix) Description of the approach undertaken for the uncertainty analysis and for the sensitivity analysis, and the results of these analyses;
(x) QA/QC procedures applied and findings from these procedures;
(xi) Comparison of the results from models, tier 3 methods or country-specific approaches with the results from lower-tier or default approaches;
(xii) References to peer-reviewed literature (where details of research on the model can be found).

3.5. Case studies

The examples below show how the review approach may be applied when reviewing the category. The examples are based on real submissions by Parties. For each question, select an answer or draft your response and submit it, in order to be able to see the suggested answer.

3.6. Case study 1 (previous recommendation)

Appendix lesson 3-1 contains a section from the NID for use in this case study. You may download the document here: https://unfccc.int/resource/tet/bw/bw3-02_app_3.1.pdf

Question 1.1: Assessing the status of implementation of a previous recommendation

The conclusions and recommendations of the previous review are listed in the TERR. For waste, one of the recommendations in the previous TERR reads:

'According to table 7.2.2 of the NID, the Party chose to use the default CH_4 generation rate constants for dry rather than wet temperate climates from the 2006 IPCC Guidelines (vol. 5, table 3.3) but did not provide an explanation for that choice. During the review, the Party provided a set of graphical data, including a histogram of precipitation and potential evapotranspiration values and a distribution map, and explained that the ratio of mean annual precipitation and potential evapotranspiration the country is between 0.48 and 1.11, with a mean of 0.60, and so the countries climate can be defined as dry temperate in accordance with table 3.4 in the 2006 IPCC Guidelines (vol. 5, chap. 3).

The TERT recommends that the Party includes in the NID the information to justify the appropriateness of the chosen default CH_4 generation rate constants for the country-specific national circumstances.'

Consider the information in the current NID.

As a reviewer, do you consider the recommendation from the previous TERR as:

A. Resolved
B. Not resolved
C. Addressing

Question 1.2: Comparing with IPCC default values

Are the values used for DOC and k in agreement with the default values from the 2006 IPCC Guidelines? Select one:

A. Both DOC values and k values are in agreement with the IPCC default values
B. DOC values are in agreement with the IPCC default values but k values are not
C. DOC values are not in agreement with the IPCC default values but k values are
D. Neither the DOC values nor the k values are in agreement with the IPCC default values

Question 1.3: Formulating conclusions on previous recommendation status for the TERR

Based on your assessment, draft the text for the TERR on the status of implementation of the previous recommendation

Please submit your draft of the text here:

3.7. Answers to case study 1

Question 1.1

The correct answer is A: Resolved. The recommendation from the previous TERR was to include the information (to justify the appropriateness of the chosen default CH_4 generation rate constants) in the NID. This information is included.

Question 1.2

The correct answer is A. Reported values for k and DOC correspond to the default values for k in the 2006 IPCC Guidelines, volume 5, chapter 3, table 3.3, and default values for DOC in volume 5, chapter 2, table 2.4.

Question 1.3

The conclusion might be formulated as follows:

Resolved. The Party provided relevant climatological information in its NID (pp.448–449) to justify the classification of its climate as dry temperate. The generation rate constants (k) are reported in NID table 7.2.2. The values used are consistent with the default values for dry temperate regions specified in the 2006 IPCC Guidelines (vol. 5, chap. 3, table 3.3).

Note:

- This conclusion in the TERR starts with “resolved”, being one of the possible conclusions on a recommendation in the previous NID. This status indicates that the issue is closed and will not be addressed in the next TERR. The other options are “not resolved” or “addressing” and previous recommendations with such a status are transferred for consideration in the next review cycle;
- The rational for the assessment of the status of a previous recommendation should always be based on clear references to relevant pages and tables in the NID or CRT and the 2006 IPCC Guidelines;
- In the example above, although the DOC values are also consistent with the IPCC defaults, they are not mentioned in the rationale. The reason is that DOC was not part of the recommendation in the previous TERR, and therefore this information is not relevant for the conclusions.

3.8. Case study 2 (AD assessment)

An African country describes the amount of waste disposed in SWDS in chapter 7.2 of its NID:

Appendix Lesson 3-2 contains a section from the NID for use in this case study. You may download the document here: https://unfccc.int/resource/tet/bw/bw3-03_app_3.2.pdf

Question 2.1: Assessing AD used

Noting the description reported in the NID, do you consider that the Party has selected the AD to estimate emissions from solid waste disposal in line with the 2006 IPCC Guidelines and provided a sufficient explanation on the assumptions used?

A. Yes
B. No

Question 2.2: Drafting a question to the Party

Based on your findings and the description of the assumption used in the NID, formulate a clarifying question to the Party regarding the waste generation rate per capita used.

Please submit your question here:

Question 2.3: Evaluation of per capita waste generation in time

According to the NID the per capita waste generation is assumed to be constant throughout 2000–2022. Do you think that this assumption is in line with the 2006 IPCC Guidelines and sufficiently justified?

A. Yes
B. No

Question 2.4: Classification of the issue

The unjustified use of constant per capita waste generation in 2000–2022 may lead to which type of issue in inventory?

A. Accuracy
B. Consistency
C. Transparency
D. Completeness

Question 2.5: Drafting a conclusion and recommendation

You decide to raise the issue with the Party. In its response, the Party acknowledges that GDP grew in 2000–2022. The Party provided an improved time series of waste disposed and a recalculation of CH_4 emissions. As a reviewer, you can agree with the recalculated emissions.

Based on your findings, formulate a possible text for the TERR regarding the constant generation rate used.

Please submit your draft of the findings here:

3.9. Answers to case study 2

Question 2.1

The correct answer is B: Items that are not transparently presented in the NID and hinder the assessment of the accuracy of the data include:

- The per capita waste generation assumed is 578.23 kg/cap/year, where the IPCC default for Africa is 290 t/cap/year. For justification, the NID refers to the State of Environment Outlook Report. This report contains some information on waste generation (8.4 million households served and waste generation has risen to 67 million m^3 per household, suggesting a waste generation of 8 m^3 per household). However, from the information obtained it remains unclear how the per capita waste generation is calculated;
- It is unclear whether this per capita waste generation is applied to the total population, or only to the share of the population that is serviced by the waste treatment companies.
- It is unclear whether the 67 million m^3 refers to MSW (and also includes waste from shops, offices, municipal services and smaller industries) or whether it refers to only waste from households;
- The fraction of waste disposed to SWDS is assumed to be 90 per cent, which is substantially higher than the default from the 2006 IPCC Guidelines (for Africa of 69 per cent). This assumption is not justified in the NID.
- For Industrial Waste, information is provided on generation. The assumption remains unclear on what part of this waste is disposed in SWDS.

Question 2.2

A possible question to the Party might read:

Chapter 7.2 in the NID describes the generation of household waste with per capita waste generation of 578.23 kg/cap/year over 2000–2022. The TERT noted that this value is about two times the 2006 IPCC default for Africa of 290 t/cap/year (see 2006 IPCC Guidelines, vol. 5, chap. 2, table 2.1). For justification the Party refers to the State of Environment Outlook Report. Although this report contains some information on waste generation (8.4 million households served and waste generation has risen to 67 million m^3 per household) it remains unclear how per capita waste generation was calculated. Could the Party provide clarification on the calculation of the per capita waste generation rate?

Question 2.3

The correct answer is B. According to the 2006 IPCC Guidelines (vol. 5, chap. 3), historical data can be reconstructed using per capita GDP as a driver, if data are not available. The information provided in the referenced documents suggests a prolonged period of economic growth, which does not support constant waste generation rate. As the product of per capita GDP seems not constant in 2000–2022, a constant per capita waste generation in this period is not in agreement with the 2006 IPCC Guidelines.

Question 2.4

The correct answer is A. Since this issue is related to a possible overestimation or underestimation of emissions, this is considered an accuracy issue.

Question 2.5

A possible text to be included in the TERR might read:

According to the NID, paragraph 7.2.2, per capita waste generation in 2000–2022 is assumed to be constant at a level of 578.23 kg/cap/year. As a justification, the NID refers to the State of Environment Outlook Report. This report, however, reads: "The country has experienced rapid growth in waste volumes, associated with a prolonged period of economic growth. During the last decade, general waste generation rose to nearly 67 million cubic meters, or by 62 per cent." This is not consistent with the assumption that per capita waste generation is constant over such a long period of time. According to the 2006 IPCC Guidelines (vol. 5, chap. 3), historical waste generation can be reproduced, using per capita GDP as a driver.

In response to questions during the review, the Party acknowledged that a gradual increase in waste generation in the period is a more likely assumption and provided an improved time series of waste generation and a recalculated time series of CH_4 emissions. The TERT agreed with the improved time series and revised estimate [that increased the emission by [value] kt CO_2 eq in the last reported year].

The TERT recommends that the Party include the revised time series of waste generated across the 2000–2022 time series and the recalculated CH_4 emissions in the next submission. The TERT also recommends that the Party document and report the waste generation rate used and justification of any assumptions used in the estimates in the NID.

4. Practical exercises

In the following section, some additional exercises are provided so that you can practise your skills as a review expert.

4.1. Exercise 1: CH_4 recovery at landfills

A Party presents the following figure 181 on CH_4 emissions and recovery.

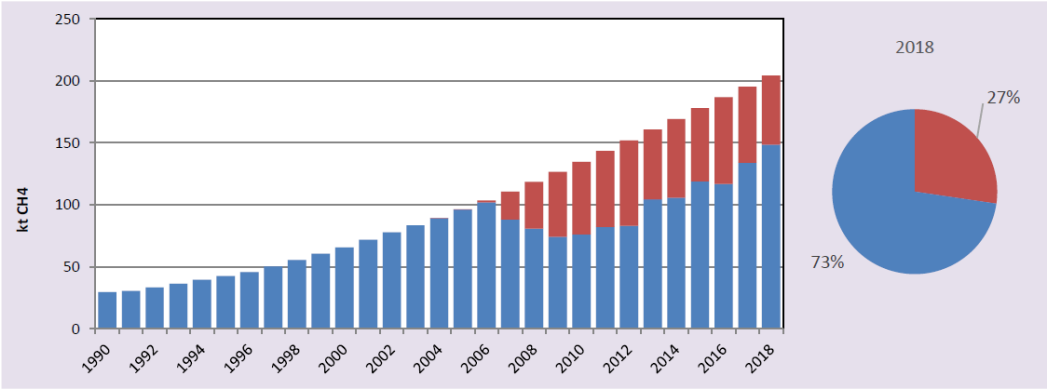


Figure 181: development of CH_4 emissions (blue) CH_4 recovery (red) over time

According to figure 181, what is the national average recovery efficiency in 2016?

A. 12 per cent
B. 33 per cent
C. 50 per cent
D. 67 per cent

4.2. Exercise 2: Justification of CH_4 recovery

A Party in its NID indicates that no direct measurement of recovered CH_4 is available for recent years. However, there is information available on the amount of electricity generated by utilizing landfill gas. For 2022, the total amount of electricity produced at landfill gas projects is 48,000 MWhe. Assuming an NCV of 50 MJ/kg and a gas engine efficiency of 35 per cent, CH_4 recovery is estimated to be 9.9 kt.

What is your reaction as a reviewer?

A. Accept the explanation by the Party because, according to the 2006 IPCC Guidelines, CH_4 recovery can be based on monitoring of electricity production
B. Calculate CH_4 recovery yourself using the information provided before deciding what to do
C. Request additional clarification from the Party on how CH_4 recovery is calculated from electricity production
D. B and/or C
E. None of the above

4.3. Exercise 3: Assessing reported DOC and L_0

For a Party, CH_4 emissions from SWDS is a key category. CH_4 emissions are calculated using a country-specific FOD model that uses equations similar to those in the IPCC waste model. The most important model parameters are L_0 (the CH_4 generation potential, Gg CH_4 per tonne of waste disposed) and the reaction constant of biodegradation (k). L_0 is estimated from the amount of dry organic matter and DOC in the SWDS and clear references are provided in the NID.

The NID (p. 253) provides information on DOC and the calculation of L_0. Download a section of NID use in the exercise here: https://unfccc.int/resource/tet/bw/bw3-04_exercise_3.2.docx

Box: L_0

The parameter L_0 is a model parameter in the LandGEM model developed by the United States Environmental Protection Agency. This model is widely used in capacity-building projects and it can be expected that some Parties will use it for their quantification of CH_4 emissions. LandGEM starts from an estimate of the CH_4 potential (L_0), which is assumed to biodegrade according to FOD kinetics. LandGEM has been frequently used in the past to estimate emissions from SWDS in developing countries and some Parties might still prefer to use LandGEM to quantify their CH_4 emissions.

L_0 in LandGEM can be compared to the IPCC waste model using equations 3.2 and 3.3. from the 2006 IPCC Guidelines (vol. 5, chap. 3). Both equations combined yield:

$L_0 = DOC*DOC_f*MCF*F*16/12$

Do you agree with the calculated average DOC value used in the calculation of L_0?

A. Yes
B. No

4.4. Exercise 4: Party with different climate zones

A Party under review consists of a large territory: the northern part is a dry subtropical region; the southern part is more mountainous, wetter and colder. The larger urban areas are in the south, at the foot of the mountains near the sea. The north consists of more rural areas. In the south, waste incineration has become the main waste treatment option over the last 10 years. In the more rural north, solid waste disposal is still the predominant method for waste treatment. Until recently, the Party quantified CH_4 emissions from SWDS, assuming one single model.

Download the current NID (chap. 7.2, p. 307) with information to be used in the exercise: https://unfccc.int/resource/tet/bw/bw3-05_exercise_3.3.docx

Carefully read the information in the NID. Is it completely transparent how the Party addresses different climates in their emissions from solid waste disposal?

A. Yes
B. No

4.5. Exercise 5: Party with different climate zones (continued)

In a response, the Party sent an Excel file of the assumed distribution of deposited waste over climate zones. The zones are characterized based on the ratio between mean annual precipitation (MAP) and potential evapotranspiration (PET): dry: MAP/PET < 1; and wet: MAP/PET > 1. The calculation started from an estimation of waste generated in each zone, with amounts generated in each zone being proportional to the size of the population in each zone. For the dry subtropical part of the country all waste generated is assumed to be landfilled; for the wet temperate region, solid waste disposal is corrected for incineration of waste. The total amount of waste disposed per year for both zones combined matches the total amount, as listed in table 7.2 in the NID.

Please draft a conclusion/recommendation for the TERR.

4.6. Exercise 6: Classification of SWDS

In the NID, a Party classifies their SWDS as follows:

'In 2009, landfill legislation came into force, aiming to prevent or reduce as far as possible the negative effects on the environment, in particular the pollution of surface water, groundwater, soil and air, and on the global environment, including the greenhouse effect, as well as any resulting risk to human health, from the landfilling of waste, during the whole life cycle of the landfill. Therefore, compliant landfills need to have a watertight sealing below the waste to prevent soil and groundwater contamination and also gas extraction to reduce CH_4 emissions.

New landfills and new compartments at existing landfills need to comply with the requirements from this landfill legislation from 1 January 2012 onward.'

For quantification of CH_4 emissions from SWDS, the following assumptions are made:

- waste prior to 2009 is assumed to be disposed of in unmanaged SWDS. Based on expert judgment of the average size of an SWDS before 2009, it is assumed that 80 per cent of unmanaged SWDS are deep and 20 per cent are shallow;
- waste after 1 January 2012 is assumed to be disposed of in managed SWDS;
- in between 2009 and 2012 a gradual implementation of management SWDS is assumed.

Do you agree with the assumption that SWDS before 2009 are unmanaged and SWDS after 2011 are managed?

A. Yes
B. No

4.7. Answers to practical exercises

Exercise 1

The answer is B: 33 per cent. Emissions in 2016 are about 120 kt; emissions plus recovery is 180 kt, so recovery is about 60 kt. Recovery efficiency is 60 kt/180 kt = 33%.

Exercise 2

The correct answer is D.

The 2006 IPCC Guidelines (vol. 5, chap. 3, p. 3.19) explicitly mention the option to estimate recovery from energy generation, so the approach is an accepted one. However, you will need to check the integrity of the calculation. As a reviewer:

- You might try to reproduce the calculation of CH_4 recovery. 48,000 Mwhe equals 172,800,000 MJ. The efficiency is 35 per cent, so the total calorific value of the gas is 172,800,000/0.35= 493,714,285 MJ. Divided by the NCV of 50 MJ/kg, this equals 9,870,000 kg CH_4 (9.87 kt);
- If you are not comfortable with the recalculation, you might ask the Party for clarification on the calculation of energy produced to CH_4 recovered.

Exercise 3

The answer is B. The average DOC can be calculated as the sum of the product of each fraction in the waste and the DOC content of each fraction. This calculation in itself is done correctly:

	Food	Garden	Paper	Wood	Textile	Disposable nappies	Plastics, other inert waste
A: fraction in waste	33%	10%	10%	2%	2%	0%	43%
B: DOC in fraction	15%	20%	40%	43%	24%	24%	15%
A*B	4.95%	2.00%	4.00%	0.86%	0.48%	0.00%	6.45%
Sum of row (A*B)	**18.74%**						

However, in this calculation, a DOC content of 15 per cent is assumed for the fraction 'plastics and other inert waste' (same as for 'food'). This is incorrect. According to the 2006 IPCC Guidelines, the default DOC content for this inert material is 0. The actual DOC content in this waste should be 122.9 kg/t waste (12.29 per cent).

Based on this value, the L_0 would be 25.5 kg/t. This value can be calculated from equation 3.2 and 3.3 in the 2006 IPCC Guidelines (vol. 5, chap. 3). Both equations combined, L0 can be calculated as:

$$L_0 = DOC * DOC_f * MCF * F * 16/12$$

Using the value of DOC of 122.9 kg/t, DOC_f=0.5; average MCF=0.55; F=0.5, this results in

$$L_0 = 122.9 \text{ kg/t} * 0.5 * 0.55 * 0.5 * 16/12 = 25.5 \text{ kg/t}$$

Exercise 4

The correct answer is B. The Party appears to consider two climate zones in its calculation of emissions. However, the distribution of amount of waste disposed of in time for each climate zone and the information on the assumptions on which the Party based its estimate of this distribution of total amounts in time, is not provided in the NID.

Exercise 5

A possible text for the TERR might read:

'The Party estimates CH_4 emissions from solid waste disposal on land, distinguishing between two climate zones (based on the ratio between MAP and PET: dry: MAP/PET < 1; and wet: MAP/PET > 1) separately for the first time in its 2024 submission. The TERT commends the Party for this methodological improvement. However, the TERT noted that the Party provided the corresponding k values for the dry and wet zones in the NID (chap. 7.2.2, pp.284–285) but does not provide any information on waste disposal amounts in each climate zone. During the review, the Party provided an Excel file specifying detailed data on disposal amounts in both regions along with the assumptions used.

The TERT recommends that the Party provide in the NID summary information on waste disposal amounts for each climate zone along with the assumptions used in the distribution.'

Exercise 6

The correct answer is B. The definitions of managed and unmanaged SWDS are provided in the 2006 IPCC Guidelines (vol. 5, chap. 3, table 3.1). Managed SWDS 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. The new landfill legislation is much stricter than the UNFCCC definition of managed SWDS and it is likely that the majority of the SWDS prior to 2009 qualify as 'managed' under the UNFCCC definition.

5. Self-check quiz

The questions set out below will allow you to check your knowledge of the category. Please be aware that you can use the information in the 2006 IPCC Guidelines when answering these questions. Select one answer from the options provided for each question.

Question 1

Managed SWDS must have:

A. Controlled placement of waste
B. Structures for introducing air in waste
C. A permeable cover layer
D. Both A and C

Question 2

Which are acceptable estimates of CH_4 recovery at managed SWDS (percentages to generation)?

A. An estimate of 25 per cent, justified by pointing out that a neighbouring country with similar SWDS legislation measured the same efficiency
B. An estimate of 12 per cent, assuming that 60 per cent of all managed SWDS have CH_4 recovery
C. An estimate of 18.9 kt CH_4, based on an inventory of available capacity for CH_4 recovery, indicating that the joint recovery capacity at all SWDS is 54 kt of CH_4
D. Both B and C
E. None of the above

Question 3

When there is open burning of waste at an uncategorized SWDS:

A. 40 per cent of the waste mass can be assumed to be combusted in open burning
B. CO_2 emissions due to burning of carbon from biomass needs to be included in the inventory
C. The amount of waste, assumed not to be available for biodegradation and CH_4 generation in category 5.A, should be equal to the amount of waste assumed to be burned in category 5.C.
D. Both A and C
E. None of the above

Question 4

The table below describes default composition of MSW for Middle Africa (2006 IPCC Guidelines, vol. 5, chap. 2, table 2.3).

	Mass in %
food waste	43.4
paper/cardboard	16.8
wood	6.5
textiles	2.5
plastic	4.5
other inert waste	26.3

What is the average DOC content, assuming the default DOC values in fractions in MSW?

A. 17.3 kg/t
B. 16.6 kg/t
C. Another value
D. Cannot be calculated because part of information is lacking

Question 5

A Party from South-East Asia has a tropical climate. This implies abundant rainfall (> 2000 mm per year), an evapotranspiration of 750–1000 mm per year and a mean annual temperature of 25.4 °C.

What are the decay rates of biodegradation for bulk waste?

A. 0.05 y^{-1}
B. 0.09 y^{-1}
C. 0.17 y^{-1}
D. 0.2 y^{-1}

Question 6

With a view to preserving the completeness of the inventory, which of the statements below is correct:

A. Sludge disposal needs to be included when sludge removal is not accounted for in category 5.D
B. Industrial waste can be assumed to be included in MSW when no other information is available
C. Waste from mining and quarrying can be excluded as the amounts can be large and the DOC and fossil carbon contents are likely to be negligible
D. Construction and demolition waste may be excluded since it consists of large inert materials

5.1. Answers to self-check quiz

Question 1

The correct answer is A. See table 3.1 and footnote 1 on anaerobic managed solid waste disposal sites (2006 IPCC Guidelines, vol. 5, chap. 3). These sites 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 SWDS may have a cover layer, but this does not necessarily need to be a permeable cover layer.

Question 2

The correct answer is D. The 2006 IPCC Guidelines (vol. 5, chap. 3, p. 3.18) provide acceptable methods for CH_4 recovery estimates. The text says (amongst others):

- When CH_4 recovery is estimated on the basis of the number of SWDS with landfill gas recovery, a default estimate of recovery efficiency would be 20 per cent. Therefore, when 60 per cent of the managed SWDS has CH_4 recovery, 20 per cent recovery efficiency can be assumed for that 60 per cent, yielding a total recovery of 12 per cent. This means that answer B is correct.
- Another conservative approach is to estimate total recovery as 35 per cent of the installed capacities. Therefore, when the joint recovery capacity is 54 kt CH_4, CH_4 recovery can be estimated to be 18.9 kt (35 per cent of 54 kt). This means that answer C is correct as well.

Question 3

The correct answer is C. According to the 2006 IPCC Guidelines (vol. 5, chap. 3, p 3.12), 'the amount of waste (and $DDOC_m$) available for decay at SWDS should be adjusted to the amount burned.'

Answer A is incorrect. There is no default value for combustion at the SWDS. For uncategorized (and uncategorized unmanaged) SWDS, MCF is 60 per cent (see table 3.1). This is because aerobic conditions occur in 40 per cent of the waste, therefore in these 40 per cent of waste CH_4 generation does not take place.

Answer B is incorrect. CO_2 emissions caused by degradation or incineration of biomass are part of a short carbon cycle and do not need to be included in the inventory.

Question 4

The correct answer is B. See table below for the calculation. As additional information, the DOC content in the waste fraction is needed. This information is supplied in table 2.4 in the 2006 IPCC Guidelines (vol. 5, chap. 2).

Total DOC can be calculated as the sum of the product of the fraction in the waste (under column A) and the DOC in the fractions (under column B).

	Mass in %	DOC (kg/t)	%mass*DOC (kg/t)
	A	B	A*B
food waste	43.4	15	6.510
paper/cardboard	16.8	40	6.720
wood	6.5	43	2.795
textiles	2.5	24	0.600
plastic	4.5	0	0
other inert waste	26.3	0	0
			16.625

Question 5

The correct answer is C. From the NID, it may be concluded that the mean annual temperature (MAT) is >20 ^{o}C; mean annual precipitation is >1000 mm y^{-1}. In table 3.3 (2006 IPCC Guidelines, vol. 5, chap. 3), such climate is characterized as tropical and wet. The CH_4 generation rate for bulk waste in this climate is 0.17 y^{-1}, according to table 3.3.

Question 6

The correct answer is C. Information regarding completeness can be found at various points in the 2006 IPCC Guidelines, so you need to know your way around the Guidelines, to have a full overview:

- Answer A is incorrect. When no sludge removal is accounted for in category 5.D, emissions due to sludge treatment and disposal are included in the estimate of 5.D. Including emissions due to sludge disposal in 5.A as well would result in double counting of emissions.
- Answer B is incorrect. When no information is available, waste generation can be estimated using information in table 2.2 (2006 IPCC Guidelines, vol. 5, chap. 2) or the default generation of industrial waste from the IPCC model.
- Answer C is correct. See footnote 4 under table 2.5 in the 2006 IPCC Guidelines (vol. 5, chap. 2).
- Answer D is incorrect. Construction and demolition waste are mentioned explicitly in the 2006 IPCC Guidelines (vol. 5, chap. 3.5, p. 3.23, third bullet point) as waste to be included, despite its low carbon content.

6. Key points to remember

- Chapter 3, volume 5, of the 2006 IPCC Guidelines provides the methodology to estimate CH_4 from solid waste disposal. The FOD method is the major calculation method for the category and is used as a basis for tier 1 and tier 2 estimates and for verification of the results of country-specific methodologies used. The IPCC waste model will be used by many of the Parties under review and, as a reviewer, you should be able to easily deal with the data reported in it.
- In the Party submission, the major elements to check for the category are chapter 7.2 of the NID (if the outline for the NID is followed by the Party) and CRT 5.A, along with all cross-cutting sections of NID and cross-cutting and summary tables of the CRT.
- Emissions need to be quantified from all wastes, disposed at SWDS (MSW, industrial, sludge, residue from MBT, clinical and hazardous) and by type of disposal sites (classified into managed, unmanaged and uncategorized). This distinction is necessary to know the amount of CH_4 emitted (waste from mining operations can be assumed to have negligible CH_4 potential).
- The category should also be assessed focusing on its interlinkages with other sectors (e.g. energy) and other categories in the waste sector (e.g. consistency of waste composition across categories in the sector). The reviewer should check emission allocation and any possible omissions or double counting of emissions.
- To ensure that there is no double counting of emissions, note that disposal of sludge is only to be included in the quantification of 5.A, when sludge is removed from the quantification of emissions from 5.D (so S>0 in the application of equation 6.1 from the 2006 IPCC Guidelines (vol. 5, chap. 6)).
- Quantification of emissions from solid waste disposal requires a time series of 50 years of AD. Historical data can be reproduced by extrapolating back for the whole period, the earliest available information, using per capita GDP and population as a driver.
- AD for solid waste disposal is the amount of waste disposed by the share of the population whose waste is collected. For countries that do not have historical data and in the absence of data on coverage of waste collection, data can be estimated to be proportional to urban population.
- When sorting analyses of solid waste (percentage of food waste, percentage of paper, etc.) are available, a country-specific value of DOC can be calculated. Trends in waste composition can be monitored when multiple sorting analyses are available over time.
- Most Parties will use the IPCC waste model to quantify CH_4 emissions while using the default values for the model parameters: MCF, k, DOC_f, F. As a reviewer, you should pay attention to the selection of these model parameters, taking into account type of SWDS, climate and region.
- The default value for CH_4 recovery is zero. CH_4 recovery should be reported only when references documenting the amount of CH_4 recovery are available.

Lesson 4: Biological treatment of solid waste

1. Introduction

This lesson describes the review of GHG emissions generated by biological treatment of solid waste and assumes prior knowledge of the 2006 IPCC Guidelines, volume 5, chapters 2 and 4.

The lesson consists of six topics:

Topic 1: Introduction

Topic 2: Category overview and methodological information

Topic 3: Review approach

Topic 4: Practical exercises

Topic 5: Self-check quiz

Topic 6: Key points to remember

1.1. Learning objectives

At the end of this lesson, you should be able to:

- Understand the key tasks to be undertaken to review a Party's reporting for biological treatment of solid waste;
- Understand how the biological treatment of solid waste category interlinks with other categories within the waste sector and other sectors of the inventory;
- Identify whether a Party's reporting for biological treatment is consistent with the requirements in the MPGs;
- Identify findings or issues and draft relevant encouragements or recommendations in a review report for this category.

1.2. Expected time needed to complete lesson 4

- For readers with experience in GHG emission inventories: 2–4 hours
- For readers with less experience in GHG inventories: 4–8 hours

2. Category overview and methodological information

2.1. Biological treatment of solid waste categories

Biological treatment of solid waste is divided into two categories, as presented in the 2006 IPCC Guidelines. Emissions from these categories are reported in CRT 5.B (biological treatment of solid waste). No changes were introduced by the 2019 refinement to the 2006 IPCC Guidelines.

Table 4.1 – Biological treatment of solid waste and gas emitted.

Categories		Gas emitted
5.B.1 - Composting	Subcategories: 5.B.1.a – MSW 5.B.1.b – Other	CH_4, N_2O
5.B.2 – Anaerobic digestion at biogas facilities	Subcategories: 5.B.2.a – MSW 5.B.2.b – Other	CH_4, N_2O*
Reported in CRT	CRT 5.B	

* N2O emissions from anaerobic digestion are assumed to be negligible.

Please see the boxes below for more information on each of the categories in table 4.1.

Box to table 4.1: Category 5.B.1 - Composting

In a composting process, organic materials in the waste are biodegraded under aerobic conditions, yielding mainly CO_2. Ammonium (NH_4^+) is the primary product of biodegradation of organic nitrogen in the waste. During aeration, part of the NH_3 is nitrified to nitrate (NO_3^-). Another part of the NH_4^+ is stripped as NH_3 with the aeration air.

When waste is not completely aerated, anaerobic pockets occur, where CH_4 is generated. Under anaerobic conditions, NO_3^- is denitrified to N_2, with traces of N_2O, resulting in N_2O emissions. Treatment of NH_4^+-containing aeration air in a biofilter might add to N_2O emissions.

There are different types of composting systems, including:

- Home composting. Normally consists of small compost piles, often enclosed in perforated boxes, allowing air to enter from the bottom. Home composting treats biodegradable waste from a single household.
- Passively aerated windrows. This is the simplest composting system and consists of piles of waste 2–5 m high dumped without compaction in long lines. Aeration of the waste occurs through natural ventilation. To improve aeration, a windrow can be turned from time to time using mobile equipment (e.g. a shovel or specialized turning equipment). Passively aerated windrows might be covered by roofs.
- Actively operated windrows. In an actively operated windrow, waste is dumped on top of a perforated tube or slotted floor. Using a compressor, air is sucked in via the waste, thus forcing aeration of the waste. Actively aerated windrows can be covered by roofs.
- Closed systems. Closed systems allow faster and more efficient processes using less space and reducing odour emissions. Many different systems have been developed, all comprising mechanical stirring of waste and active aeration in an entirely closed process. Exhaust gases are

captured in exhaust channels and are generally treated in biofilters to reduce odour emissions. Such a biofilter might also affect CH_4 and N_2O emissions.

Composting is used by both developed and developing countries. Since composting reduces waste to landfills and since the product of composting often can be reused, composting fits very well into many nations' waste policies. As a result, there is a growing trend of composting waste in many parts of the world.

Box to table 4.1: Category 5.B.2 - Anaerobic digestion at biogas facilities

Anaerobic digestion is the biodegradation of organic wastes under anaerobic conditions, generating biogas, which is a mixture of 50–65 vol% CH_4 and 35–50 vol% CO_2. Oxygen acts as an inhibitor to anaerobic digestion and therefore anaerobic digestion always takes place in closed systems. Given the conditions required for the anaerobic process, the 2006 IPCC Guidelines assume N_2O generation and emissions to be negligible.

Anaerobic digestion is mostly performed on an industrial scale. In industrial anaerobic digesters, the residue ('digestate') is post-treated on-site. Post-treatment of digestate might include a composting step. In most cases, when a Party mentions emissions from anaerobic digestion, it refers to emissions from the entire facility for anaerobic digestion, including pre- and post-treatment. Although not explicitly mentioned in the 2006 IPCC Guidelines, it is the common understanding that the IPCC subcategory refers to all emissions from an anaerobic digestion facility, including a possible composting step as post-treatment. Post-treatment might result in N_2O emissions and, as a result, an inventory using a country-specific N_2O EF for anaerobic digestion might have N_2O emissions, which are not negligible.

In developing countries, in addition to anaerobic digestion on an industrial scale, anaerobic digestion might also take place on a household scale, producing biogas for domestic use. Often a mixture of locally available substrates, such as animal manure and green wastes, is co-digested.

- CO_2 emissions from the biological treatment of solid waste, whenever they occur, are considered to be of biogenic origin and are not estimated for the category and included in the national total.
- The relevant chapter in the 2006 IPCC Guidelines (vol. 5, chap. 4) also covers the mechanical-biological treatment (MBT) and residues after anaerobic digestion, but these categories are not treated as separate subcategories under biological treatment of solid waste. See the two Boxes belowfor further information on the emissions related to MBT and residues from anaerobic digestion and their reporting.

To learn more about composting and biological treatment of solid waste, read chapter 4, volume 5, of the 2006 IPCC Guidelines.

Box: Mechanical-biological treatment of waste

MSW might be treated biologically as part of an MBT system. MBT is intended to improve the reuse of waste and reduce the volume of waste to be disposed of in an SWDS or incinerated. An MBT system consists of a number of mechanical separation steps where different materials are separated from the waste and made fit for reuse. Examples of materials that might be removed are plastics, glass, paper, iron and other metals. To reduce the mass of waste even further, the residue after mechanical treatment is composted or anaerobically digested. The residue after MBT is not suitable for use as a fertilizer because it is contaminated by plastics and heavy metals. It is therefore mostly landfilled or incinerated.

Since MBT comprises a biological treatment step, it results in CH_4 and N_2O emissions, which should be included in the emission inventory using the methodology in chapter 4. Emissions during mechanical operations can be assumed to be negligible. Most Parties with MBT report their emissions under category 5.B. Note that, even if a Party reports emissions from MBT of MSW separately under category 5.E ('other'), the guidance on 5.B ('biological treatment of solid wastes') can still be used.

When reviewing an inventory by country that practises MBT, check if and where emissions from MBT are accounted.

Box: Residue after biological treatment

Waste is not completely converted to gas during biological treatment. There will always be a residue consisting of less degradable organic matter and inorganic inert material. This residue is often referred to as 'compost' or sometimes 'digestate'. This compost might be subsequently marketed as a natural fertilizer. When the quality of the compost is unsuitable for use as fertilizer (e.g. when its heavy metal content is too high), the residue might be landfilled or incinerated. Reuse, landfilling or incineration of 'compost', or 'digestate', might also result in GHG emissions. These emissions are reported elsewhere (see section 2.5 on cross-category linkages in this lesson).

2.2. Methods for estimating emissions

The methodology to quantify emissions presented in the 2006 IPCC Guidelines (vol. 5, chap. 4) is the same for both composting and anaerobic digestion. The choice of methods primarily depends on the availability of measured data.

Tier 1: Calculation of emissions using equations 4.1 (for CH_4) and 4.2 (for N_2O) based on default EFs.

Tier 2: Calculation of emissions using equations 4.1 (CH_4) and 4.2 (N_2O) and use of country-specific EFs based on representative measurements to cover relevant biological treatment options applied in the country.

Tier 3: Calculation of emissions using equations 4.1 (CH_4) and 4.2 (N_2O) and use of country-specific EFs based on facility-/site-specific measurements.

Unlike for other categories, there is no decision tree suggested by the 2006 IPCC Guidelines for this category and there is no explicit mention of the tier to apply when the category is a key category. Please note that, for most Parties, the category is not a key category. CO_2 emissions from the biological treatment of solid waste, whenever they occur, are considered to be of biogenic origin and are not estimated for the category.

- Please note that equation 4.1 contains a term R, which represents total CH_4 recovered in the inventory year.
- In the case of composting, no CH_4 is recovered. As a result, R in equation 4.1 equals 0. The cells for recovery in CRT 5.B are shaded for composting.
- When applying equation 4.1 to anaerobic digestion, it should be taken into account that the default EF in table 4.1 already accounts for CH_4 recovery, as specified in the note below table 4.1. Therefore, if the default EF is used, emissions should not be corrected for recovery (R should not be subtracted). This prevents recovery from being accounted twice in the estimate.
- When available, the amount of gas recovered, R, needs to be specified in CRT 5.B and it is important to quantify emissions from the utilization of biogas (reported under the energy sector).

2.3. Activity Data

As for AD, the amount of biologically treated waste used is based on national statistics or information from regional authorities or waste management facilities. Lower accuracy may be associated with the data being based on volume of waste composted, assuming a waste density. The use of data from weighing bridges at treatment facilities may achieve higher accuracy.

When checking the AD reported by the Party, the reviewer should consider the following:

- While a Party might have no statistics on amount of waste digested, it may have information on the amount of CH_4 produced during anaerobic digestion. The CH4 generated can be collected and used to produce heat or electricity and is usually reported in the energy sector. However emissions of CH4 from anaerobic digestion facilities due to unintentional leakages should be calculated and reported in the waste sector. In this case, the IPCC default assumption might be used: 'In the absence of further information, use 5 per cent (of CH_4 generation) as a default value for the CH_4 emissions', from leakage.. Where technical standards for biogas plants ensure that unintentional CH_4 emissions are flared, CH_4 emissions are likely to be close to zero.
- Table 2.1 of the 2006 IPCC Guidelines gives some regional default values of composting shares for the year 2000. A more complete overview is provided in annex 2A.1 of chapter 2, volume 5, of the 2006 IPCC Guidelines. It is however good practice for countries to use national data, collected annually or periodically where possible.

- Information on AD source and coverage (e.g. whether composting at households is included or not), as well as conversion from a wet to dry waste basis, should be included in the NID.
- For most types of waste, AD are obtained on a wet waste basis. For specific wastes (e.g. sludge), statistics might provide AD on a dry waste basis. The AD in the CRT should be reported on a dry waste basis. As a reviewer, make sure that the reporting is correct and there are no inconsistencies in the reported values in the NID and CRT.

2.4. Emission Factors

Table 4.1 of the 2006 IPCC Guidelines provides CH_4 and N_2O EFs for waste on a wet and dry weight basis. When AD are available on a wet weight basis, make sure that they are combined with the EF on a wet weight basis when the Party is using default EFs.

When assessing a Party's EFs and IEFs, the reviewer should consider the following:

- The AD and IEF in CRT 5.B should be reported on a dry weight basis. This has to be taken into account when comparing the IEFs with the default EFs from the 2006 IPCC Guidelines, as well as the fact that the default EFs already account for the recovery.
- There were corrections to table 4.1 in the corrigenda to volume 5 of the 2006 IPCC Guidelines. The reviewer should use the latest edition of the 2006 IPCC Guidelines available online with the corrected EFs and the note under table 4.1.
- There is no default EF for N_2O from anaerobic digestion as the emissions are assumed to be negligible. Therefore, if the Party does not report N_2O emissions from the subcategory, no recommendation on completeness may be given. However, if the cells in CRT 5.B are left empty and/or no explanation is provided on the reporting of the N_2O emissions from anaerobic digestion in the NID, a recommendation on transparency may be given.
- When country-specific EFs are used, the reviewer should assess whether the Party documented any reference sources and the assumptions used to choose them.

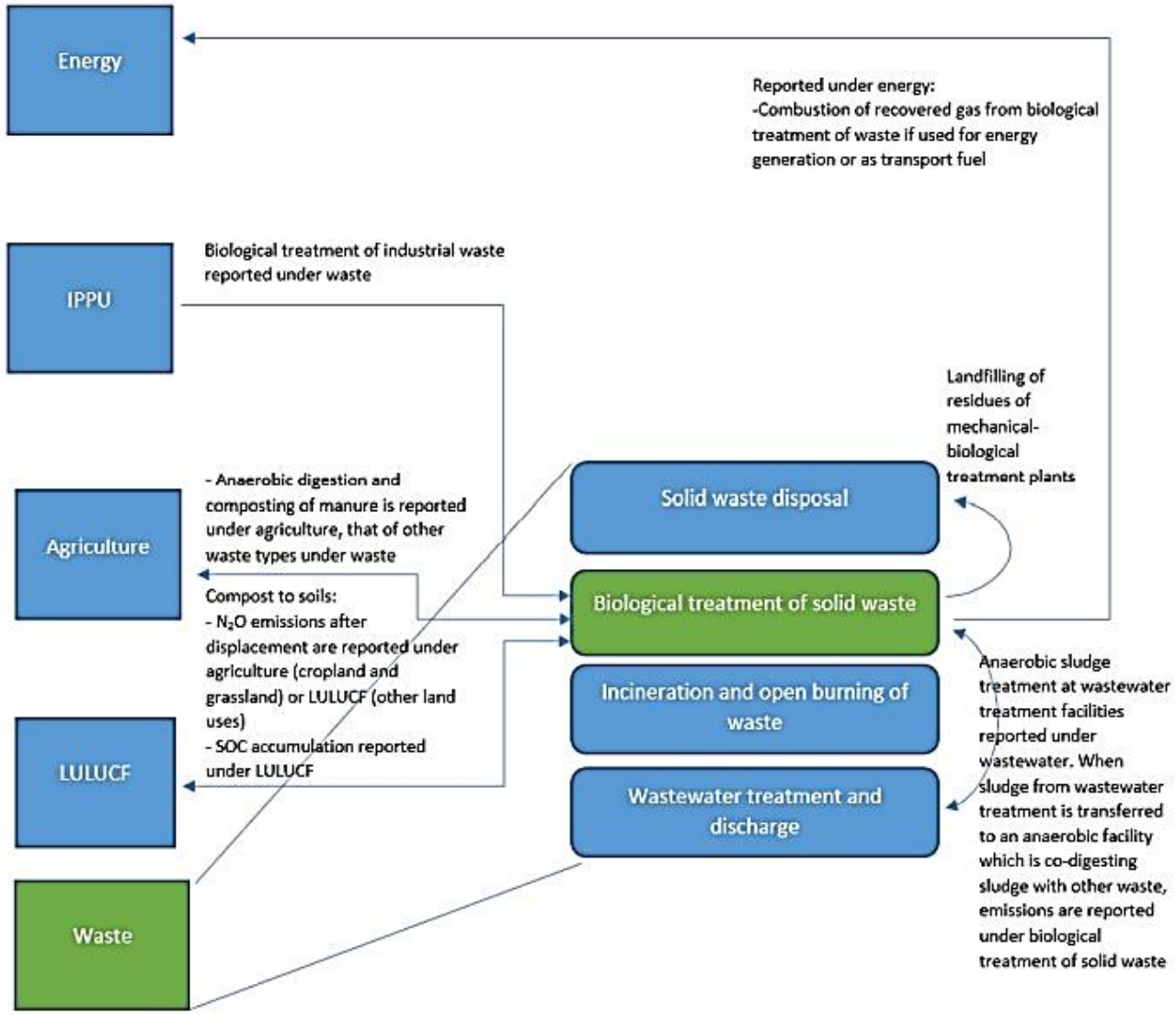
Box: IEFs

The implied emission factors are part of the sectoral background data tables of the CRT. They are automatically calculated in the CRT based on the ratio between the reported emissions and AD. IEFs allow comparison across Parties and, in some cases, comparison with the default EFs. When emissions are estimated by multiplying AD and a default EF, the IEF would be equal to the default EF

2.5. Linkage in reporting biological treatment of solid waste and other categories and sectors

Figure 4.1 provides an overview of the main linkages between biological treatment of solid waste and other categories and sectors. Understanding these linkages will allow you to understand cross-sectoral issues and the necessary cross-checks of AD and emissions between sectors to make sure that the emissions are not omitted or double counted.

H. Figure 4.1. Overview of main linkages of the category with other sectors and categories



Examples of cross-sectoral linkages where you may need to consult with the expert responsible for another sector in the review are:

- Emissions from the utilization of recovered CH_4 for energy purpose must be reported in the energy sector. This also refers to CH_4 that remains unburned in gas engines and is emitted with a gas engine's exhaust. Emissions should be reported in the energy sector under the category where the CH_4 is utilized.
- Emissions from the biological treatment of manure should be reported in the agriculture sector.
- Different waste streams might be co-composted in one installation. For example, during the anaerobic digestion of manure, residues from the food industry might be added to increase CH_4 generation and improve the economic profitability of the digester. If the AD cannot be separated, emissions should be reported under either the agriculture or the waste sector. You should check to ensure that emissions are not omitted or double counted.
- The residue from biological treatment ('compost') could be reused as a fertilizer and then reported under agriculture. When the quality of the product is unsuitable for fertilizer, the residue is treated as waste. However, emissions from the reuse and/or treatment of the residue from biological treatment are not reported under category 5.B. Instead, they need to be reported under the appropriate waste category depending on the fate of the compost.

Cross-category linkages also exist within the waste sector. Reporting on CH_4 and N_2O emissions from biological treatment will complement the reporting of emissions from SWDS, incineration of waste and wastewater treatment. To avoid the omission or double counting of emissions, you, as a reviewer, should check the AD (the amount of waste treated) in those waste management activities. This is particularly important in countries where biological treatment of waste is, or is becoming, significant.

- Sludge, produced at wastewater treatment plants, is usually pretreated on-site. Biological treatment of sludge (either anaerobic digestion or composting) is often part of sludge pretreatment. When the Party does not account for sludge removal in category 5.D (S=0 in their application of equation 6.1 from the 2006 IPCC Guidelines (vol. 5, chap. 6)), all emissions from sludge treatment and disposal are included in the estimate of 5.D and therefore emissions from sludge should not be included under 5.B. When the Party does account for sludge removal (S>0), the amount of sludge removed should be consistent with the amounts of sludge used or treated in other categories: for example sludge used as fertilizer in the agriculture sector or treated under the waste categories 5.A, 5.B or 5.C). In such cases, emissions should be quantified, wherever sludge is treated or disposed, using the appropriate methodologies.
- The emissions from the residue of biological treatment should be reported under category 5.A in case the residue is disposed of in a SWDS or under category 5.C in case the residue is incinerated or open burned .

3. Review approach

3.1. Overview

Topic 4 in lesson 2 gives overall guidance on review approach (prepare – assess – draft) with a reference to this particular category. This lesson focuses on aspects that are specific to biological treatment of solid waste category. Please refer back to lesson 6 (Review process overview) of the course on general guidance and cross-cutting issues for the review of GHG inventories if you would like a refresher on the approach to conducting a GHG inventory review.

Prepare → Assess → Draft

The choice of methods and assumptions, collection of AD and selection and development of EFs are the main drivers of inventory quality. Hence, as a reviewer, you must assess and ensure that the selection of these data and the reporting, documentation and justification in the inventory submission are in accordance with the 2006 IPCC Guidelines and the requirements of MPGs and other relevant UNFCCC decisions. The specific section of the inventory submission to check for the category along with specific questions you may consider when assessing the submission are provided in the following slides, along with examples of key considerations when reviewing the category. Examples of the review steps, follow-up communication with the Party and inputs for the review reports are provided in the case studies and practical examples.

In addition, there are several common elements to be assessed across sectors/categories when reviewing the quality of the Party's submission (i.e. uncertainty analysis, QA/QC, time-series consistency, recalculations and progress in implementing improvements). Lesson 2 of the current course provides a list of possible checks and examples of assessment of cross-cutting issues.

Box: Prepare

During this stage you obtain and familiarize yourself with all the materials needed to undertake the review. The overall preparation of the review includes the careful study of all documents that are available to inform your assessments, such as:

- Refreshing your knowledge of (i) the UNFCCC reporting and review guidelines; (ii) the 2006 IPCC Guidelines; and (iii) review tools and other supporting materials;
- Familiarizing yourself with the Party's submission;
- Focusing on the sector under your responsibility:
    - The category-specific information contained in the Party's submission;
    - The issues for the sector in the previous review reports.

Box: Assess

During this stage you evaluate whether the recommendations of the previous review are implemented and carry out an in-depth review of the emission inventory, possibly resulting in the identification of new issues and recommendations related to the implementation of the TACCC principles. Performing the review, you might make use of the review tools as provided by the secretariat. Identify possible capacity-building needs for those Parties that need it in the light of their capacities.

Lesson 2 of the current course provides details on the general approach to take when performing a review. This lesson focuses on aspects specific to the biological treatment of waste. Further details are provided in the slide on key considerations (section 3.4) in the current lesson.

Recommendations in previous TERR

One of the tasks during a review is to evaluate each recommendation in the previous TERR: whether it can be considered resolved or not resolved, or whether the Party is addressing the recommendation. The NID might include a paragraph which summarizes the status of implementation of each recommendation according to the Party. The Party may provide further information during the review. However, for each recommendation, you need to check the relevant sections or chapters in the NID and the relevant CRT to conclude whether the implementation of the recommendation and the changes to the NID and/or CRT are satisfactory to consider the recommendation as resolved.

Your conclusion on the recommendations from the previous TERR are documented in the current review report. Your conclusion has to be specific to all elements of what is recommended, making clear references to the page in the NID or to the specific CRT where improvements are made by the Party. If the issue is not yet resolved, the status should be clearly documented based on the inventory submission and any follow-up information received during the review.

Review tools provided by the secretariat

Before the review, the secretariat will make available user-friendly review tools that provide access to the secretariat's CRT database and therefore all the data submitted by Parties in their CRTs. The review tools will allow you to sort or search data according to Party, submission or inventory year, category, GHG and specific data type (e.g. emissions, AD, EFs). The review tools allow you to search for data for a particular Party or for all Parties. They will help you discover outliers in the time series or, when comparing data across countries, allow a quick check of the magnitude of recalculations across submissions for any data point. Review tools give you quick access to data with maximum flexibility. It is often the most efficient way to find the data you are searching for while performing a review

Box: Draft

This stage is linked to the outputs of the assessment process and drafting questions to the Party for clarification on the submission and preparing the findings on the waste sector to be included in the review report. For guidance on drafting your conclusions and recommendations from a review, refer to lesson 2. With regard to biological treatment of solid waste, there are no special issues with drafting conclusions and recommendations. Some practical examples in drafting issues for the TERR are included in the case studies and examples included in this lesson.

3.2. Category-specific parts of a Party's submission

In the Party's submission, the main information on the quantification of emissions from biological treatment of waste can be found in:

- The NID, which provides a description of the methods, AD and EFs used and the assumptions made to calculate emissions. Each NID is organized in the same way, with similar chapters. Information on biological treatment of solid waste according to the outline of the NID will be included in chapter 7.3;
- The CRTs, which provide the numerical inventory information with calculated emissions, the AD used and back-calculated IEFs. CRT 5.B provides a summary of the results for emissions from biological treatment of solid waste.

During the review, make sure to also check the cross-cutting information provided in CRTs 7–10, as explained in lesson 2, topic 3, as well as the cross-cutting chapters of the NID (chaps. 1, 2, 9 and 10 and annexes), which would contain additional information relevant for your assessment.

3.3. CRT 5.B

As a reviewer you must be familiar with CRT 5.B on biological treatment of waste, where AD, CH_4 recovery and emissions and the resulting IEF are specified.

When reviewing CRT 5.B, consider the following:

- CRT 5.B distinguishes two categories: Composting and anaerobic digestion at biogas facilities. AD in the CRT need to be specified on a dry weight basis. Biological treatment from MSW needs to be specified separately from the biological treatment of other wastes (e.g. separately collected green wastes).
- The IEF for anaerobic digestion is calculated on the basis of gross emissions (sum of net emissions and the amount reported for recovery and flaring). So this IEF cannot be compared to the IPCC default EF, because the later considers only the amount of CH4 that is lost (leakaged) during the process and CH4 recovered is already subtracted (R as in equation 4.1 of the 2006 IPCC Guidelines).
- Emissions from CH_4 recovered and used for energy should be provided in the CRT table 5.B only for information purposes. The emissions arising from the CH_4 recovered and used for energy should be reported in the energy sector under 'biomass' in CRT 1.A(a).
- When a Party reports the notation keys "NE" or "IE", this should be explained in the NID and in CRT 9.

3.4. Key considerations when assessing biological treatment of waste

The GHG inventory should be prepared and reported in accordance with the MPGs, following the good practice provided in the 2006 IPCC Guidelines. The fundamental principles for developing a GHG inventory, as reaffirmed by the MPGs, are transparency, accuracy, completeness, consistency and comparability (the TACCC principles). You assess the inventory for its compliance with these principles. Possible questions related to the implementation of each of the TACCC principles in the inventory for biological treatment of waste can be accessed via specific questions as summarized below.

- Is the inventory sufficiently transparent?
- Is the inventory complete?
- Is the inventory consistent?
- Is the inventory comparable?
- Is the inventory accurate?

When the time comes to participate in an actual GHG inventory review, study any further review materials provided to you by the secretariat suggesting further possible checks you may want to use.

The examples provided in this lesson are not intended to provide an exclusive list of possible questions, but a starting point to stimulate your thinking. You may add or modify the questions as appropriate while conducting a review.

Issue 1. Is the inventory sufficiently transparent?

On transparency, you may ask yourself the following questions:

- Is all relevant information for the category available in the NID or in the documents referred to in the NID?
- Is the information in the NID consistent with the information in the CRT?
- Does the Party provide an overview of total waste generation and treatment in the NID in chapter 7.1 and is the reporting on the category in line with the sector outline? Are the AD clearly described and data sources clearly specified in the NID?
- If biological treatment of waste occurs in other sectors (e.g. treatment of manure under agriculture or treatment of sludge in wastewater treatment and discharge), did the Party clearly explain the allocation of the emission to make it possible to assess whether the inventory is complete and to ensure no double counting of emissions occurred?
- Is information provided on the types of waste composted or treated anaerobically (e.g. food waste, garden and park waste)?
- Does the Party report MBT of waste in its general description of the waste sector and specify where the emissions are allocated, if relevant?
- Did the Party provide information on the collection frequency and coverage of AD (e.g. whether composting at households is included or not)?
- Is it clear what EFs are used and are they properly referenced?
- If country-specific EFs are used, are they properly documented and justified?
- If the notation keys “IE” or “NE” are used, are they explained in CRT 9?

Issue 2. Is the inventory complete?

On completeness, you may ask yourself the following questions:

- Has the Party reported emissions from both composting and anaerobic digestion? If not, has the Party described in the NID why these emissions are not reported, for example explanation wheather these emissions are “not occurring” or whether they do not report because of lack of data?
- If the Party reports notation key “NE” for an insignificant category, is there justification for the use of that notation key in line with the requirements of the reporting guidelines?

Is there mention in the NID whether or not home composting is included in the inventory? If home composting is included, is a clear description provided in the NID on how AD are estimated?

Issue 3. Is the inventory consistent?

On consistency, you may ask yourself the following questions:

- Did the Party perform any recalculations compared to the previous submission? If so, has the Party described the relevant changes and their impact on the emission trends in the NID?
- Has the Party applied the same methods and sources of AD and EFs over the time series?
- If you find the Party does not have sufficient data to apply the same methods or sources of AD and EFs over the time series, has it properly applied splicing techniques from the 2006 IPCC Guidelines (vol. 1, chap. 5) to ensure time-series consistency?
- Is the time series in AD in line with expectation, considering the overall trends in waste generation, waste policies and also changes in activities for other waste treatment processes? For example, when a Party starts to collect green wastes separately in order to compost them, does this have an impact on the amount and composition of waste deposited in SWDS or incinerated?

Issue 4. Is the inventory comparable?

On comparability, you may ask yourself the following questions:

- Are all composted waste fractions, other than MSW and manure (included in agriculture), in CRT 5.B reported under ‘other’?
- Are the estimated CH_4 and N_2O emissions from composting or anaerobic treatment of sludge consistent with the reported emissions from treatment of sludge in the wastewater treatment and discharge category? Has the Party ensured that no omission or double counting has occurred?
- When residues from MBT are landfilled, are emissions from further degradation of the residues included in the quantification of emissions from SWDS (5.A)?
- If recovered CH_4 is used for energy, are the emissions from combustion correctly included under the energy sector? Has the Party provided a reference to the category in the energy sector where the emissions are included?
- Does the Party refer in the NID to co-composting or co-digestion of manure and food wastes? If so, does it provide sufficient information for you as a reviewer to be sure that there is no omission and no double counting?
- If a Party includes biological treatment of sludge, is sludge removal accounted for in the quantification of emissions from category 5.D - wastewater treatment and discharge (see lesson 6)?
- When a Party operates facilities for MBT of waste, are the amounts of waste biologically treated as a part of MBT included in the AD and emissions for 5.B?

Issue 5. Is the inventory accurate?

On accuracy you may ask yourself the following questions:

- What AD is used? For example, were national statistics available and if some assumptions were made, are they well justified? If data from a facility were used, are they representative for the entire country?
- When a Party uses country-specific EFs, are they well documented and properly justified? (Note: See lesson 2 for a general description on justification of country-specific EFs. The justification might be of a technical nature and beyond the expertise of you as a reviewer. In such a case, you might evaluate whether the QA/QC process for determining a country-specific model parameter is sufficient.)
- If a Party performs MBT of wastes, did the Party use the methodologies from the 2006 IPCC Guidelines (vol. 5, chap. 4) in quantifying emissions?

3.5. Case studies

The two examples below show how the review approach may be applied for the two categories of biological treatment of solid waste. The examples are based on real submissions by Parties. For each question, select an answer or draft your response and submit it in order to be able to see the suggested answer.

3.6. Case study 1 (composting)

A Party reports emissions from biological treatment of waste (composting, category 5.B.1) in its CRT.

The file Case study 4.1.xls contains a CRT for use in this and also the next case study. You may download the file here: https://unfccc.int/resource/tet/bw/bw4-01_Case_study_4.1.xlsm

Question 1.1: Assessing the IEFs reported in CRT 5.B

Have a look at CRT 5.B.

Does the Party use the default EFs from the 2006 IPCC Guidelines to estimate both, CH_4 and N_2O emissions, under category 5.B.1 (composting)?

A. Yes
B. No

Question 1.2: Checking consistency between CRT 5.B and the NID

To find out whether the Party uses a country-specific CH_4 EFs for composting and whether this EF is justified, you should check the appropriate section in the NID, as follow:

The Party explains in the NID that it uses a country-specific EF of 1.6 kg CH_4 per tonne of wet waste. To justify this CH_4 EF, the NID refers to a document by the National Research Organization (NRO) from 2007. This document however cannot be found in a simple Internet search and no additional documentation and justification of the EF was provided in the NID.

Is the CH_4 EF reported in the NID consistent with the IEF in CRT 5.B for category 5.B.1 (composting)?

A. Yes
B. No

Question 1.3: Drafting a question to the Party

The Party indicated in the NID that it applies a country-specific EF for CH_4 but the explanation provided in the NIR was not sufficient to understand how the EF was derived. You may need additional information from the Party. In lesson 2 of the waste course, you learned how to formulate questions. Now it is time to practise.

Utilize your knowledge and formulate a question on the issue to the Party.

Please submit your question here:

Question 1.4: Drafting a finding and recommendation for the TERR

After receiving the documentation, you find that the document itself does not contain any measurement information. Instead, the document refers to a personal communication with a foreign expert from 1990, in which this country-specific EF was suggested. The document does not discuss why this EF is considered representative for the composting plants of the Party and the EF is not supported by a review of any relevant emission measurements or a justification of why the 1990 information could still be considered appropriate.

Based on the received information, conclude on the issue and draft a finding for the review report.

Please explain the TERT finding with references to the CRT and/or NID, summarize any communication with the Party during the review, indicate why the TERT finds that the Party is not meeting applicable reporting requirements of the MPGs and include the TERT recommendation or encouragement in a precise and clear manner.

Please submit your draft of the finding here:

3.7. Case study 2 (anaerobic digestion)

Continue to use the CRT submission for 2022 provided in case study 4.1.xls: https://unfccc.int/resource/tet/bw/bw4-01_Case_study_4.1.xlsm

In chapter 7.1 (p.7.4) of the NID, the Party describes general trends in waste management, as follow:

"As a result of national waste policies, significant shifts have occurred in the past 15 years. Green wastes are collected separately and composted, and incineration capacity has increased. In addition, an anaerobic digester for pretreated MSW began operation in 2022".

Question 2.1: Assessing reporting on category 5.B.2 in the Party's submission

Do you notice any inconsistencies between the information in the NID and in the CRT regarding category 5.B.2?

A. Yes
B. No

Question 2.2: Checking explanation of notation keys in the CRT.

Is the use of the notation key "NE" properly explained in the CRT 9?

A. Yes
B. No

Question 2.3: Drafting a question to the Party

As a reviewer, you can ask the Party a question for clarification. Please draft such a question to the Party at hand.

Please submit your question here:

Question 2.4: Assessing a Party's response to a TERT question

In a reply to your initial question, the Party indicates that the anaerobic digester has a capacity of 100 t green waste per day. The digester has been in use since 1 September 2022. Assuming that the digester operated at full capacity for one third of a year, an estimated 12,000 t green waste was digested. Assuming the default EF from the 2006 IPCC Guidelines of 0.8 g CH_4 per kg wet waste, this results in an emission of 9.6 t CH_4. This is below the threshold of significance.

Do you agree with the Party, bearing in mind that: (a) the Party's total emissions can be found in the CRT summary 2; and (b) the Party is not using the flexibility provision regarding the significance threshold used?

A. Yes
B. No

Question 2.5: Drafting a finding and recommendation for the TERR

As a reviewer, would you consider writing a recommendation on the observations you made on the reporting of emissions from anaerobic digestion?

A. No
B. Yes, I would provide the following observation and recommendation:

3.8. Answers to case study 1 (composting)

Question 1.1

The correct answer is B. According to the CRT 5.B, the CH_4 IEF is 4.00 g CH_4/kg dry waste, whereas the IPCC default EF is 10.00 g CH_4/kg dry waste (see 2006 IPCC Guidelines, vol. 5, chap. 4, table 4.1). For N_2O the IEF in CRT 5.B is 0.6 g N2O/kg waste and is in agreement with the default N_2O EF from the 2006 IPCC Guidelines.

Note that the CH_4 IEF is the same as the CH_4 EF for wet waste from the 2006 IPCC Guidelines. So either the inventory compilers used a country-specific EF or they mixed up the wet and dry waste EFs.

Question 1.2

The correct answer is A. The Party assumes a country-specific EF of 1.6 kg CH_4 per tonne of wet waste. Assuming a moisture content in the wet waste of 60 per cent, the waste contains 40 per cent of dry waste per t of waste. The country specific EF of 1.6 kg CH_4 per t of wet waste equals to 1.6 kg CH_4 per 0.4 t of dry waste. So the EF expressed in dry waste is 1.6/0.4=4 kg CH_4 per t of dry waste. Therefore, the country-specific EF is in agreement with the IEF in the CRT 5.B.

Question 1.3

A possible question to clarify how the EF was derived might be as follows:

In the NID (p.7.24), the Party stated that emissions from composting are calculated assuming a country-specific EF of 1.6 kg CH_4 per tonne of wet waste. This country-specific EF is justified by referring to a National Research Organization document from 2007. However, the TERT was not able to find the referenced document. Could the Party provide the document referenced in the NID and any further information justifying the applicability and representativeness of the country-specific EF used in the inventory?

Question 1.4

The correct conclusion on this issue is that the country-specific EF is not properly justified.

A possible draft for the finding on this issue in the TERR would be as follow:

The Party quantifies its CH_4 emissions from category 5.B.1 (composting) assuming a country-specific EF of 1.6 kg CH_4 per tonne of waste (NID, p.7.24). As a justification, the Party refers to a national report (National Research Organization, 2007) without any further explanation provided in the NID. During the review, the Party provided the referenced document. This document clearly showed that the country-specific EF was based on a personal communication with a foreign expert. However, the document does not clarify the measurements on which this expert judgment is based. In addition, the data are noted to be based on 1990 data, which may be outdated. The 2006 IPCC Guidelines (vol. 1, chap. 2.2.4) give guidance on determining country-specific EFs and suggest a protocol for expert elicitation (vol. 1, chap. 2, annex 2A.1). An inventory compiler might perform a literature review and use literature values from international bodies, but on the condition that they reflect national circumstances. However, from the information provided in the NID, the EF used does not meet these criteria. As a result, the TERT considers that the country-specific EF is not properly documented and sufficiently justified and may lead to underestimation of the CH_4 emissions from composting.

The TERT recommends that the Party improve the justification of the country-specific EF used in line with IPCC requirements or to quantify the CH_4 emissions from composting using the default EF as specified in the 2006 IPCC Guidelines (vol. 5, chap. 4, table 4.1) of 10 g CH_4/kg dm waste composted.

3.9. Answers to case study 2 (anaerobic digestion)

Question 2.1

The correct answer is A. In 2022, MSW was anaerobically digested according to the information in the NID. However anaerobic digestion (AD, emissions and CH_4 recovery) in CRT 5.B for 2022 is reported as "NE" for MSW and as "NO" for subcategory 'other'.

Question 2.2

The correct answer is B. Whenever a Party uses the notation key "NE", its use should be explained in CRT 9 (as well as in the NID). However, no such explanation for anaerobic digestion of waste (category 5.B.2) could be found in CRT 9 or the NID.

Question 2.3

A possible question to clarify the use of "NE" for AD and emissions might be as follows:

In chapter 7.1 (p.7.4) of the NID, the Party describe general trends in waste management. In 2022 an anaerobic digester, which converts green waste to biogas, began operation. In CRT 5.B for 2022, the notation key "NE" is used to describe AD and emissions for anaerobic digestion. Use of the notation key "NE" needs to be justified in CRT 9, however your CRT 9 contains no such justification. Can the Party justify the use of notation key "NE" for anaerobic digestion?

Question 2.4

The correct answer is A. As the Party is not using the flexibility provisions of the MPGs, emissions should be considered insignificant if the likely level of emissions is below 0.05 per cent of the national total GHG emissions and does not exceed 500 kt CO_2 eq.

Assuming a GWP for CH_4 of 28, 9,600 kg CH_4 equals 270 t CO_2 eq, or 0.27 kt. Total emissions without LULUCF by the Party are 20,265 kt CO_2 eq (see CRT summary 2). The threshold of significance can be calculated as 0.0005*20,265=10.13 kt CO_2. The estimated emission of 0.27 kt is below the significance threshold. Therefore, the use of "NE" is justified.

Question 2.5

The correct answer is B. You need to formulate a recommendation on transparency in the TERR because the Party failed to justify the use of the notation key "NE".

A possible draft for the findings on this issue in the TERR would read as follows:

The Party reported in CRT 5.B the notation key "NE" for AD, emissions and recovery for anaerobic digestion of green waste. However, the use of this notation key is not explained in CRT 9 or in the NID.

During the review, the Party provided additional information justifying that emissions can be estimated as 0.27 kt CO_2 eq, which is below the significance threshold of 10.13 kt CO_2. The TERT concluded that the use of "NE" is justified, but is not transparently presented in the CRT and NID.

The TERT recommends that the Party either justify the use of the notation key "NE" in CRT 9 and in the NID or include the estimate of CH_4 emissions from anaerobic digestion of 0.01 kt in the CRT 5.B.

4. Practical exercises

In the following section, some additional exercises are provided so that you can practise your skills as a review expert. Each exercise consists of different tasks.

4.1. Exercise 1

A Party from Eastern Europe describes emissions from the biological treatment of waste in chapter 7.3 (pp.7.12–7.13) in its NID.

See Appendix Lesson 4-1 for a section of NID:
https://unfccc.int/resource/tet/bw/bw4-02_app_4.1.pdf

See also CRT 5.B for use in this exercise:
https://unfccc.int/resource/tet/bw/bw4-01_Example_4.1.xlsm

Exercise 1 – Question 1

Read the text in the NID. Can you reproduce the estimates for the CH_4 and N_2O emissions from composting based on the information reported in the NID?

A. Yes
B. No

Exercise 1 – Question 2

Analyse the AD and IEF reported in the CRT 5.B, for composting, compared with the information in the NID. Is the information consistent?

A. Yes
B. No

Exercise 1 – Question 3

Draft your finding for the TERR.

Please submit your draft of the finding here:

Hint: The quantification of emissions for category 5.B.1 is correct. However, the IEF in CRT 5.B differs from the default CH_4 EF for composting for dry waste (10 g CH_4/kg waste) because of the assumptions applied by the Party for converting wet AD and EF to dry AD and EF. Table 4.1 in the 2006 IPCC Guidelines (vol. 5, chap. 4) calculates the default EFs assuming a moisture content of 60 per cent. However, there is no other mention in any table or text in the 2006 IPCC Guidelines on this sector that this 60 per cent moisture content is the guidance to be used to convert AD and EFs from wet to dry basis.

Exercise 1 – Question 4

Reviewing table 7.8 from the NID, do you have any concerns related to the time series of reported AD? If your response is yes, draft a clarifying question to be sent to the Party.

A. No
B. Yes. Please submit your question to the Party here:

4.2. Exercise 2

A Party from South-East Asia describes emissions from the biological treatment of waste in chapter 7.3 in the NID.

See Appendix Lesson 4-2 for a section of NID for use in this exercise. You may download the document here: https://unfccc.int/resource/tet/bw/bw4-03_app_4.2.pdf

Exercise 2 – Question 1

Using the information from table 48 and an assumed emission loss of 5 per cent, can you estimate the CH_4 emissions from anaerobic digestion, in accordance with what is showed in table 49?

A. 12 t
B. 36 t
C. 18 t
D. 5 t

Exercise 2 – Question 2

The weblink below table 47 leads to an article, that clarify that most anaerobic digester are mainly household digesters and that 'waste' is characterized as 'dung', as follow:

'*The National Biodigester Program (NBP) was established in 2006 with the aspiration of building and maintaining household biodigesters throughout country. The NBP supports and monitors the creation of an in-country network of masons, trained to build the "Farmer's Friend" biodigester. The digester requires skilled local labour to construct on-site and lacks moveable parts. The digester is installed below ground level and varies from 4 m^3 to 12 m^3 or larger. A 4 m^3 digester can accommodate the green waste from one household, along with the waste of 2 to 3 cows or 4–6 pigs.*'

The text suggests that the waste indicated as dung is actually a mixture of green waste from households and animal manure. Do you think that a specific cross-sectoral check is needed to confirm the accuracy and/or comparability of the inventory?

A. Yes
B. No

4.3. Answers to practical exercises

Exercise 1 – Question 1

The correct answer is A. According to the NID, default EFs from the 2006 IPCC Guidelines are used. EFs are defined for both wet and dry waste. NID table 7.8 specifies AD. However, there is no mention of whether the AD refer to wet or dry waste. Since MSW is the main substrate and data on MSW are usually specified as wet waste, it is likely that the AD in the NID refer to wet waste.

Assuming the wet waste EF for CH_4 and N_2O from table 4.1 in the 2006 IPCC Guidelines (vol. 5, chap. 4.1.3), emissions can be reproduced. For example, from NID table 7.8, 0.07 million t waste was composted in 2022. Assuming the default EFs of 4 g CH_4/kg waste and 0.24 g N_2O per kg waste, emissions are calculated as 0.28 kt CH_4 and 0.02 kt N_2O. The reported CH_4 emissions in the NID and CRT 5.B afor category 5.B.1.a re slightly different (0.26 kt CH_4) but this might be the result of rounding of AD In case of concerns, you might take a closer look at information in the CRT.

Remember to use the latest English version of the 2006 IPCC Guidelines available online for making final determinations during the review. For example, in the case of the default N_2O EF for composting, this factor was updated through a corrigendum to the 2006 IPCC Guidelines. The corrections were made in the English version only.

Exercise 1 – Question 2

The correct answer is A. The CH_4 and N_2O emissions reported in the CRT 5.B for composting are consistent with the emissions specified in table 7.8 in the NID. The amount of waste composted in the CRT 5.B is 50 per cent of the amount composted reported in table 7.8 in the NID. Most likely upon conversion of MSW (wet waste) to MSW (dry matter), a moisture content of 50 per cent is assumed (confirmed by the Party during the review). The IEFs therefore do not match the EFs from table 4.1 in the 2006 IPCC Guidelines (e.g. the default CH_4 EF in table 4.1 is 10 g CH_4/kg waste, whereas the IEF according to the CRT 5.B is 8 g CH_4/kg waste).

The cause of this could be different assumptions on moisture content in waste in the EF in table 4.1 in the 2006 IPCC Guidelines (under 'remarks' a moisture content of 60 per cent is assumed) and in the CRT (where a moisture content of 50 per cent is assumed). In the end, the calculation is based on wet waste AD and wet waste EFs and these assumptions have no impact on emissions.

Exercise 1 – Question 3

A valid conclusion and recommendation would read as follows:

The Party reported in the NID (pp.7.12–13) AD and EFs based on wet waste and calculated the emissions from category 5.B.1 using the default EFs provided in table 4.1 of the 2006 IPCC Guidelines (vol. 5, chap. 4). However, in converting the AD to dry matter for the purposes of reporting in CRT 5.B, a different moisture content was assumed from that used in table 4.1 of the 2006 IPCC Guidelines. The result is that it is no longer apparent from CRT 5.B that the default EFs from the 2006 IPCC Guidelines are used. During the review, the Party confirmed that a moisture content of 50 per cent was used.

The TERT recommends that the Party include information in the NID on the moisture content used to calculate dry waste AD for composting. Noting that the 2006 IPCC Guidelines do not provide a default

moisture content to be used in the sector, but considering the remark in the table with the default EFs for the category, the TERT encourages the Party to use 60 per cent moisture content, in line with the assumption made in the 2006 IPCC Guidelines (vol. 5, chap. 4, table 4.1) when reporting AD in order to ensure comparability of the IEF reported in CRT 5.B with the IPCC default EFs and across Parties.

Exercise 1 – Question 4

The correct answer is B. Your concerns could relate to the sharp drop in the amount of MSW composted reported in table 7.8, which is not explained in the NID.

A possible question might read as follows:

Table 7.8 in the NID indicates a sharp drop in the amount of MSW composted since 2015. The cause of this trend is not discussed in the NID. However, the downward trend is surprising, since most Parties have waste policies in place promoting composting of waste instead of landfilling. Could the Party kindly explain the reduction in the amount of waste composted (e.g. in connection with the implementation of waste policies)?

Exercise 2 – Question 1

The correct answer is A.

As a reviewer you need to have sufficient knowledge of the 2006 IPCC Guidelines. This does not necessarily include the knowledge to calculate mass of CH_4 from volumes of biogas, but you might want to be able to reproduce the data provided during the review. It is therefore useful to gain some experience in converting volumes to mass of gas.

Table 48 specifies that, in 2022, 734,617 m^3 biogas is collected at anaerobic digesters. Biogas is a mixture of predominantly CH_4 and CO_2. The CH_4 content of the biogas is unknown but, in a first estimate (and for the purpose of validating the result in table 49), CH_4 content of biogas might be taken as 50 vol%, meaning 734,617 m^3 biogas is 367,309 m^3 CH_4. The density of CH_4 depends on temperature and pressure, but assuming CH_4 volume is measured at 20 °C and 1 atm, the density is 0.67 kg/m^3. The CH_4 can be estimated as 367,309 m^3 * 0.67 kg/m^3 = 246 t CH_4. Assuming 5 per cent leakage loss means CH_4 emissions of 246*0.05 = 12.3 t CH_4 or 0.012 kt CH_4 in 2022. Table 49 specifies 0.01 kt of CH_4 emissions in 2022.

Exercise 2 – Question 2

The correct answer is A. When manure and green wastes are co-digested, you need to consult the agricultural expert in the review team to avoid double counting of emissions. It should be clear from the NID that the amount of manure co-digested is not included in the AD used to quantify emissions from manure treatment in the agriculture sector. If this is not the case, either you or the agricultural expert will have to contact the Party for additional information. In case double counting of emissions occurs, the amount of manure co-digested needs to be removed either from the AD for manure treatment in agriculture or from the amount of waste biologically treated in category 5.B.

When anaerobic digestion is predominantly manure (with little or no other wastes), emissions should be preferably reported under agriculture using the appropriate methodology. Clarification on emission allocation would be needed to make sure that there is no overestimation of emissions and that allocation of the emissions is in line with the 2006 IPCC Guidelines.

5. Self-check quiz

The questions set out below will allow you to check your knowledge for this category. Please be aware that you can use the information in the 2006 IPCC Guidelines when answering these questions. Select one answer from the options provided for each question.

Question 1

N_2O emissions from anaerobic digestion:

A. Are calculated assuming 0.24 g/kg wet waste by default
B. Are negligible, since anaerobic digestion conditions prevent the generation of N_2O
C. Can occur owing to nitrification/denitrification during pre- or post-treatment of digestate
D. B and C
E. None of the above

Question 2

The CRT 5.B contains AD, presented as dry waste. How many tonnes of dry waste is 240 t wet waste, assuming a moisture content of 60 per cent?

A. 600 t
B. 400 t
C. 144 t
D. 96 t

Question 3:

An anaerobic digester treats 100 kt green waste (wet) per year. From monitoring of biogas generation, the recovery rate is estimated to be 40 m^3 biogas per tonne of waste. Can you quantify annual CH_4 emissions assuming the default EF from the 2006 IPCC Guidelines and provide an estimate of CH_4 recovery?

Physical properties of CH_4 to be used in the calculation: specific heat of CH_4 is 50 MJ/kg; CH_4 content in biogas is 60 per cent; molecular weight is 16 g/mole; specific volume of CH_4 is 1.4 m^3/t; specific weight of CH_4 is 0.7 kg/m^3.

A. CH_4 emissions are 80 t/year; recovery of 76 kt/year
B. CH_4 emissions are 80 t/year; recovery of 1,680 t/year
C. CH_4 emissions are 200 t/year; recovery of 190 kt/year
D. CH_4 emissions are 200 t/year; recovery of 1,680 t/year

Question 4:

During MBT of solid waste:

A. Part of the waste can be composted

B. Part of the waste can be anaerobically digested

C. Both A and B

D. Waste is neither composted nor digested

Question 5

Emissions from category 5.B:

A. Are the most important category in the waste sector for many countries

B. Are likely to be a key category in developed countries

C. Are likely to be a key category in developing countries

D. Are not a key category for most countries

5.1. Answers to self-check quiz

Question 1

The correct answer is D. Emissions from the digester itself are negligible and thus the 2006 IPCC Guidelines do not provide a default EF. However, a country-specific EF might include emissions due to pre- or post-treatment where N_2O might be generated.

Question 2

The correct answer is D. 240 t wet waste with a moisture content of 60 per cent contains (60%*240 t=) 144 t water and (40%*240 t=) 96 t dry waste.

Question 3

The correct answer is B. CH_4 emissions are calculated using the IPCC default value of 0.8 g/kg waste. This is 0.8 kg/t wet waste. Treatment of 100 kt per year is 100,000 t per year and this results in the emission of 100,000 * 0.8= 80,000 kg CH_4 per year (80 t).

CH_4 recovery (R) is 40 m^3 of biogas. Assuming 60 per cent CH_4 in biogas, this is (40 m^3 * 60% =) 24 m^3 CH_4 or (24 m^3 * 0.7 kg/m^3 =)16.8 kg CH_4 per tonne of wet waste. 100 kt green waste is 100,000 t green waste and this allows a recovery of 1,680,000 kg CH_4 per year or 1,680 t.

Please note that, in this example, CH_4 loss/leakage (80 t) is 4.7 per cent of the amount recovered (1,680 t), which is close to the 5 per cent leakage loss mentioned in the 2006 IPCC Guidelines (vol. 5, chap. 4). Therefore, when calculating emissions of anaerobic digestion using the default EF in equation 4.1 of the 2006 IPCC Guidelines the amount of CH_4 recovery (R) should not be considered in the equation. If you were to attempt to quantify CH_4 emissions as in equation 4.1 (M*EF–R), this would result in a double counting of subtracting recovery and in negative CH_4 emissions.

Question 4

The correct answer is C. During MBT, part of the waste is mechanically separated by industrial magnets, eddy current separators, trommel sieves, shredders, and systems, or the sorting is done manually at handpicking stations. The residue after mechanical separation is often biologically treated (composted or anaerobically digested).

Question 5

The correct answer is D. Emissions from category 5.B are no key category for most countries. This is because the amount of waste biologically treated is small compared with the amount disposed in SWDS or incinerated and because the EF per tonne of waste treated is low.

6. Key points to remember

- Many Parties have waste policies in place which mean that waste treatment and waste composition might change significantly over time. Reconstruction of the entire time series often requires combining different types of information. As a reviewer, you should ensure that the qualitative description of policies in the NID is consistent with the emission trends reported.
- Chapter 4, volume 5, of the 2006 IPCC Guidelines provides the methodology to estimate CH_4 and N_2O emissions from composting and anaerobic digestion of organic waste. The default methodology does not include a default N_2O EF for anaerobic digestors as the emissions are assumed to be negligible.
- In the Party submission, the major elements to check for the category are included in chapter 7.3 of the NID (if the outline for NID is followed by the Party) and CRT 5.B, along with all cross-cutting sections of the NID and cross-cutting and summary tables of CRTs.
- The category should also be assessed focusing on its interlinkages with other sectors (e.g. energy and agriculture) and other categories in the waste sector (e.g. solid waste disposal or wastewater management). In some cases, the 2006 IPCC Guidelines are not explicit on the allocation of emissions (e.g. from co-digestion of manure and green wastes). In all cases the reviewer should check emission allocation and any possible omission or double counting of emissions.
- For most Parties, biological treatment of waste is not a key category. This is because: (i) normally only a small percentage of the total waste is treated biologically; and (ii) emissions per tonne of waste are relatively small (e.g. compared with emissions from disposal of waste in a SWDS).
- Where AD for anaerobic digestion are not available, CH_4 emissions from anaerobic digestion should be quantified on the basis of the amount of CH_4 recovered, assuming 5 per cent leakage loss.
- MBT of waste often includes a biological treatment step (composting or anaerobic digestion). Emissions from this treatment step need to be quantified using the same methodology from the 2006 IPCC Guidelines (vol. 5, chap. 4) and included in the inventory.
- The default EFs for anaerobic digestion in the 2006 IPCC Guidelines (vol. 5, chap. 4, table 4.1) calculates the amount of CH4 emissions from leakages during the process of anaerobic digestion, and the amout of CH4 recovered is already subtracted from the CH4 emissions estimates. Therefore, when applying equation 4.1 of the 2006 IPCC Guidelines the amount of CH4 recovered (R) do not need to be accounted (see footnote to table 4.1).
- Although CRT 5.B requests AD as dry waste, most Parties will calculate emissions using AD as wet waste. As a result, there could be a mismatch between the AD and EFs/IEFs in the NID and in the CRT. In the 2006 IPCC Guidelines (vol. 5, chap. 4, table 4.1), a moisture content of 60 per cent is assumed for the conversion of wet waste EFs to dry waste EFs.

Lesson 5: Incineration and open burning

1. Introduction

This lesson describes the review of GHG emissions generated upon incineration and open burning and assumes prior knowledge of the 2006 IPCC Guidelines, volume 5, chapters 2 and 5

The lesson consists of six topics:

Topic 1: Introduction
Topic 2: Category overview and methodological information
Topic 3: Review approach
Topic 4: Practical exercises
Topic 5: Self-check quiz
Topic 6: Key points to remember

1.1. Learning objectives

At the end of this lesson, you should be able to:

- Understand the key tasks to be undertaken to review the category;
- Understand how the category interlinks with other categories within the waste sector and other sectors of the inventory;
- Identify whether a Party's reporting for incineration and open burning is consistent with the requirements in the MPGs;
- Identify issues and draft relevant recommendations in a review report for this category.

1.2. Expected time needed to complete lesson 5

- For readers with experience in GHG emission inventories: 3–6 hours
- For readers with less experience in GHG inventories: 6–12 hours

2. Category overview and methodological information

2.1. Incineration and open burning categories

Incineration and open burning of solid waste is divided into two categories, as presented in the 2006 IPCC Guidelines. Emissions from these categories are reported in CRT 5.C (incineration and open burning of waste). The 2019 refinement to the 2006 IPCC Guidelines (vol. 5, chap. 5) provided some updates, e.g. on the definition of and information on pyrolysis, gasification and plasma technologies; on oxidation factor of MSW open burning; and default EFs for pyrolysis melting and gasification-melting

for specific plant types. As a reviewer, you should be aware of the changes and updated methodological information for the categories

Clique on the categories on table 5.1 below to have more information.

Table 5.1 – Incineration and open burning of waste and gas emitted.

Categories		Gas emitted
5.C.1 – Waste incineration	Subcategories: 5.C.1.a – Biogenic 5.C.1.b – Non biogenic	CO_2,CH_4, N_2O
5.C.2 – Open burning of waste	Subcategories: 5.C.2.a – Biogenic 5.C.2.b – Non biogenic	CO_2, CH_4, N_2O
Reported in CRT	CRT 5.C	

Box to table 5.1: Category 5.C.1 – Waste incineration

Waste incineration is the combustion of solid and liquid waste in controlled incineration facilities with tall stacks and specially designed combustion chambers. In many developed countries, a significant proportion of waste (e.g. MSW, industrial, hazardous waste, clinical waste, sewage sludge) is incinerated in incinerators. In developing countries, incinerators are commonly used for clinical waste incineration.

Box to table 5.1: Category 5.C.2 – Open burning of waste

Part of the waste might be burned on piles in the open air under uncontrolled conditions. In some countries, open burning of waste is an accepted practice, as it is often the only way to regularly reduce the amount of waste. In countries with well-functioning waste collection systems, open burning might take place sporadically (e.g. for bonfires at special festivities). For these countries, it is good practice to investigate whether any organic carbon is burned in the open environment.

In many countries, combustion of waste is a major treatment option for solid wastes, alongside solid waste disposal. Technologies for waste incineration vary widely from open burning piles of waste in open air to incineration of wastes in advanced incineration plants with gas exhaust cleaning.

The main products of incineration are CO_2 and water vapour. In addition, flue gases contain a range of trace components, including CH_4 and N_2O. Compared to CO_2 and on a mass basis, CH_4 and N_2O emissions are relatively small. However, for open burning and when CH_4 is corrected to CO_2 eq, the global warming potential of CH_4 emissions are the same order of magnitude as CO_2 and can even be higher.

CH_4 emissions from incineration and open burning of waste are a result of incomplete combustion of carbon in waste. Important factors affecting CH_4 emissions are temperature, residence time and air ratio (i.e. air volume in relation to the waste amount). In large and well-functioning incinerators, CH_4 emissions are usually very small. CH_4 emissions are particularly relevant for open burning, where conditions favour incomplete combustion.

N_2O is generated during incineration from nitrogen-containing materials in waste (e.g. food and garden wastes, certain plastics and polymers). Generation of nitrogen also depends on the conditions upon incineration. Modern waste incinerator plants have a system to reduce air pollutant emissions. Specific technologies to reduce NO_X from flue gases might result in additional N_2O emissions.

Box: trace components from incineration

For legislators, other trace components (such as NOX, SO2, NMVOC, dioxins, particulate matter) are of more concern than CH4 and N2O because they contribute to acidification (acid rain) and affect local air quality. Therefore, modern incinerators take measures to reduce emissions of NOX and SO2, particulate matter and dioxins. Depending on the NOX-reducing technology used, N2O concentrations might be increased.

Box: GWP

GWP is the Global warming potential and describes the heat absorbed by a GHG in the atmosphere. GWP is expressed in CO2 eq. In the UNFCCC process, CH4 is assumed to have a GWP of 28, which means that 1 kg CH4 has the same effect as 28 kg CO2. For N2O, the GWP is 265.

The formal decision on GWP can be found in decision 5/CMA.3, paragraph 25, which clarifies that the 100-year time-horizon GWP values referred to in decision 18/CMA.1, annex, paragraph 37, shall be those listed in table 8.A.1 of the Fifth IPCC Assessment Report, excluding the value for fossil CH4.

- In the waste sector, only waste incineration without energy recovery is reported. When waste is incinerated with energy recovery for energy use, emissions are reported under the energy sector.
- Biogenic carbon in biomass materials (e.g. paper, food and wood waste) has a relatively short carbon cycle, meaning that the CO_2 released upon burning of biomass was only recently captured from the atmosphere by vegetation. Those biogenic carbon emissions are estimated and reported in the relevant tables for the category for information purpose only, and therefore, not accounted in the national totals, where only emissions from fossil origin are added.

To learn more about incineration and open burning, read chapter 5, volume 5, of the 2006 IPCC Guidelines .

- Trends in waste incineration are mainly the result of a Party's choice between incineration and disposal in SWDS. Relevant considerations are costs, availability of space and perceived environmental impact of waste disposal and incineration. In some parts of the world (e.g. North America, Australia), waste disposal in managed SWDS is perceived as an acceptable treatment option and the fraction of waste incinerated will remain low in the foreseeable future. In other parts of the world (e.g. Europe), solid waste disposal is gradually being phased out and an increasing amount of waste is incinerated.
- In certain developing countries, open burning of waste on a regular basis is an accepted practice as locally it is often the only way to reduce the amount of waste.
- In developed countries with well-functioning waste collection systems, open burning is often strictly regulated and, in many cases, completely forbidden as a waste management practice. Nonetheless open burning might still take place sporadically in addition to other waste treatment options (e.g. when waste is not collected or to avoid costs).

2.2. Methods for estimating emissions

The methodology to quantify emissions is the same for both incineration and open burning, but the methodology suggested for CO_2 in the 2006 IPCC Guidelines (vol. 5, chap. 5) differs from that for CH_4 and N_2O.

As a reviewer, be aware that:

- On methodology and EFs: the quantification of CO2 emissions is more complex and requires information on waste composition. For incineration of liquid wastes, a slightly different methodology is used for CO2. The quantification of CH4 and N2O emissions is rather straightforward and emissions are quantified as the product of AD and an EF depending on the type of incineration or technology.
- On AD: for incineration, many Parties will have AD available from statistics. Where such AD are not available, the 2006 IPCC Guidelines provide a default method to estimate the amount of waste incinerated. For open burning, determining AD is more complicated and often requires expert judgment by the Party.

The methodological information included in this course focuses mainly on the methodology to quantify CO_2 emissions and determine AD for open burning. The methodology for non- CO2 emissions (CH_4 and N_2O) is more straightforward (emissions = AD*EF) while for CO_2 emissions is more complicated; the same for open burning in which statistical data is more difficult than for incineration. The methodology to estimate non-CO2 emissions is briefly described ahead.

Even if you feel comfortable with the contents of the 2006 IPCC Guidelines, please consider the notes in the boxes indicated by the yellow bulb sign, which highlight the items to focus on when you review the category.

2.3. CO_2 emissions

For quantification of CO_2 emissions, the 2006 IPCC Guidelines (vol. 5, chap. 5) distinguish three tiers, one of which (tier 2) is subdivided into two further tiers (tiers 2a and 2b). Please check the decision tree in figure 5.1 (vol. 5, chap. 5) to see the guidance on which tier to use. The choice depends on availability of data and whether the category is a key category. When incineration and open burning of waste is a key category, tier 2 or higher needs to be used with country-specific data on waste generation, composition and management practice.

Tier 1 Calculation of emissions using data on the amount of waste incinerated or open burned with default data for parameters related to EFs (see table 5.2 of the 2006 IPCC Guidelines (vol. 5, chap. 5)). AD can be the total amount of waste combusted (as equation 5.1) or the MSW composition (as equation 5.2). AD can be default or country specific (see table 5.1).

Tier 2a Calculation of emissions using country specific AD for MSW based on the waste composition (percentages of paper, wood, plastics, etc. in waste) as in equation 5.2, with default data for parameters related to EFs (see tables 5.1 and 5.2). For other types of waste (e.g industrial waste, sludge, clinical, etc) country specific AD on the amount is required (equation 5.1).

Tier 2b As tier 2a but with country specific parameters for dry matter content and carbon content. For fossil carbon fraction and oxidation factor if can be used default or country specific data.

Tier 3 Use of plant-specific data. The total fossil CO_2 emissions from waste incineration are calculated as the sum of all plant-specific fossil CO_2 emissions. It is good practice at this tier level to consider parameters affecting both the fossil carbon content and the oxidation factor.

As a waste sector reviewer, you should be familiar with the decision tree in figure 5.1 of the 2006 IPCC Guidelines.

Take note that:

- In most developed countries with a well-functioning waste collection system, incineration and open burning of waste is not a key category. This is because:
  - CO2 emissions per tonne of waste incinerated are much lower than CH4 emissions (expressed in CO2 eq) upon disposal of the same amount of waste in a SWDS.
  - Waste incinerators with energy recovered for energy use are state of the art. As a result, most emissions from waste incineration will be reported in the energy sector. Waste incineration without energy recovery is often limited to:
    - older incinerators that have not been retrofitted for energy use;
    - incineration of specific wastes (hazardous waste, hospital waste, etc.).
  - No or negligible regular open burning of waste takes place.
- In developing countries where substantial amounts of waste are open burned, both the CO2 and CH4 emissions from incineration and open burning of waste might be key categories.
- According to the MPGs, Parties should make every effort to use a recommended method (tiers level) in accordance with the decision trees in the 2006 IPCC Guidelines. If

a Party is unable to use the recommended method owing to lack of resources, the Party may use tier 1 but must clearly document in the NID why the methodological choice was not in line with the corresponding decision tree of the IPCC guidelines (MPGs, paras. 21 and 23).

Decision 5/CMA.3, paragraph 28, notes that the Parties may use on a voluntary basis the 2019 Refinement to the 2006 IPCC Guidelines. Hence, as a reviewer you must be aware of the improvements in the 2019 Refinement. Guidance on quantifying emissions from incineration and open burning under the 2019 Refinement to the 2006 IPCC Guidelines (vol.5, chap. 5) can be found here[3]. Below it is an overview of the main changes between the 2006 IPCC Guidelines and the 2019 Refinement to the 2006 IPCC Guidelines.

Main changes for solid waste disposal in the 2019 Refinement to the 2006 IPCC Guidelines

The 2019 IPCC Refinement to the 2006 IPCC Guidelines has one major change in the methodology used to quantify CO_2 emissions from incineration and open burning: the default oxidation factor for open burning is 71 per cent (compared with 58 per cent in the 2006 IPCC Guidelines).

The 2019 refinements also updated information on definition of thermal technology including pyrolysis, gasification and plasma and provided CH4 and N2O EFs for pyrolysis-melting and gasification-melting for specific plant types

The 2006 IPCC methodology estimates CO_2 emissions from incineration and open burning as the product of three parameters:

- Amount of waste incinerated or open burned;
- Fossil carbon content in the waste burned, which requires data on waste composition;
- Oxidation factor.

The Guidelines provide two equations to calculate CO_2 emissions from solid waste:

- Equation 5.1 provides a general method of calculation for CO_2 emissions based on the amount of waste incinerated or open burned;
- Equation 5.2 can be used to quantify emissions from the incineration of MSW.

Equation 5.3 is used to calculate CO_2 emissions from liquid waste.

As a reviewer, keep in mind that:

- Both equations 5.1 and 5.2 assume AD on a wet weight basis;
- For emissions from MSW, equation 5.2 is preferred over equation 5.1 as it results in a more accurate emission estimate;
- When equation 5.2 is used to quantify emissions from incineration or open burning of MSW, equation 5.1 should still be used to quantify emissions from other types of waste.

[3] https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_5_Ch05_IOB.pdf

Waste incinerated or open burned

Most Parties that incinerate waste have reliable AD available. Where data are not available, default waste generation and an estimate of the share incinerated are available in the 2006 IPCC Guidelines (vol. 5, chap. 2, table 2.1).

Most countries have no reliable statistics on open burning of waste. The 2006 IPCC Guidelines (vol. 5, chap. 5, p.5.16) suggest two methods to estimate AD for open burning:

- Using data from period surveys, research projects or expert judgments to estimate the total amount of waste burned;
- Using equation 5.7 (2006 IPCC Guidelines, vol. 5, chap. 5) to estimate the total amount of MSW open burned.

Equation 5.7 includes the amount of MSW open burned for both the population whose waste is not collected and the population whose waste is collected and open burned in open dumps (unmanaged SWDS).

- A Party might decide to apply equation 5.7 twice in parallel: (i) to assess open burning of MSW by the population whose waste is not collected; and (ii) to assess open burning of waste by the population whose waste is collected but burned at open dumps. Performing separate calculations in this way might improve the transparency of the emission estimate.
- As a reviewer, please note that the default per capita MSW generation and fraction incinerated in the 2006 IPCC Guidelines (vol. 5, chap. 2, table 2.1) refer to the population whose waste is collected and are based on data from the year 2000. They may be outdated for some Parties. In addition, they do not apply to populations whose waste is not collected; expert judgment is required to estimate per capita waste generation for such populations.
- B_{frac} is the fraction of the waste amount that is burned relative to the total amount of waste treated. When reviewing the value B_{frac}, note that it does not account for incomplete combustion arising from inefficiencies in the combustion process, which is described by the oxidation factor (default oxidation factor value is 58 per cent for open burning). B_{frac} mainly refers to burning at open dumps, where a relatively large part of the waste remains unburned. B_{frac} should be estimated using surveys based on available research data or by using expert judgment.

Fossil carbon content

To calculate emissions, in addition to the amount of waste burned, information on waste composition is needed. Carbon in waste is either of biogenic origin (e.g. carbon in food waste, garden and park waste, paper and wood) or fossil origin (plastics). As explained before, for incineration, only CO_2 emissions from the incineration of fossil carbon are included in the totals.

As a reviewer, note that, when available, sorting analyses of waste (e.g. percentage of food waste, percentage of garden and park waste, percentage of paper, etc.) can be used in combination with the fossil carbon content in table 2.4 in the 2006 IPCC Guidelines (vol. 5, chap. 2) to calculate fossil

carbon content. However, if such data are not available, table 2.3 in the 2006 IPCC Guidelines (vol. 5, chap. 2) provides a default composition.

For industrial waste, clinical waste, sewage sludge and fossil liquid waste, default values on fossil carbon content are provided in table 5.2 of the 2006 IPCC Guidelines (vol. 5, chap. 5). Tables 2.5 and 2.6 provide information for industrial waste and clinical waste.

- Waste composition (percentage food waste, percentage garden and park waste, percentage paper, etc.) is also used in the quantification of CH_4 emissions from solid waste disposal. Biogenic carbon can biodegrade to generate CH_4, whereas fossil carbon is important in terms of CO_2 emissions from incineration. The sum of biogenic carbon and fossil carbon is total carbon in waste. The waste composition data across subcategories should be consistent.
- Waste composition can change over time, owing, for example, to existing waste policies and autonomous trends. When a Party reports a change in waste composition over time, as a reviewer you need to check its documentation and justification and whether the change in composition is in line with expectations based on the Parties waste policy (e.g. when green wastes are collected separately, the fraction of food and garden wastes in household waste can be expected to be reduced and all other fractions to be increased).

Oxidation factor

The oxidation factor describes what part of fossil carbon is converted to CO_2. Table 5.2 (2006 IPCC Guidelines, vol. 5, chap. 5) presents default oxidation factors by management practice and waste type. For waste incinerators it is assumed that the oxidation factor is 100 per cent, while the oxidation factor of open burning is substantially lower.

The oxidation factor is the fraction of carbon left unburned. It consists of the carbon remaining in the ashes after incineration. Only few Parties will have the information necessary to define a country-specific value for the oxidation factor. Where this is done, as a reviewer, you need to check the justification of this oxidation factor.

2.4. Non-CO_2 emissions

The 2006 IPCC Guidelines (vol. 5, chap. 5) provide three tiers for CH_4 and N_2O emissions from waste incineration. The decision tree in figure 5.2 gives guidance on which tier to use. The choice depends on availability of data and whether the category is key. Emissions are estimated using equations 5.4 (for CH_4) and 5.5 (for N_2O). AD (amount and composition of waste) should be consistent with the AD used for estimate CO_2 emissions from incineration and open burning of waste.

Tier 1 Use the total amount of waste incinerated/open burned and default EFs.

Tier 2 Use country-specific data including AD and EFs by waste, technology or management practice.

Tier 3 Use plant-specific data. All incinerators should be considered and their emissions summed.

- For incineration, CH_4 and N_2O emissions are generally much lower than CO_2 emissons. When a Party has little or no open burning, CH_4 and N_2O emissions are generally not key categories.
- For open burning, CH_4 emissions can be of the same magnitude as CO_2 emissions when expressed as CO_2 eq. N_2O emissions from open burning are generally substantially less significant than CO_2 and CH_4 emissions.

Some Parties may report emissions from incineration to the relevant authorities and upload them to a national pollutant register. From here, emissions from all incinerators are aggregated to generate a national total.

As a reviewer, note that, since EFs are defined for different incineration technologies, a further specification of the AD based on the technologies used is required in the NID.

Default **EFs** may be used as follows:

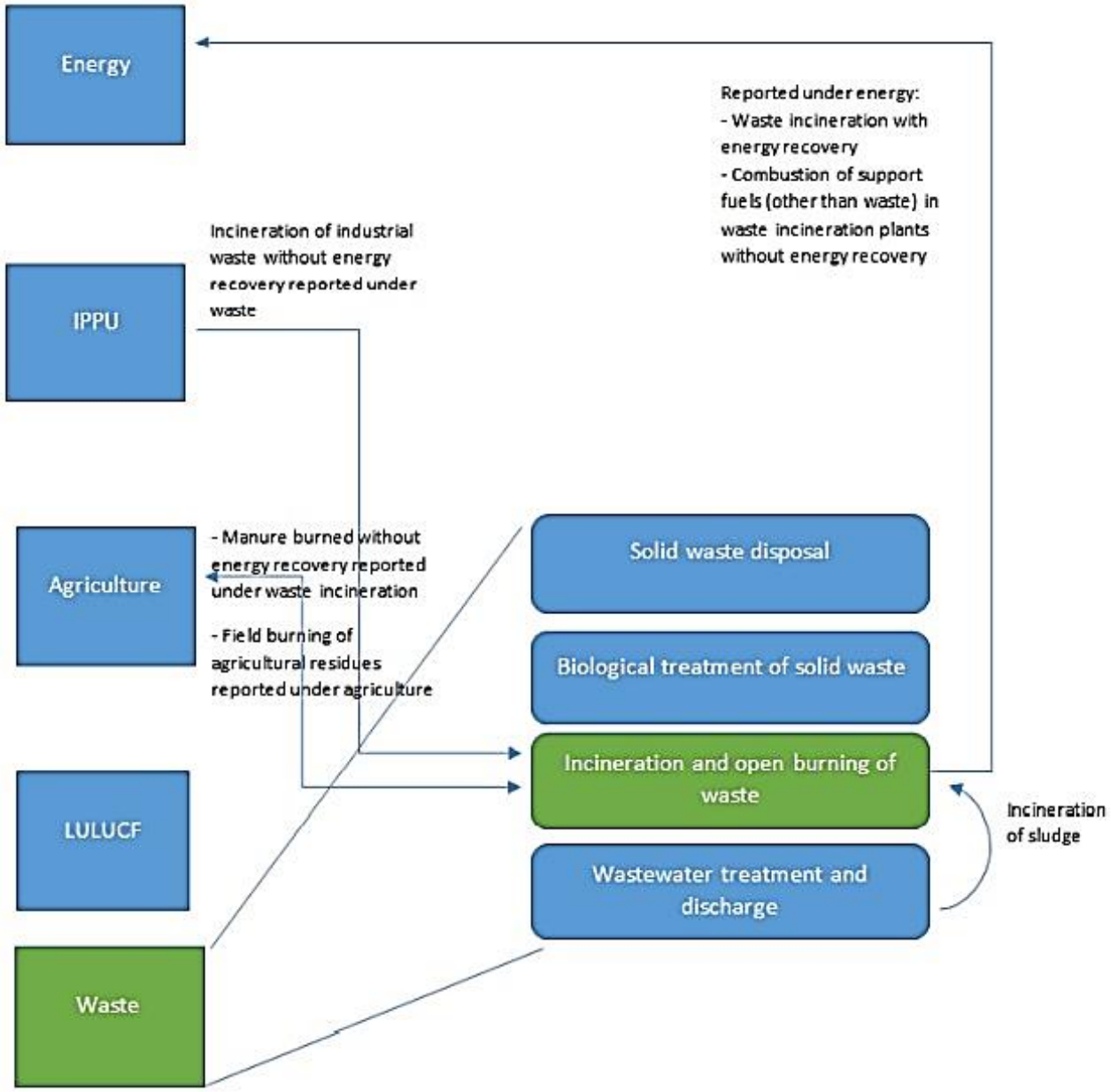
CH_4	• Default CH_4 EF for MSW incinerators by type of incineration/technology are provided in table 5.3 in the 2006 IPCC Guidelines (vol.5, chap. 5.4.2). • For continuous incineration, it is good practice to apply the CH_4 EFs provided in the 2006 IPCC Guidelines (vol. 2, chap. 2, table 2.2). EFs here however are expressed in kg per TJ. Therefore, in order to use these EFs, information is required on the calorific value of waste (TJ/Gg waste). • For open burning, a default EF is mentioned in the text below table 5.3, which says that, for open burning of waste, a CH_4 EF of 6500 g/t MSW wet weight has been reported.
N_2O	• Default EFs for N_2O for various types of incinerators are provided in table 5.6 in the 2006 IPCC Guidelines (vol.5, chap. 5.4.3). • For open burning, the 2006 IPCC Guidelines propose using an EF of 150 g N_2O per kg dry matter.

As a reviewer, note that the default EFs are mainly provided on a wet weight basis and make sure that the Party explain in the NID whether wet or dry weight AD are used in a consistent way.

2.5. Linkage in reporting incineration and open burning of waste and other categories and sectors

Figure 5.1 below provides an overview of the main linkages between incineration and open burning of waste and other categories and sectors. Understanding these linkages will allow you to understand cross-sectoral issues and the necessary cross-check AD between sectors to make sure that the emissions are not omitted or double counted.

I.Figure 5.1. Overview of main linkages of the category with other sectors and categories



Examples of cross-sectoral linkages where you may need to consult with the expert responsible for another sector in the review are:

- CO_2, CH_4 and N_2O emissions from waste incineration with energy recovery are reported in the energy sector;
- Emissions from open burning of agricultural residues should be reported in the agriculture sector.

Cross-category linkages also exist within the waste sector:

- When waste is burned at SWDS as a way to reduce the volume of waste to be landfilled, emissions are attributed to category 5.C (incineration and open burning). The amount of waste reported as the source of CH_4 generation and emissions for this SWDS in category 5.A should be adjusted according to the amount of waste burned (the amount/composition of the waste burned should be subtracted/adjusted from the amount of waste landfilled) .
- Sludge produced at wastewater treatment plants, might be incinerated. When the Party does not account for sludge removal in category 5.D (S=0 is applied in equation 6.1 from the 2006 IPCC Guidelines (vol. 5, chap. 6)), all emissions due to sludge treatment and disposal are included under category 5.D. Therefore emissions from sludge incinerated should not be accounted for under category 5.C. When the Party account for sludge removal (S>0), the amount of sludge removed under category 5.D should be consistent with the amounts of sludge used or treated in other categories: For example sludge used as fertilizer in the agriculture sector or treated under the waste categories, 5.A, 5 B or 5.C. In such cases, emissions from sludge should be quantified, wherever sludge is treated or disposed, using the appropriate methodologies.

3. Review approach

Topic 4 in lesson 2 gives overall guidance on review approach (prepare – assess – draft) with a reference to this particular category. This lesson focuses on aspects that are specific to incineration and open burning. Please refer back to lesson 6 (Review process overview) of the course on general guidance and cross-cutting issues for the review of GHG inventories if you would like a refresher on the approach to conducting a GHG inventory review.

Prepare → Assess → Draft

The choice of methods and assumptions, collection of AD and selection and development of EFs are the main drivers of inventory quality. Hence, as a reviewer, you must assess and ensure that the selection of these data and the reporting, documentation and justification in the inventory submission are in accordance with the 2006 IPCC Guidelines and the requirements of MPGs and other relevant UNFCCC decisions. The specific section of the inventory submission to check for the category along with specific questions you may consider when assessing the submission are provided in the following slides, along with examples of key considerations when reviewing the category. Examples of the review steps,

follow-up communication with the Party and inputs for the review reports are provided in the case studies and practical examples.

In addition, there are several common elements to be assessed across sectors/categories when reviewing the quality of the Party's submission (i.e. uncertainty analysis, QA/QC, time-series consistency, recalculations and progress in implementing improvements). Lesson 2 of the current course provides a list of possible checks and examples of assessment of cross-cutting issues.

Box: Prepare

During this stage you obtain and familiarize yourself with all the materials needed to undertake the review. The overall preparation of the review includes the careful study of all documents that are available to inform your assessments, such as:

- Refreshing your knowledge of (i) the UNFCCC reporting and review guidelines; (ii) the 2006 IPCC Guidelines; and (iii) review tools and other supporting materials (see also lesson 2, topic 4);
- Familiarizing yourself with the Party's submission;
- Focusing on the sector under your responsibility:
    - The category-specific information contained in the Party's submission;
    - The issues for the sector in the previous review reports.

Box: Assess

During this stage you evaluate whether the recommendations of the previous review are implemented and carry out an in-depth review of the emission inventory, possibly resulting in the identification of new issues and recommendations related to the implementation of the TACCC principles. Performing the review, you might make use of the review tools as provided by the secretariat. Identify possible capacity-building needs for those Parties that need it in the light of their capacities.

Recommendations in previous TERR

One of the tasks during a review is to evaluate each recommendation in the previous TERR: whether it can be considered resolved or not resolved, or whether the Party is addressing the recommendation. The NID might include a paragraph which summarizes the status of implementation of each recommendation according to the Party. The Party may provide further information during the review. However, for each recommendation, you need to check the relevant sections or chapters in the NID and the relevant CRT to conclude whether the implementation of the recommendation and the changes to the NID and/or CRT are satisfactory to consider the recommendation as resolved.

Your conclusion on the recommendations from the previous TERR are documented in the current review report. Your conclusion has to be specific to all elements of what is recommended, making clear references to the page in the NID or to the specific CRT where improvements are made by the Party. If the issue is not yet resolved, the status should be clearly documented based on the submission and any follow-up information received during the review.

Review tools provided by the secretariat

Before the review, the secretariat will make available user-friendly review tools that provide access to the secretariat's CRT database and therefore all the data submitted by Parties in their CRTs. The review tools will allow you to sort or search data according to Party, submission or inventory year, category, GHG and specific data type (e.g. emissions, AD, IEF). The review tools allow you to search for data for a particular Party or for all Parties. They will help you discover outliers in the time series or, when comparing data across countries, allow a quick check of the magnitude of recalculations across submissions for any data point. Review tools give you quick access to data with maximum flexibility. It is often the most efficient way to find the data you are searching for while performing a review.

Box: Draft

This stage is linked to the outputs of the assessment process and drafting questions to the Party for clarification on the submission and preparing the findings on the waste sector to be included in the review report. For guidance on drafting your conclusions and recommendations from a review, refer to lesson 2. With regard to incineration and open burning, there are no special issues with drafting conclusions and recommendations. Some practical examples in drafting issues for the TERR are included in the case studies and examples included in this lesson.

3.1. Category-specific parts of a Party's submission

In the Party's submission, the main information on the quantification of emissions from incineration and open burning can be found in:

- The NID, which provides a description of the methods, AD and EFs used and the assumptions made to calculate emissions. Each NID is organized in the same way, with similar chapters. Information on incineration and open burning according to the outline of the NID will be included in chapter 7.5;
- The CRTs, which provide the numerical inventory information with calculated emissions, the AD used and back-calculated IEFs. CRT 5.C provides a summary of the results for emissions from incineration and open burning.

During the review, make sure to also check the cross-cutting information provided in CRTs (7–10), as explained in lesson 2, topic 3, as well as the cross-cutting chapters of the NID (chaps. 1, 2, 9 and 10 and annexes), which will contain additional information relevant for your assessment.

3.2. CRT 5.C

As a reviewer you must be familiar with CRT 5.C on incineration and open burning, where AD, CH_4 recovery and emissions and the resulting IEF are specified.

When reviewing CRT 5.C, consider the following:

- CRT 5.C distinguishes two categories: Incineration and open burning of waste. AD in the CRT 5.C need to be specified on a wet basis. In most developed countries, waste is incinerated with energy recovery and AD and emissions are reported under the energy sector. In developing countries, significant amount of waste might be open burned. When waste is disposed in unmanaged SWDS (AD in CRT 5.A), waste can be expected to be open burned in these unmanaged SWDS.
- The amount of waste incinerated with energy recovery should also be reported under information item in CRT 1.A(a)s4 to allow for cross sectoral and cross fuel checks for AD and emissions
- The CRTs require emissions to be specified from both biogenic and non-biogenic sources. Parties must clearly document their allocation. Most countries report the fraction of waste containing biomass material under 'biogenic' and other wastes under 'non-biogenic'. Reported allocation and total AD and emissions should be clearly explained and consistent with the information in the NID;
- The CO_2 emission values reported under 5.C.1.a and 5.C.2.a (biogenic) should not be reported aggregated under categories 5.C.1 and 5.C.2;
- If data are available, Parties are encouraged to report disaggregated data for industrial solid wastes, hazardous waste, clinical waste and sewage sludge. As the EFs are provided at the disaggregated level, check if such data are available even if not presented in the CRT, to assess the accuracy and completeness of the estimates.

3.3. Key considerations when assessing incineration and open burning

The GHG inventory should be prepared and reported in accordance with the MPGs, following the good practice provided in the 2006 IPCC Guidelines. The fundamental principles for developing a GHG inventory, as reaffirmed by the MPGs, are transparency, accuracy, completeness, consistency and comparability (the TACCC principles). You assess the inventory for its compliance with these principles. Possible questions related to the implementation of each of the TACCC principles in the inventory for incineration and open burning can be accessed via specific questions as summarized below.

- Is the inventory sufficiently transparent?
- Is the inventory complete?
- Is the inventory consistent?
- Is the inventory comparable?
- Is the inventory accurate?

When the time comes to participate in an actual GHG inventory review, study any further review materials provided to you by the secretariat suggesting further possible checks you may want to use.

The examples provided in this lesson are not intended to provide an exclusive list of possible questions, but a starting point to stimulate your thinking. You may add or modify the questions as appropriate while conducting a review.

Box: Is the inventory sufficiently transparent?

- Does the NID include information on the IPCC tier used?
- Are the descriptions of the method complete and transparent?
- Are all AD clearly described?
- Where a Party estimates emissions from open burning, are AD properly documented and referenced in the NID, including any expert judgments that may be used?
- Are the assumptions on waste composition and fossil carbon content clearly described?
- Are all EFs clearly referenced and/or described and, where used, are country-specific EFs properly justified?

Box: Is the inventory consistent?

- Did the Party perform any recalculations and were they properly applied across the time series?
- Has the Party applied the same methods and used the same sources to determine AD and EFs over the entire time series? If not, how did the Party ensure time-series consistency?
- Is the time series in AD in line with expectation, considering the overall trends in waste generation, waste policies and also changes in activities for other waste treatment processes?

Is the inventory complete?

- Does the inventory cover all waste types: MSW, industrial waste, hazardous waste and hospital waste? Please note that CRT 5.C allows for these wastes to be reported separately, thereby allowing for a rapid evaluation of completeness.
- Has the Party reported only emissions from waste incineration without energy recovery? Emissions from waste incineration with energy recovery should be reported under the energy sector and you can check the NID (chapter 3) to ascertain whether this is the case. Does the Party clearly indicate where emissions from waste incineration with energy recovery are reported in the inventory?
- Has the Party reported emissions from open burning? If not, does the Party justify in the NID the absence of emissions from open burning as either not occurring owing to national circumstances (e.g. legislation) or insignificant?
- Is the open burning of waste from the share of the population whose waste is not collected and from rural populations considered?
- Is open burning at unmanaged SWDS considered?

Is the inventory comparable?

- Are emissions from incineration of waste with energy recovery reported under the energy sector?
- Are biogenic and fossil wastes reported separately?
- Is sludge properly allocated across categories in the waste sector? Where sludge from wastewater treatment facilities is incinerated, has the Party ensured that no double counting with the wastewater treatment category occurs?

Is the inventory accurate?

- Is the methodological tier in agreement with the decision trees in the 2006 IPCC Guidelines (vol. 5, chap. 5) and properly applied?
- Is the fossil carbon content in the waste calculated correctly?
- Are the estimates for carbon content in incinerated waste fractions consistent with the assumed DOC content in the quantification of CH4 emissions from solid waste disposal (same fractions assumed for food, garden and park, paper, wood and plastic wastes)?
- Have all CO_2 emissions of fossil origin been reported and included in the total?
- Have the CH_4 and N_2O EFs been applied correctly (i.e. regarding wet or dry weight) and considering the technology type?

3.4. Case Studies

The examples below show how the review approach may be applied when reviewing the category. The examples are based on real submissions by Parties. For each question, select an answer and/or draft your response. Once you have submitted your answer you will be able to see the suggested answer.

3.5. Case study 1 (open burning MSW)

See Appendix Lesson 5-1 for chapter 7.4.5 in the NID of an Eastern European country to use in this case study. You may download the document here: https://unfccc.int/resource/tet/bw/bw5-01_app_5.1_cs1.pdf

Question 1.1 Assessing default parameters

According to the NID, default values for parameters dmj, CFj and FCFj are used for MSW (see equation 5.2 (vol. 5, chap. 5)).

Where in the 2006 IPCC Guidelines are these parameters for MSW defined and where can you find the default values?

A. Volume 5, chapter 5, table 5.2
B. Volume 5, chapter 2, annex 2A.1
C. Volume 5, chapter 2, table 2.3
D. Volume 5, chapter 2, tables 2.4 and 2.5

Question 1.2: Drafting a question to the Party

The NID states that the fractions of MSW that can be open burned by the rural and urban population were identified based on the on the morphological composition showed in table 7-10. The NID also states that equation 5.2 from the 2006 IPCC Guidelines (vol. 5, chap 5) was used to quantify emissions, along with the default values for dmj, CFj, FCFj and OFj.

When you evaluate the waste types in table 7-10, you notice that they differ from those specified in table 2.4 in the 2006 IPCC Guidelines (vol. 5, chap. 2) and it is unclear what assumptions the Party makes on dm_j, CF_j and FCF_j for phytotechnical waste, furniture and electronic equipment.

What question can you ask the Party?

Please submit your question here:

Question 1.3: Assessing accuracy of per capita waste generation

As a reviewer do you think that the values reported for per capita waste generation for urban and rural population reported in the NID are in agreement with the 2006 IPCC Guidelines and the UNFCCC reporting requirements?

A. Yes
B. No

Question 1.4: Assessing time series

For estimating AD throughout the entire time series, a constant per capita waste generation is assumed. As a reviewer, do you agree with such an assumption?

A. Yes
B. No

Question 1.5: Drafting a finding and recommendation for the TERR

In this case study, several problems were observed with the estimation and reporting of CO_2 emissions from the category. To recapitulate:

- Transparency: The Party did not explain their assumptions on dm_j, CF_j and FCF_j for phytotechnical waste, furniture and electronic equipment (see question 1.2);
- Transparency: The Party did not justify the urban and rural waste generation of 0.9 and 0.5 kg per capita per day which is below the default IPCC values (see question 1.3);
- Accuracy: The per capita waste generation is kept constant throughout the entire time series, even where an increase is expected as a result of increasing GDP (see question 1.4).

As a reviewer (and in consultation with the lead reviewer and UNFCCC review officers), you will need to decide whether to formulate a description of the finding and a recommendation in the TERR for each of the four problems individually or combine several problems in a single finding or recommendation.

If you decide to combine the transparency issues with the accuracy issue, please draft a text for the TERR noting that, during the review, the Party provided the following information: 1) the urban waste generation of 0.9 kg per capita per day and the information on waste composition came from a research report by the National Technical University, which was made available to the TERT; 2) this report includes a literature review containing information on fossil carbon content in phytotechnical waste, furniture and electronic equipment; and 3) the rural waste generation is based on expert judgment from an expert of the Ministry of Environment.

Please submit your draft of the finding here:

3.6. Case study 2 (incineration of industrial waste)

See Appendix Lesson 5-1 for a description of emissions from incineration of industrial waste on page 301 in the NID of a Party from East Asia:
https://unfccc.int/resource/tet/bw/bw5-02_app_5.1_cs2.pdf

Also, please download CRT 5.C here:
https://unfccc.int/resource/tet/bw/bw5-03_Case_study_5.2..xlsx

Question 2.1. Assessing application of the IPCC methodology for CO_2

Does the Party quantify CO_2 emissions using the IPCC default values?

A. Yes
B. No

Question 2.2: Assessing accuracy of CO_2 emissions

Is the calculation of CO_2 emissions accurate, considering the information provided in CRT 5.C and the NID?

A. Yes
B. No

Question 2.3: Drafting a question to the Party

Draft a relevant question to the Party.

Please submit your question here:

Question 2.4: Assessing accuracy of CH_4 and N_2O emissions

The IEFs from CRT 5.C represent the ratio between emissions and AD. Where emissions are estimated as AD*EF and only one type of AD is used, the IEF should be equal to the EF. For incineration of industrial waste, only one EF for both CH_4 and N_2O is considered for all types of incinerators. Therefore, for CH_4 and N_2O, the IEF should be equal to the EF.

Evaluate whether the IEFs for CH_4 and N_2O in CRT 5.C are in agreement with the EF specified in the NID in table 7.12.

A. Both the IEFs for CH_4 and N_2O from CRT 5.C are in agreement with the EF from table 7.12.
B. The IEF for CH_4 is and the IEF for N_2O is not in agreement with the EF from table 7.12.
C. The IEF for CH_4 is not and the IEF for N_2O is in agreement with the EF from table 7.12.
D. Both the IEF for CH_4 and N_2O from CRT 5.C are not in agreement with the EF from table 7.12.

Question 2.5: Drafting a finding and recommendation on CH_4 and N_2O EFs

In a reply to questions during the review, the Party indicated that it had made a mistake in the units in table 7.12. The units for the EFs for CH_4 and N_2O should be kg/Gg. The error is only a representation error and the actual calculation was done using the correct EF. In addition, the Party explained that the default values for the CH_4 EF from incineration are taken from table 5.3 and for N_2O from table 5.6 (2006 IPCC Guidelines, vol. 5, chap. 5). Your check shows that, after the conversion in the units (as explained in question 2.4), the N_2O EF corresponds to the default value of 100 g N_2O/t (= 100 kg N_2O/Gg). However, the referenced table for CH_4 is only valid for MSW.

During a real review, you may wish to further investigate and communicate with the Party on this observation. However, for the purpose of this exercise, please draft a recommendation on the basis of the issues detected and the Party's response to your initial question.

Please submit your draft of the finding and recommendation here:

3.7. Answers to case study 1 (open burning)

Question 1.1

The correct answer is D. Default values for dmj, CFj and FCFj can be found in table 2.4 in the 2006 IPCC Guidelines (vol. 5, chap. 2). Please note that the symbols from chapter 5 (CFj, FCFj) are not explicitly mentioned in table 2.4. However, from the definitions in equation 5.2 (vol. 5, chap. 5), it becomes clear that dm is listed in the second column "dry matter content in % of wet weight" of table 2.4 (vol. 5, chap. 2); CFj is listed in the fifth column "total carbon content in % of dry weight" and FCFj in the sixth column "fossil carbon fraction in % of total carbon".

For construction and demolition waste, total carbon content and fossil carbon content is listed in table 2.5 (vol. 5, chap. 2).

Question 1.2

A possible question might read:

For open burning of waste, the NID (chap. 7.4.5.2, p.290) states that equation 5.2 with default values from the 2006 IPCC Guidelines (vol. 5, chap. 5) are used. The composition of MSW that can be burned is specified in table 7-10 in the NID. However, the TERT notes that table 2.4 in the 2006 IPCC Guidelines (vol. 5, chap. 2) does not provide default values for dm_j, CF_j and FCF_j in phytotechnical waste, furniture and electronic equipment. Could the Party explain what assumptions for dm_j, CF_j and FCF_j were used for these wastes and provide the relevant justifications for the values used?

Question 1.3

The correct answer is B. In the absence of official data, the per capita waste generation for the urban population was assumed to be 0.9 kg per capita per day. The urban waste generation of 0.9 kg per capita per day (= 0.33 t per capita per year) can be compared with the default value in table 2.1 of the 2006 IPCC Guidelines (vol. 5, chap. 2), which is 0.38 t per capita per year for Eastern Europe in 2000. As a reviewer, you need to ask the Party for an explanation on the assumptions used to define its urban waste generation, which is below the default value for 2000, which in any case was expected to increase across the time series.

The rural per capita waste generation is assumed to be 0.5 kg per capita per day and therefore 45 per cent lower than urban waste generation. Even though this might seem reasonable to you as a reviewer, the justification of the assumptions used is not documented in the NID. You might ask a question to check the justification of this value.

Question 1.4

The correct answer is B. The 2006 IPCC Guidelines (vol. 5, chap. 2.2.1) indicate that waste generation for subsequent or earlier years can be estimated using the guidance on how to estimate historical emissions from SWDS (vol. 5, chap. 3.2.2) and the methods for extrapolation and interpolation using drivers (vol. 1, chap. 5). It is clear in the Guidelines (vol. 5, chap. 3.2.2) that per capita GDP is one of the drivers to estimate historic waste generation that needs to be taken into consideration. When GDP increases over time, an increase in per capita waste generation can be expected.

Question 1.5

A possible finding and recommendation might be:

The Party reported in the NID (chap. 7.4.5.2, p.290) its emissions from open burning of waste. The share of the population whose waste is assumed to be open burned (P_{frac}) is based on the rural population plus the 25 per cent of the urban population that does not benefit from sanitation services. The urban waste generation is assumed to be 0.9 kg per capita per day and rural waste generation is assumed to be 0.5 kg per capita per day. These values are below the IPCC default values and were assumed to be constant for the entire time series. The composition of waste is based on available analyses, as provided in the NID table 7-10. However, the TERT finds the per capita waste generation for both rural and urban waste to be insufficiently justified in the NID. The Party did not explain in the NID why per capita waste generation for both rural and urban waste are below the IPCC default values and why a constant value is applied for the entire time series. In addition, there is no explanation in the NID on the assumptions made for dm_j, CF_j and FCF_j for phytotechnical waste, furniture and electronic equipment. During the review, the Party provided a research report by the National Technical University which contains the assumptions for urban waste generation per capita, information on waste composition and a literature review containing information on fossil carbon content in phytotechnical waste, furniture and electronic equipment. The Party also explained that rural waste generation is based on expert judgment from an expert of the Ministry of Environment. The ERT agreed with the assumptions and sources used but considers that per capita waste generation should be extrapolated or interpolated based on the guidance provided in the 2006 IPCC Guidelines (vol. 1, chap. 5 and vol. 5, chap. 3.2.2)

The TERT recommends that the Party justify in the NID the values used for urban waste generation per capita and the assumptions on dmj, CFj and FCFj for phytotechnical waste, furniture and electronic equipment by including a link to the research report of the National Technical University. The TERT also recommends that the Party improve the justification of the per capita waste generation for rural waste by clarifying that this is based on expert judgment by an expert of the Ministry of Environment. This expert judgment needs to be properly documented, for example by making use of the template in the 2006 IPCC Guidelines (vol. 1, chap. 2, annex 2A.1, table 2A.1). In addition, the TERT recommends that the Party recalculate historical data for waste generation per capita using methods for extrapolation and interpolation as provided in the 2006 IPCC Guidelines (vol. 1, chap. 5 and vol. 5, chap. 3.2.2).

3.8. Answers to case study 2 (incineration of industrial waste)

Question 2.1

The correct answer is B. Table 5.2 in the 2006 IPCC Guidelines (vol. 5, chap. 5) provides default values for incineration of industrial waste. The Party uses default total carbon (50 per cent of dry weight) and default fossil carbon fraction (90 per cent of total carbon content). However, the oxidation factor used by the Party (95 per cent) is lower than the IPCC default (100 per cent).

As a reviewer, you need to ask the Party to justify the value of the oxidation factor of 0.95.

Question 2.2

The correct answer is B. According to the 2006 IPCC Guidelines (vol. 5, chap. 6, equation 5.1), CO_2 emissions from the incineration of industrial waste can be calculated as:

CO_2 emissions = $SW_{IW} * dm_{IW} * CF_{IW} * FCF_{IW} * OF_{IW} * 44/12$

in which

- SW_{IW} = total amount of solid waste of industrial waste (wet weight) incinerated or open burned, Gg/year
- dm_{IW} = dry matter content in industrial waste (wet weight) incinerated or open burned, (fraction)
- CF_{IW} = fraction of carbon in the dry matter (total carbon content), (fraction)
- FCF_{IW} = fraction of fossil carbon in the total carbon, (fraction)
- OF_{IW} = oxidation factor, (fraction)
- 44/12 = conversion factor from carbon to CO_2

CRT 5.C indicates AD are reported in wet weight. Table 7-12 in the NID contains values for all parameters in equation 5.1 except for a value for dm_{IW}. The value of dm_{IW} assumed can be calculated by rearranging equation 5.1 as follows:

$$dm_{IW} = CO_2 \text{ emissions} / (SW_{IW} * CF_{IW} * FCF_{IW} * OF_{IW} * 44/12)$$

or

$$dm_{IW} = 132.5 \text{ Gg} / (80.7 \text{ Gg} * 0.5 * 0.9 * 0.95 * 44/12) = 1$$

So it appears that either the Party did not take into account the dry matter in industrial waste, when quantifying emissions or the value of AD in CRT 5.C is provided on a dry matter basis.

The 2006 IPCC Guidelines do not provide a default value of dry matter in industrial waste (see vol. 5, chap. 5, table 5.2, where dry matter in industrial waste is characterized as not available). However the calculation of CO_2 emissions requires this parameter, which might be based on expert judgment.

Question 2.3
A possible question to clarify the dm_{IW} used by the Party might be as follows:

The NID (p. 301) explains the calculation of emissions from incineration of industrial waste. Table 7-12 shows the parameters used to estimate emissions. The Party stated in the NID that emissions are calculated using equation 5.1 from the 2006 IPCC Guidelines (vol. 5, chap. 5). However, this equation requires a value for dry matter in industrial waste (dm_{IW}) but no such value is specified in table 7-12. When trying to reproduce the calculation of CO_2 emissions, it appears that dm_{IW} is either not taken into account or assumed to be 1. Could the Party justify why dm_{IW} is not taken into account in its quantification of CO_2 emissions from industrial waste?

Question 2.4
The correct answer is D. Neither IEF is in agreement with the EFs in the NID regarding their units. IEFs are expressed in kg CH_4/t waste. 1 kg/t equals 1000 g/Mg or 1 g/kg. The EFs in table 7-12 are expressed in g/Gg. 1 g/kg is 1,000,000 g/Gg. The IEF for CH_4 is 0.11 kg/t = 0.11 g/kg = 110,000 g/Gg. It appears that the IEFs from CRT 5.C are a factor of 1000 higher than the EF in table 7.12.

In addition to this conversion factor problem, the CH_4 EF in table 7.12 is not in agreement with the IEF for CH_4 in CRT 5.C (CH_4 EF in table 7.12 is 118.5 g CH_4/Gg, whereas the IEF for CH_4 in CRT 5.C is 0.108 kg/t).

Errors with conversion factors are quite common. Please familiarize yourself with the most common conversion factors for weight, such as Gg to g, Gg to kg, kt to Gg, t to Mg.

Question 2.5
A possible draft of the finding and recommendation might read:

The Party reports the EF used in its calculation of CH_4 and N_2O emissions from incineration of industrial waste in NID table 7.2 (118.5 g CH4/Gg and 100 g N2O/Gg). The TERT noted that the values in CRT 5.C are 0.108 kg CH4/t and 0.10 kg N2O/t and therefore the values are not in agreement regarding their units between the NID and CRT 5.C (for example, 0.108 kg CH4/t is equal to 108,000 g CH4/Gg, while in the NID it is 118.5 g CH4/Gg, a value lower by a factor of 1000). In addition, the value of the CH4 EF reported in the NID is different from that reported in CRT 5.C (118.5 versus 108,000 g CH4/Gg) and both numbers are not consistent with the default values in the 2006 IPCC Guidelines.

During the review, the Party confirmed a mistake in the units reported in the NID. The units for EF for CH_4 and N_2O should be kg/Gg in table 7-12. The Party explained that the error is only a representation error and the actual calculation was done using the correct EF as in CRT 5.C. In addition, the Party explained that the default values for the CH_4 EF from incineration are taken from table 5.3 and those for the N_2O EF are taken from table 5.6 (2006 IPCC Guidelines, vol. 5, chap. 5).

The TERT notes that the CH_4 EF from table 5.3 refers to incineration of MSW. Moreover, there is no EF of 118.5 kg/Gg waste in this table. The TERT further notes that, for continuous incineration of industrial wastes, it is good practice to apply the CH_4 EFs provided in the 2006 IPCC Guidelines (vol. 2, chap. 2, table 2.2).

The TERT recommends that the Party justify the CH_4 EF or use the EF for incineration of industrial waste in large and well-functioning incinerators from the 2006 IPCC Guidelines (vol. 2, chap. 2, table 2.2), applying a consistent approach across the time series and justifying any assumptions and values (e.g. NCV) used in the NID. The TERT also recommends that the Party correctly report the CH_4 and N_2O EFs in table 7.2 of its next NID.

4. Practical exercise

In the following section, some additional exercises are provided to practice your skills as a review expert. Each exercise consists of different tasks.

The excel file for this exercise contain CRT 5.A, 5.C, summary2 and CRT 9 of a Party from South-Central Asia as provided here:
https://unfccc.int/resource/tet/bw/bw5-04_Exercise_5.1.xlsx
This set of CRTs are used in the next exercises.

4.1. Exercise 1: Justifying use of notation key "NE"

For emissions from open burning of solid waste (category 5.C.2 - biogenic), the notation key "NE" is used (see CRT 5.C and CRT 9). The Party provided in its NID, the following justification:

"In accordance with the 2006 IPCC Guidelines, the rate of MSW generation per capita of the rural population is 0.4 kg/person/day, the estimated value of CH_4 emissions is 7,497 t CH_4. Assuming a GWP of CH_4 of 28, this implies that possible emissions from open burning of MSW are 210 kt of CO_2 eq.

Thus, emissions from open burning of MSW amounted to less than 500 kt of CO_2 eq and are considered insignificant (decision 18/CMA.1, annex, para. 32)."

Notes to this exercise: 1) Rural population in 2022 is 7.9 million people; 2) the Party has not reported the use of flexibility regarding paragraph 32 of the MPGs.

Do you agree with the conclusion that the CH_4 emissions from open burning can be considered as insignificant?

A. Yes
B. No

Box: Insignificance threshold (decision 18/CMA.1, annex, para. 32)

Each Party may use the notation key "NE" when the estimates would be insignificant in terms of level according to the following considerations: emissions from a category should only be considered insignificant if the likely level of emissions is below 0.05 per cent of the national total GHG emissions, excluding LULUCF, or 500 kt CO2 eq, whichever is lower. The total national aggregate of estimated emissions for all gases from categories considered insignificant shall remain below 0.1 per cent of the national total GHG emissions, excluding LULUCF. Parties should use approximated AD and default IPCC EFs to derive a likely level of emissions for the respective category. Those developing country Parties that need flexibility in the light of their capacities with respect to this provision have the flexibility to instead consider emissions insignificant if the likely level of emissions is below 0.1 per cent of the national total GHG emissions, excluding LULUCF, or 1,000 kt CO2 eq, whichever is lower. The total national aggregate of estimated emissions for all gases from categories considered insignificant, in this case, shall remain below 0.2 per cent of the national total GHG emissions, excluding LULUCF.

4.2. Exercise 2: Assessing CH_4 emissions

Using the information provided in the previous exercise regarding waste generation per capita and rural population (7.9 million people), can you reproduce the estimate of the CH_4 emissions for category 5.C.2 (open burning - biogenic) to compare with the values provided by the Party for justifying insignificance?

A. Yes
B. No

4.3. Exercise 3: Assessing use of default waste generation

The Party states that, in accordance with the 2006 IPCC Guidelines, the rate of MSW generation per capita of the rural population is 0.4 kg/person/day.

Do you consider the value properly applied?

A. Yes
B. No, but could be acceptable to explore the order of magnitude of emissions
C. No

4.4. Exercise 4: Assessing completeness

In exercises 1–3, emphasis was on open burning of uncollected waste (rural population). Please have another look at the CRTs. Do you think there is a risk of open burning of collected waste at unmanaged SWDS (CRT 5.A)?

A. Yes
B. No

4.5. Exercise 5: Calculating fossil carbon content to estimate CO_2 emissions in open burning and incineration of waste

For the calculation of CO_2 emissions in open burning, waste composition is required. The emissions can be calculated starting from the default waste composition and default data on characteristic parameters in the 2006 IPCC Guidelines (vol 5., chap 2, tables 2.3 and 2.4).

For your convenience the IPCC default composition for South-central Asia and the default parameters are provided in the Excel-file Exercise 5.1-2.xls. You may download the file here: https://unfccc.int/resource/tet/bw/bw5-05_Exercise 5.1.2.xlsx

Can you calculate the CO_2 emissions from open burning of 1 ton MSW, based on the IPCC default composition for South-Central Asia (table 2.3) and the default parameters (table 2.4)?

A. 0.019 ton CO_2 per ton of MSW
B. 0.122 ton CO_2 per ton of MSW
C. 0.569 ton CO_2 per ton of MSW
D. the information is insufficient.

4.6. Answers to practical exercises

Exercise 1
The correct answer is B. An emission should only be considered insignificant if the likely level of emissions is below 0.05 per cent of the national total GHG emissions or does not exceed 500 kt CO_2 eq, whichever is lower. The "national total GHG emissions" refers to the total GHG emissions without LULUCF for the latest reported inventory year.

Total GHG emissions without LULUCF can be found in the CRT summary 2 and are 354,869.62 kt CO_2 eq, of which 0.05 per cent is 177 kt CO_2 eq. Therefore the threshold of significance is 177 kt CO_2 eq but the CH_4 emissions reported by the Party as insignificant is 210 kt CO_2 eq.

Exercise 2
The correct answer is A. The rural population is 7.9 million people. The amount of MSW open burned is 7.9 million people *0.4 kg MSW/person/day*365 days/year = 1,153 kt per year in a wet weight basis. The default CH_4 EF is 6,500 g/t wet waste = 0.65 t/kt waste (2006 IPCC Guidelines, vol. 5, chap. 5, p.5.20). CH_4 emissions are calculated to be 6.5 t/kt waste * 1,153 kt waste= 7,497 kt CH_4.

Exercise 3
The correct answer B. The default value for waste generation for South-Central Asia is 0.21 t per capita per year (2006 IPCC Guidelines, vol. 5, chap. 2, table 2.1). However, as specified in the table, the value is for the urban population and based on data for the year 2000. Rural population will have a lower per capita waste generation. As per capita GDP will have grown since 2000, per capita waste generation will also have increased.

The value used (0.4 kg per capita per day) is 0.146 t per capita per year and is below the default value for urban waste generation in the year 2000. For rural population it might be a good starting assumption to explore significance of emissions, but once emissions are demonstrated to be potentially significant, the per capita rural waste generation needs further justification.

Exercise 4
The correct answer is A. When looking at CRT 5.A, you notice that a substantial amount of solid waste is collected and subsequently disposed in unmanaged SWDS. At unmanaged SWDS, open burning of solid waste can take place and it should be accounted in the emissions. Parties should provide in the NID information on how open burning in unmanaged SWDS is considered in the inventory.

Exercise 5

The correct answer is B.

CO_2-emissions upon open burning of MSW van can be calculated using equation 5.2 in the 2006 IPCC Guidelines (vol 5., chap 5, page 5.7):

$$CO_2\text{-emissions} = MSW * \Sigma (WF_j * dm_j * CF_j * FCF_j * OF_j) * 44/12$$

The summation in equation 5.2 ($\Sigma (WF_j * dm_j * CF_j * FCF_j * OF_j)$) is calculated in the Table below.

	fraction in waste	dry matter content	total carbon in dry waste	Fossil carbon fraction of total carbon	Oxidation factor	
	WF_j	dm_j	CF_j	FCF_j	OF_j	$WF_j * dm_j * CF_j * FCF_j * OF_j$
food waste	40,30%	40%	38%	0%	58%	0,0000
paper/cardboard	11,30%	90%	46%	1%	58%	0,0003
wood	7,90%	85%	50%	0%	58%	0,0000
textiles	2,50%	80%	50%	20%	58%	0,0012
rubber/leather	0,80%	84%	67%	20%	58%	0,0005
plastic	6,40%	100%	75%	100%	58%	0,0278
metal	3,80%	100%	0%	0%	58%	0,0000
glass	3,50%	100%	0%	0%	58%	0,0000
other	21,90%	90%	3%	100%	58%	0,0034
					$(\Sigma (WF_j * dm_j * CF_j * FCF_j * OF_j) =$	0,0332

CO_2-emissions upon open burning of one ton of MSW are calculated as:

$$CO_2\text{-emissions} = MSW * \Sigma (WF_j * dm_j * CF_j * FCF_j * OF_j) * 44/12$$

$$= 1 * 0{,}332 * 44/12 = 0.122 \text{ ton } CO_2 \text{ per ton of MSW}$$

5. Self-check quiz

Select one answer from the options provided for each question. Please be aware that you can use the information in the 2006 IPCC Guidelines when answering these questions.

Question 1

The emission inventory needs to be consistent between categories. Categories 5.A and 5.C share many parameters. Which parameter from 5.A is relevant for 5.C and vice versa?

A. The amount of MSW generated
B. The composition (fractions organic, paper, wood, etc.) of the MSW
C. The amount of MSW open burned in open dumps
D. The fraction of MSW incinerated
E. A and C
F. A, B, C and D
G. None of the above

Question 2

Which of the following CO_2 emissions need to be included under category 5.C totals in the inventory?

A. CO_2 from a biogenic source from incineration without energy recovery
B. CO_2 from a biogenic source from incineration with energy recovery
C. CO_2 from a fossil source from incineration without energy recovery
D. CO_2 from a fossil source from incineration with energy recovery

Question 3

What parameters are relevant to calculate CO_2 emissions from incineration?

A. Carbon content in the waste
B. Thermal degradability of the waste
C. Fraction of fossil carbon in total carbon
D. Moisture content of the waste
E. A, C and D are relevant
F. All of the above are relevant

Question 4

Which of the following groups of people might be relevant for emissions from open burning of waste?

A. Rural population in a developing country whose waste is not collected
B. Urban population in a developing country whose waste is collected
C. Rural population in a developed country whose waste is collected
D. Rural population in a developed country whose waste is not collected
E. All of the above
F. None of the above

5.1. Answers to self-check quiz

Question 1
The correct answer is F. The information in A, B, C and D are relevant for emissions from categories 5.A and 5.C:

A. The amount of waste generated is the overall driver for waste disposal and incineration. AD are generally calculated as waste generated and fraction disposed/incinerated;
B. Composition is important because it determines the amounts of organic and fossil carbon in waste, which are important parameters to calculate emission in both categories;
C. The amount of waste that is open burnt in open dumps, reduces the amount of waste that biodegrades in landfills;
D. The fraction of waste incinerated is relevant to the fraction of waste disposed in SWDS. Generally, an increase in incinerator capacity results in a reduction in waste disposal in SWDS.

Question 2
The correct answer is C. Only emissions from incineration of fossil carbon without energy recovery are included in the estimated emissions from category 5.C. Emissions from incineration with energy recovery are accounted for under the energy sector. CO_2 emissions from biogenic sources are reported for information purposes but not included in the total emissions.

Question 3
The correct answer is E. In line with equations 5.1 and 5.2, emissions are calculated as the product of a number of parameters. Two of those parameters are CF (carbon content) and FCF (the fraction of fossil carbon in total carbon). Dry matter content (dm) is another parameter and can be calculated as '1 minus moisture content'. Thermal degradability of the waste is not used as a parameter in the 2006 IPCC Guidelines. Equations 5.1 and 5.2 do use an oxidation factor (OF). This OF however, is an incinerator property and not a waste property; The OF describes how well the incinerator is able to incinerate all combustible material (see also vol. 5, chap. 5.4.1.3 of the 2006 IPCC Guidelines).

Question 4

The correct answer is E. In theory, A, B, C and D could all be parts of the population that undertake open burning of waste. In practice, C is least likely to be relevant for open burning of waste.

According to the 2006 IPCC Guidelines (vol. 5, chap. 5, equation 5.7), the amount of waste open burned is proportional to the fraction of the population burning waste (P_{frac}) and the fraction of the waste amount that is burned relative to the total amount of waste treated (B_{frac}).

For developing countries, P_{frac} can be estimated from the sum of:

- the share of the population whose waste is not collected. This is often a significant part of rural population (answer A);
- in addition, part of the waste might be open burned after collection at an open dump as part of a waste management strategy. As a result, urban waste that is collected (answer B) might still be open burned.

For developed countries, P_{frac} can be assumed to be the rural population for a rough estimate. In a region where urban population exceeds 80 percent of total population, one can assume no open burning of waste occurs (see vol 5, chap.5, p. 5.16, of the 2006 IPCC Guidelines).

In most developed countries, B_{frac} for collected rural waste will be low since collected waste is generally treated in managed SWDS or waste incinerators. As a result, answer C is most likely not a relevant source of emissions. The waste in a rural population whose waste is not collected might still be open burned owing to lack of alternatives (answer D).

6. Key points to remember

- Chapter 5, volume 5, of the 2006 IPCC Guidelines provides the methodology to estimate CO_2, CH_4 and N_2O emissions from incineration and open burning of waste.
- In the Party submission, the major elements to check for the category are included in chapter 7.4 of the NID (if the outline for NID is followed by the Party) and CRT 5.C, along with all cross-cutting sections of the NID and cross-cutting and summary tables of CRTs.
- The category should also be assessed focusing on its interlinkages with other sectors (e.g. energy) and other categories in the waste sector (e.g. solid waste disposal). In all cases the reviewer should check if AD is consistent, emission allocation and any possible omission or double counting of emissions.
- In developed countries, incineration and open burning of waste are typically not a key category. For incineration it is because state-of-the-art waste incineration includes energy recovery; and for open burning because in these countries there are regulations prohibiting open burning of waste. Emissions from incinerators with energy recovery are reported in the energy sector. Only emissions from waste incineration without energy recovery is reported in category 5.C.
- In developing countries, incineration and open burning of waste can be a key category when large amounts of waste are open burned in unmanaged landfills or in rural areas.
- Open burning in developing countries requires an estimate of open burning of collected and uncollected waste and an estimate of the share of collected waste burned at open dumps (unmanaged SWDS).
- AD and composition of incinerated waste need to be consistent with other waste categories (mainly category 5.A).
- Some of the default parameters in the 2006 IPCC Guidelines are based on dry weight, while the CRTs require data in wet weights. As a reviewer, make sure that the reporting is correct and that any necessary conversions between wet and dry mass were done in the estimates.
- For incineration and open burning, only CO_2 emissions of fossil origin are to be included in the national totals.
- Default per capita waste generation values (2006 IPCC Guidelines, vol. 5, chap. 2) refer to urban population. When these default values are applied to rural populations, they need to be considered as country-specific AD and require justification.

Lesson 6: Wastewater treatment and discharge

1. Introduction

This lesson describes the review of GHG emissions generated by wastewater treatment and discharge and assumes prior knowledge of the 2006 IPCC Guidelines, volume 5, chapters 2 and 6.

The lesson consists of six topics:

Topic 1: Introduction
Topic 2: Category overview and methodological information
Topic 3: Review approach
Topic 4: Practical exercises
Topic 5: Self-check quiz
Topic 6: Key points to remember

1.1. Learning objectives

At the end of this lesson, you should be able to:

- Understand the key tasks to be undertaken to review a Party's reporting for wastewater treatment and discharge;
- Understand how the wastewater treatment and discharge category interlinks with other categories within the waste sector and other sectors of the inventory;
- Identify whether a Party's reporting for wastewater treatment and discharge is consistent with the requirements in the MPGs and the 2006 IPCC Guidelines;
- Identify findings or issues, draft relevant encouragements or recommendations in a review report for this category.

1.2. Expected time needed to complete lesson 6

- For readers with experience in GHG emission inventories: 3–6 hours
- For readers with less experience in GHG inventories: 6–12 hours

2. Category overview and methodological information

2.1. Wastewater treatment and discharge categories

Wastewater treatment and discharge is divided into two mainly categories (domestic and industrial wastewater), as presented in the 2006 IPCC Guidelines. Emissions from these categories are reported in CRT 5.D (wastewater treatment and discharge). The 2019 refinement to the 2006 IPCC Guidelines (vol. 5, chap. 3) introduced some changes as for example new and revised default data and EFs and

improved guidance on estimating N_2O emissions from domestic and industrial wastewater. As a reviewer, you should be aware of the changes and updated methodological information for the categories.

Clique on the categories on table 5.1 below to have more information.

Table 6.1 – wastewater treatment and discharge and gas emitted.

Categories	Gas emitted
5.D.1 – Domestic wastewater	CH_4, N_2O
5.D.2 – Industrial wastewater	CH_4, N_2O*
Reported in CRT	CRT 5.D

* The 2019 refinements included a new chapter providing further guidance on how to estimate N_2O in industrial wastewater.

The IPCC provides methodologies for CH_4 and N_2O emissions, as CO_2 emissions are of biogenic origin and not included in the estimates for the category.

To learn more about wastewater treatment and discharge, read chapter 6, volume 5, of the 2006 IPCC Guidelines. The slides that follow provide only a short summary of the methodologies suggested by the Guidelines.

Box to table 6.1: Category 5.D.1 - Domestic wastewater

Domestic wastewater consists of sewage and/or wastewater from individual households as well as wastewater collected via a communal sewer system. Communal sewers collect wastewater from households and shops, offices and smaller industries.

Box to table 6.1: Category 5.D.2 - Industrial wastewater

Industrial wastewater originates from an industrial facility. Emissions associated with industrial wastewater that is managed and treated at the industrial facility is reported under industrial wastewater. Industries that produce large volumes of wastewater and contain high levels of degradable organics include the pulp and paper industry and the meat and poultry processing industries.

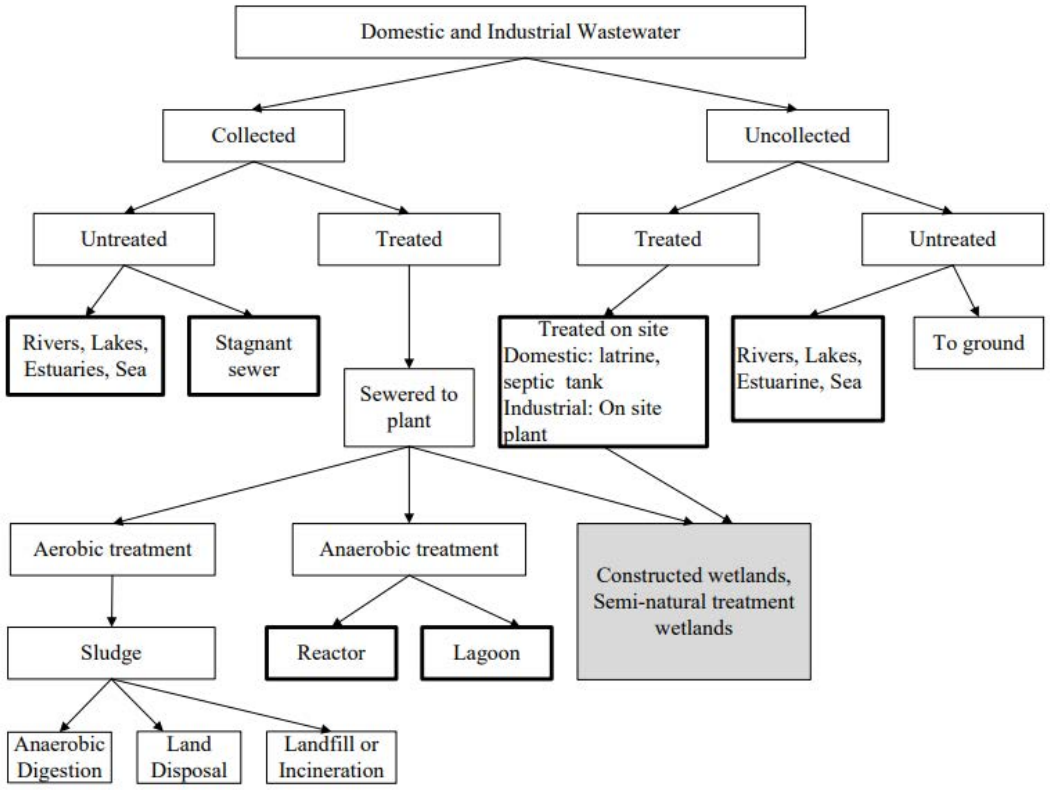
2.2. Pathways for treatment and discharge of wastewater

Wastewater is produced by domestic and industrial sources. Within a single country, different treatment and discharge pathways coexist for wastewater from the source to the destination, for example:

- Wastewater might be directly discharged into a river, lake or sea;
- Wastewater might be treated individually at households in latrines or septic tanks or on-site at industries in an industrial wastewater treatment plant (WWTP);
- Wastewater might also be collected and sent to a communal WWTP, with the treated effluent discharged to open waters.

Figure 6.1 below (from vol. 5, chap. 6 of the 2006 IPCC Guidelines) presents an overview of possible wastewater treatment systems and discharge pathways. The figure includes the additional pathway "constructed wetlands, semi-natural treatment wetlands" as presented in the wetlands supplement.

J. Figure 6.1: Wastewater treatment systems and discharge pathways



It is good practice to draw a diagram similar to figure 6.1 above (from the 2006 IPCC Guidelines) for the country to consider all treatment and discharge systems and pathways and identify potential anaerobic environments that produces CH_4 , including collected and uncollected, as well as treated and untreated. "Potential anaerobic" refers to aerobic wastewater treatment where anaerobic zones in the aerobic systems cannot be ruled out.

Treatment and discharge systems can sharply differ between countries. Also, treatment and discharge systems can differ for rural and urban users, and for urban high-income and urban low-income users. Consult table 6.1 of the 2006 IPCC Guidelines (vol. 5, chap. 6) for information on CH_4 and N_2O emission potentials for wastewater and sludge treatment and discharge systems.

2.3. Methodological information for CH_4 emissions from the category

The 2006 IPCC methodology for CH_4 focuses on estimating the national total amount of organics in wastewater and the distribution of this load over the different wastewater treatment systems and discharge pathways. Upon treatment this total organically degradable carbon in wastewater may:

- Biodegrade and generate CH_4 and CO_2 (CO2 is biogenic and do not need to be estimated or reported)
- Settle as a suspended solid material, often referred to as sludge. Sludge can be removed from wastewater and is often pre-treated. Pre-treatment can range from dewatering, or drying, to composting and anaerobic digestion. The pre-treated sludge can be disposed in SWDS, incinerated with other solid wastes or reused as a fertilizer in agriculture;
- Remain untreated and is flushed out to open water.

In all phases of the treatment systems and discharge pathways described above, CH_4 might be generated. The actual CH_4 generation depends on the:

- Amount of biodegradable organic matter in the wastewater;
- Temperature of the water;
- Type of treatment system and the extent to which anaerobic conditions may occur in the water phase.

2.4. Methods for estimating emissions - CH_4 emissions

The methodology for estimating CH_4 emissions differs for domestic and industrial wastewater treatment. In both cases, however, there are three different methodological tiers available in the 2006 IPCC Guidelines (vol. 5, chap. 6) for estimating CH_4 emissions from wastewater treatment and discharge. According to the decision trees in figure 6.2 (for domestic wastewater) and figure 6.3 (for industrial wastewater), the choice of tier depends on whether the wastewater treatment and discharge is a key category and on availability of AD and EFs.

Tier 1 Use default values for the EF and activity parameters. This method is suitable for countries with limited data. When wastewater treatment and discharge is a key category and the relevant subcategory is significant, a higher-tiered method should be used.

Tier 2 Use the same method as tier 1 but with a country-specific AD and EF. For example, a specific EF for a prominent treatment system based on field measurements could be incorporated under this method. The amount of sludge removed for incineration, landfills and agricultural land should be taken into consideration.

Tier 3 Use a country-specific method based on plant-specific data from large wastewater treatment facilities (for a country with good data and advanced methodologies).

As a waste sector reviewer, you should be familiar with the decision trees in the 2006 IPCC Guidelines and should bear in mind the following:

- Wastewater treatment and discharge (5.D) may be a key category, especially when large part of wastewater is treated in latrines and septic tanks;
- According to the MPGs, Parties should make every effort to use a recommended tier from decision trees in the 2006 IPCC Guidelines. If a Party is unable to use the recommended method owing to lack of resources, the Party may use tier 1 but must clearly document in the NID why the methodological choice was not in line with the corresponding decision tree of the IPCC guidelines (MPGs, paras. 21 and 23).
- Decision 5/CMA.3, paragraph 28, notes that Parties may use on a voluntary basis the 2019 Refinement to the 2006 IPCC Guidelines. Hence, as a reviewer you must be aware of the changes and improvements in the 2019 Refinement. Guidance on quantifying emissions from wastewater treatment and discharge under the 2019 Refinement to the 2006 IPCC Guidelines can be found here.[4] Below it is an overview of the main changes between the 2006 IPCC Guidelines and the 2019 Refinement to the 2006 IPCC Guidelines regarding CH_4 emissions.

[4] https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Box: Main changes for CH_4 emissions from wastewater treatment and discharge in the 2019 Refinement to the 2006 IPCC Guidelines

The 2019 Refinement to the 2006 IPCC Guidelines contains major changes in the methodology used to quantify CH_4 emissions from wastewater treatment and discharge. The main changes are as follows:

- EFs (values of MCF) have been updated;
- The distinction between well-managed and less well managed/overloaded WWTPs has been removed;
- The default value for the amount of TOW removed as sludge (S) is no longer 0. Instead the 2019 refinements introduced a method to quantify the amount of TOW removed as sludge. For septic tanks, Sludged treatment offsite (e.g. for septic tanks) is also highlighted in the refinements.
- CH_4 emissions from remaining TOW in wastewater after treatment are now considered using default removal efficiencies that have been introduced for various wastewater treatment technologies.

Box: Overall emission approaches

Domestic wastewater	Industrial wastewater
Equation 6.1 in the 2006 IPCC Guidelines describes the calculation of CH_4 emissions from domestic wastewater treatment and discharge. According to the Guidelines, the distribution of wastewater over the various treatment systems or discharge pathways can be estimated, based on the degree of urbanization and the population in various income groups. It is good practice to treat the three categories (rural population, urban high-income population and urban low-income population) separately. Table 6.5 provides distributions over treatment systems and discharge pathways for a selection of countries that might be considered regional defaults.	Larger industries do not discharge wastewater into the communal sewer system. Instead, they treat their wastewater on-site. Emissions from industrial wastewater treatment are estimated as a separate category using equation 6.4.  Some industries might discharge wastewater into the communal sewer system, after which it is treated and discharged with domestic wastewater. The emissions that result from this type of wastewater are covered by the correction factor (I) of 1.25 for estimating TOW for domestic wastewater (see equation 6.3 in the 2006 IPCC Guidelines (vol.5, chap. 6)).
Both Equations 6.1 and 6.4 allow for the correction of the TOW to account for organics removed as sludge (S) when estimating emissions. The default for S is zero. For wastewater discharged to aquatic environments, there is no sludge removal (therefore, S = 0) and no CH_4 recovery (R = 0)."	
The default for CH_4 recovery is zero (tier 1). If a Party chooses to report CH_4 recovery, it is good practice to distinguish between flaring and CH_4 recovery for energy generation. The latter should be reported in the energy sector, taking into account the need to avoid double counting of emissions from CH_4 flared and recovered for energy generation. In addition, it is important to highlight that a Party cannot report CH_4 recovery for a treatment or pathway for which they have not estimated emissions.	

2.5. CH_4 emissions: AD

Domestic wastewater: To determine the use of each type of treatment or discharge system, it is good practice to refer to national statistics. If these data are not available, Parties may use data from wastewater associations, urbanization statistics and international organizations such as the World Health Organization. In many cases, data may be supplemented with an expert judgment.

The principal factor in determining the CH_4 generation potential of domestic wastewater is the amount of organic material in wastewater (TOW). For domestic wastewater, this parameter is calculated from human population and BOD generation per person using equation 6.3. The 2006 IPCC Guidelines (vol. 5, chap. 6, table 6.4) give default values for BOD produced per capita and per day for selected countries.

- As a reviewer, you should check the documentation of data sources and the justification of the assumptions used.
- If sludge removal data are available, the data should be consistent across all sectors and categories, for example, with sludge (a) disposed at SWDS, (b) applied to agricultural land, (c) incinerated (d) or used elsewhere should be equal to the amount of TOW removed as sludge in equations 6.1 and 6.4.

Box: BOD/COD

Biochemical oxygen demand (BOD) and chemical oxygen demand (COD) are widely used to characterize the amount of organics in wastewater. Both parameters represent the amount of oxygen required to oxidize (or break down) these organics. A COD of 100 mg/l means that chemical oxidation of the organics in 1 l of wastewater requires 100 mg oxygen.

The difference between BOD and COD is that, in a BOD test, organics are oxidized by bacteria. This is a slow and incomplete conversion. In a COD test, chemicals are used to oxidize organics. This is a rapid and complete conversion. As a result, the COD (rapid, complete oxidation) of wastewater is always higher than the BOD (slow, incomplete oxidation). In the 2006 IPCC Guidelines, a ratio of COD/BOD of 2.4 is assumed, i.e. wastewater with a COD-content of 240 mg/l has a BOD content of 100 mg/l.

Traditionally, domestic wastewater treatment is characterized by its BOD (which is useful as an indicator of easily biodegradable organic material), while industries tend to characterize wastewater by its COD.

Industrial wastewater: COD (chemical oxygen demand) serves as an indicator of TOW for industrial wastewater.

The 2006 IPCC Guidelines state that CH_4 production potential in industrial wastewater is based on the concentration of degradable organic matter (i.e., the COD) of the wastewater, the volume of wastewater, and the propensity to treat the wastewater in anaerobic systems. Major industrial wastewater sources are pulp and paper manufacturing; meat and poultry processing; alcohol, beer and

starch production; organic chemicals production; and food and drink processing. In most countries, three or four industrial sectors account for the majority of TOW, so these sectors must be covered. Periodically, these sectors might be reconsidered, particularly if some industries are growing rapidly.

Only a few Parties have statistics available on the amount of wastewater generated (W_i) and the COD of the wastewater (COD_i), which can be used as AD. When no further information is available, the 2006 IPCC Guidelines provide in equation 6.6 a method to estimate TOW based on industrial output (in t) of the industrial sectors. Table 6.9 gives default values for wastewater per tonne of product.

- Be aware that the 2006 IPCC Guidelines use the term 'effluent' to describe the wastewater produced. In wastewater technology, water that runs from households/industry to the WWTP is called 'influent' and the water after treatment is called 'effluent'.
- Some Parties have statistics available on the amount of COD discharged with the effluent of industrial wastewater. Please be aware that this often refers to the amount of COD in the wastewater after treatment in the industrial WWTP, whereas equation 6.4 requires the amount of COD in the untreated wastewater fed into an industrial WWTP (influent).
- Where only effluent data are available, they can be used to estimate COD in the influent by assuming a COD removal efficiency for the WWTP. If a Party uses an assumed COD removal efficiency, they should provide justification for how that removal fits the performance of their wastewater treatment systems

2.6. CH_4 emissions: EFs

The EFs of treatment systems and discharge pathways are values calculated using equation 6.2 (for domestic wastewater) and equation 6.5 (for industrial wastewater) as a product of B_O (maximum CH_4 producing capacity) and an MCF (methane correction factor (fraction)). The IPCC default value for B_O is 0.6 kg CH_4/kg BOD, or 0.25 kg CH_4/kg COD. The 2006 IPCC Guidelines give default values for MCF by type of treatment system in tables 6.3 and 6.8 (vol. 5, chap. 6).

In reality, a WWTP could consist of several units for different stages of wastewater treatment including removal, storage and treatment of sludge. The default MCFs in table 6.3 represent all emissions from all such stages within the perimeter of a WWTP.

The CH_4 emissions for various wastewater treatment options and discharge pathways depend on the amount of TOW, water temperature and the anaerobic conditions in the treatment systems. Some examples of variation include:

- Emissions from stagnant sewers are higher than those of flowing sewers owing to the longer residence times and the risk of heating up wastewater in stagnant sewers;
- In WWTPs, wastewater is actively aerated, resulting in largely aerobic conditions. As a result, CH_4 emissions from well-managed aerobic treatments are small. When the treatment plant is overloaded or not well managed, CH_4 emissions increase;
- Shallow lagoons (less than 1 m in depth) generally provide aerobic conditions, meaning little or no CH_4 is likely to be produced. In deeper lagoons anaerobic conditions will prevail and significant CH_4 generation can be expected.

2.7. Methodological information for N_2O emissions from the category

Wastewater also contains nitrogen (e.g. urea from urine and proteins from human excretion). Under aerobic conditions, nitrogen components are biologically converted to nitrate (nitrification) and subsequently converted to N_2 under anaerobic conditions (denitrification). Nitrification and denitrification result in N_2O emissions and can occur in two ways:

- as direct emissions from WWTPs;
- as indirect emissions from wastewater after discharge of effluent into waterways, lakes or seas.

In CRT 5.D, direct emissions are reported under N_2O 'plant' and indirect emissions are reported under N_2O 'effluent'.

Direct emissions from nitrification and denitrification at WWTPs may be considered as a minor source

2.8. N_2O emissions: Methodology

In the 2006 IPCC Guidelines, the N_2O emissions from domestic wastewater treatment and discharge are calculated as the product of nitrogen in the effluent and an EF using equation 6.7 (vol. 5 chap. 6.3). With this equation, N_2O emissions are calculated for all treatment and discharge pathways simultaneously.

Since industrial wastewater contains little or no nitrogen, N_2O emissions are considered insignificant in the 2006 IPCC Guidelines when compared with domestic wastewater (and further guidance on N2O emissions from industrial wastewater is provided in the 2019 Refinements).

When information is available on wastewater treatment in advanced centralized WWTPs, the 2006 IPCC Guidelines provide a method (vol. 5, chap. 6, box 6.1) to determine N_2O emissions from these advanced centralized WWTPs separately. Nitrification and denitrification of wastewater in these plants reduce the discharge of nitrogen into open waters and subsequently reduce the generation of indirect N_2O emissions. Considering that the direct emissions from nitrification and denitrification at WWTPs may be a minor source, the 2006 IPCC Guidelines indicate that direct emissions need to be estimated

only for countries that have predominantly advanced centralized WWTPs with controlled nitrification and denitrification steps.

When assessing the N_2O emissions from the category, keep in mind the following:

- N_2O emissions from wastewater treatment and discharge (5.D) are not a key category for most Parties;
- Unlike other categories, there is no decision tree for the choice of methodology for estimating N_2O from domestic wastewater in the 2006 IPCC Guidelines;
- Decision 5/CMA.3, paragraph 28, notes that Parties may use on a voluntary basis the 2019 Refinement to the 2006 IPCC Guidelines. Hence, as a reviewer you must be aware of the improvements in the 2019 Refinement. Guidance on quantifying emissions from wastewater treatment and discharge under the 2019 Refinement to the 2006 IPCC Guidelines can be found here.[5] Below it is an overview of the main changes between the 2006 IPCC Guidelines and the 2019 Refinement to the 2006 IPCC Guidelines regarding N_2O emissions.

Box: Main changes for N_2O from wastewater treatment and discharge in the 2019 Refinement to the 2006 IPCC Guidelines

In the 2019 IPCC Refinement to the 2006 IPCC Guidelines, the methodology to quantify N_2O emissions is more in line with the quantification of CH_4 emissions.

- A decision tree for domestic and industrial wastewater is added, to assist in the choice of a methodological tier.
- The quantification starts from the distribution of wastewater over various treatment and discharge pathways and, for each treatment method, N_2O EFs are defined. Part of the nitrogen is discharged into open waters, where indirect N_2O emissions occur.
- A methodology to quantify N_2O emissions from industrial wastewater is added, similar to the method used to quantify CH_4 emissions from industrial wastewater.

[5] https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

2.9. N_2O emissions: AD

The amount of nitrogen in the wastewater effluent ($N_{EFFLUENT}$) is used as AD for quantification of N_2O emissions. The 2006 IPCC Guidelines (vol. 5, chap. 6, equation 6.8) give a method to estimate $N_{EFFLUENT}$ from the annual protein intake per capita.

- Per capita protein intake (consumption) is available from the Food and Agriculture Organization (FAO). One of the usual checks during the reviews is comparison of the national data with the FAO data on protein consumption.
- When a Party chooses to quantify N_2O emissions from advanced centralized WWTPs separately, equation 6.9 (in box 6.1) can be used to quantify emissions. The degree of utilization of these advanced centralized WWTPs, T_{PLANT}, can be used to calculate the amount of nitrogen treated in these plants.
- When a country chooses to include N_2O emissions from plants, the amount of nitrogen associated with these emissions (N_{WWT}) must be back-calculated and subtracted from the $N_{EFFLUENT}$. The N_{WWT} can be calculated by multiplying N_2O_{PLANTS} by 28/44, using the molecular weights.

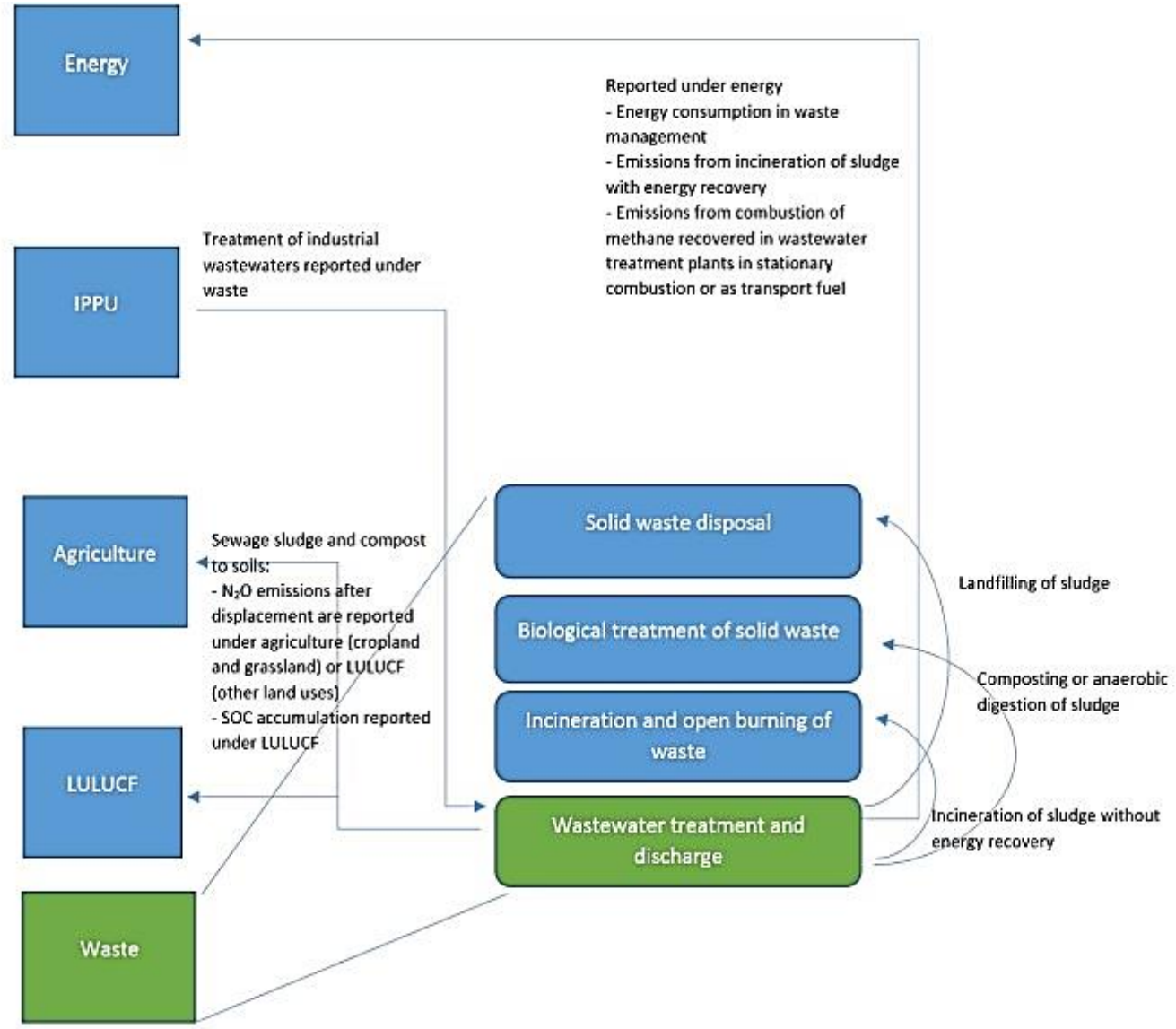
2.10. N_2O emissions: EFs

Table 6.11 in the 2006 IPCC Guidelines (vol. 5, chap. 6) gives default values for parameters in the equations 6.7, 6.8 and 6.9. The default EF for N_2O emissions from domestic wastewater nitrogen effluent is 0.005 (with a range of 0.0005–0.25) kg N_2O-N/kg N.

2.11. Linkage in reporting wastewater treatment and discharge and other categories and sectors

Figure 6.2 provides an overview of the main linkages between wastewater treatment and discharge and other categories and sectors. Understanding these linkages will allow you to understand cross-sectoral issues and the necessary cross-check AD between sectors to make sure that the emissions are not omitted or double counted.

K. Figure 6.2.: Overview of main linkages of the category with other sectors and categories



Both cross-category and cross-sectoral links need to be considered. Cross-category links are links within the waste sector that you need to resolve yourself. Cross-sectoral links are links with other sectors where you may need to consult with the expert responsible the sector in question. Examples of cross-category and cross-sectoral links are included below:

- Sludge is usually pre-treated at the wastewater treatment plants. Pre-treatment might consist of a biological treatment step, like composting or anaerobic digestion. However, statistics on sludge mostly refer to sludge as being removed from the perimeter of a WWTP. Emissions from pre-treatment of sludge are reported under wastewater treatment and discharge (5.D). As a reviewer, you should clarify the nature and scope of the sludge statistics used in the national GHG inventory.
- Sludge might be reused as a fertilizer (and reported under the agriculture or LULUCF sectors), disposed in SWDS (reported in category 5.A) or incinerated (reported in category 5.C). If sludge removal is accounted for in category 5.D, data should be consistent across the sectors and categories. The amount of sludge disposed at SWDS (category 5.A), applied to agricultural land (agriculture sector) or incinerated (category 5.C) need to be consistent with the amount of organic component removed from the TOW as sludge reported in category 5.D. When no sludge removal is accounted for under 5.D, sludge needs not to be included in these categories/sectors to avoid double counting of emissions.
- Where CH_4 is recovered for energy use, the GHG emissions as a result of energy recovery (e.g. exhaust emissions of a gas engine) should be reported under the energy sector. Emissions from flaring are not significant, as the CO_2 emissions are of biogenic origin, and the CH_4 and N_2O emissions are very small so good practice in the waste sector does not require their estimation. However, if a Party wishes to do so, emissions from flaring could be reported under the waste sector.
- Category 5.D only estimates N_2O emissions from surface waters due to the treatment and discharge of wastewaters. There are other additional sources for discharge of nitrogen on surface waters, such as fertilizer use. However, these emissions are not accounted for in the waste sector. For example, indirect N_2O emissions from nitrogen leaching and run-off from agricultural land to surface water are covered in chapter 11, volume 4, of the 2006 IPCC Guidelines.
- Constructed wetlands systems are fully human-made wetlands for wastewater treatment. “Semi-natural treatment wetlands” for wastewater treatment are natural wetland systems that have been modified for this purpose. Chapter 6 of the Wetlands Supplement provides guidance on estimating CH_4 and N_2O emissions from both types of wetlands used for wastewater treatment. The EFs to cover constructed wetlands and semi-natural treatment wetlands are provided in the Wetlands Supplement and cover both domestic and industrial wastewater.
- CH_4 emissions from constructed wetlands for wastewater treatment are reported in the waste sector under the categories of domestic or industrial wastewater. CH_4 emissions from constructed wetlands treating collected run-off from agricultural lands are reported under the category of industrial wastewater.

The use of the Wetlands Supplement is not mandatory for Parties. Parties are only encouraged to estimate emissions from the treatment pathway which are indicated in the Wetlands Supplement. When a Party reports emissions from these wastewater treatments, consult the Wetlands Supplement when reviewing that Party's consistency in reporting. If emissions from constructed wetlands represent a key wastewater treatment pathway it is good practices to apply the Wetlands Supplement.

3. Review approach

3.1. Overview

Topic 4 in lesson 2 gives overall guidance on review approach (prepare – assess – draft) with a reference to this particular category. This lesson focuses on aspects that are specific to wastewater treatment and discharge category. Please refer back to lesson 6 (Review process overview) of the course on general guidance and cross-cutting issues for the review of GHG inventories if you would like a refresher on the approach to conducting a GHG inventory review.

Prepare → Assess → Draft

The choice of methods and assumptions, collection of AD and selection and development of EFs are the main drivers of inventory quality. Hence, as a reviewer, you must assess and ensure that the selection of these data and the reporting, documentation and justification in the inventory submission are in accordance with the 2006 IPCC Guidelines and the requirements of MPGs and other relevant UNFCCC decisions. The specific section of the inventory submission to check for the category along with specific questions you may consider when assessing the submission are provided in the following slides, along with examples of key considerations when reviewing the category. Examples of the review steps, follow-up communication with the Party and inputs for the review reports are provided in the case studies and practical examples.

In addition, there are several common elements to be assessed across sectors/categories when reviewing the quality of the Party's submission (i.e. uncertainty analysis, QA/QC, time-series consistency, recalculations and progress in implementing improvements). Lesson 2 of the current course provides a list of possible checks and examples of assessment of cross-cutting issues.

Box: Prepare

During this stage you obtain and familiarize yourself with all the materials needed to undertake the review. The overall preparation of the review includes the careful study of all documents that are available to inform your assessments, such as:

- Refreshing your knowledge of (i) the UNFCCC reporting and review guidelines; (ii) the 2006 IPCC Guidelines; and (iii) review tools and other supporting materials (see also lesson 2, topic 4);
- Familiarizing yourself with the Party's submission;
- Focusing on the sector under your responsibility:
    - The category-specific information contained in the Party's submission;
    - The issues for the sector in the previous review reports.

Box: Assess

During this stage evaluate whether the recommendations of the previous review are implemented and make an in-depth review of the emission inventory, possibly resulting in the identification of new issues and recommendations related to the implementation of the TACCC principles. Performing the review, you might make use of the review tools as provided by the secretariat. Identify possible capacity-building needs for those Parties who need it in the light of their capacity.

Recommendations in previous TERR

One of the tasks during a review is to evaluate each recommendation in the previous TERR: whether it can be considered resolved or not resolved, or whether the Party is addressing the recommendation. The NID might include a paragraph which summarizes the status of implementation of each recommendation according to the Party. The Party may provide further information during the review. However, for each recommendation, you need to check the relevant sections or chapters in the NID and the relevant CRT to conclude whether the implementation of the recommendation and the changes to the NID and/or CRT are satisfactory to consider the recommendation as resolved.

Your conclusion on the recommendations from the previous TERR are documented in the current review report. Your conclusion has to be specific to all elements of what is recommended, making clear references to the page in the NID or to the specific CRT where improvements are made by the Party. If the issue is not yet resolved, the status should be clearly documented based on the submission and any follow-up information received during the review.

Review tools provided by the secretariat

Before the review, the secretariat will make available user-friendly review tools that provides access to the secretariat's CRT database and therefore all the data submitted by Parties in their CRT. The review tools will allow you to sort or search data according to Party, submission or inventory year, category, GHG and specific data type (e.g. emissions, AD, IEF). The review tools allow you to search for data for a particular Party or for all Parties. They will help you discover outliers in the time series or, when comparing data across countries, allow a quick check of the magnitude of recalculations across submissions for any data point. Review tools give you quick access to data with maximum flexibility. It is often the most efficient way to find the data you are searching for while performing a review.

Box: Draft

This stage is linked to the outputs of the assessment process and drafting questions to the Party for clarification on the submission and preparing the findings on the waste sector to be included in the review report. For guidance on drafting your conclusions and recommendations from a review, refer to lesson 2. With regard to wastewater treatment and discharge, there are no special issues with drafting conclusions and recommendations. Some practical examples in drafting issues for the TERR are included in the case studies and examples included in this lesson.

3.2. CRT 5.D

As a reviewer, you must be familiar with CRT 5.D on wastewater treatment and discharge, where AD, CH_4 recovery and emissions and the resulting IEF are specified.

When reviewing CRT 5.D, consider the following:

- The DC (degradable organic component) to be reported in the CRT 5.D should be BOD for domestic wastewater and sludge removed (S) and COD for industrial wastewater. DC is therefore the same as TOW in the 2006 IPCC Guidelines (vol. 5, chap. 6);
- The CH_4 IEF is calculated on the basis of gross emissions, namely the net emissions reported together with the amount reported for recovery and flaring in order to ensure comparability among Parties reporting and not reporting recovery;
- CRT 5.D askes for separate reporting of N_2O emissions from plants (direct emissions) and effluent (indirect emissions). If the emissions are reported together, make sure that the notation key "IE" is used, as applicable;
- Emissions from energy recovery should be included in the energy sector and provided in the table only for information purposes with their allocation explained;
- When a Party reports the notation keys "NE" or "IE", this should be explained in the NID and in CRT 9;
- The table provides additional information that may be very useful in the review, e.g. the population number may be used to calculate the emissions per capita to compare with neighbouring countries; the protein consumption used may be compared with the FAO data. Check whether the rest of the parameters are in agreement with the values in the 2006 IPCC Guidelines;
- The value T_{PLANT} shows the share of the population whose wastewater is treated in large WWTPs with nitrogen removal.
- When T_{PLANT} is low, the IEF for N_2O should be about the product of $EF_{EFFLUENT}$ * 44/28 = 0.005*44/28= 0.008 (see equation 6.7, 2006 IPCC Guidelines, vol. 5, chap. 6). When T_{PLANT} is high, the IEF will be substantially lower.

3.3. Key considerations when assessing wastewater treatment and discharge

The GHG inventory should be prepared and reported in accordance with the MPGs, following the good practice provided in the 2006 IPCC Guidelines. The fundamental principles for developing a GHG inventory, as reaffirmed by the MPGs, are transparency, accuracy, completeness, consistency and comparability (the TACCC principles. You assess the inventory for its compliance with these principles. Possible questions related to the implementation of each of the TACCC principles in the inventory for wastewater treatment and discharge can be accessed via specifics question as summarized below.

- Is the inventory sufficiently transparent?
- Is the inventory complete?
- Is the inventory consistent?
- Is the inventory comparable?
- Is the inventory accurate?

When the time comes to participate in an actual GHG inventory review, study any further review materials provided to you by the secretariat suggesting further possible checks you may want to use.

The examples provided in this lesson are not intended to provide an exclusive list of possible questions, but a starting point to stimulate your thinking. You may add or modify the questions as appropriate while conducting a review.

Box: Is the methodology transparent?

On transparency you might ask yourself the following questions:

- Is all the information required to understand the methodology and assumptions available in either the NID or the documents referred to in the NID?
- Is the distribution of wastewater across discharge pathways clearly described and justified?
- Has the Party documented the methodology to quantify emissions, AD and EFs?
- When country-specific methods and/or EFs are used, has the Party justified their use?
- When sludge removal is considered, does S refer to 'TOW, removed as sludge' and not 'sludge (dry mass)'?
- When the notation keys "IE" or "NE" are used, are they explained in CRT 9?
- Is the information in the NID consistent with the information in the CRT?

Box: Is the inventory complete?

- Is the inventory of domestic wastewater complete? Does the inventory include emissions from all relevant treatment and discharge pathways, including emissions from untreated wastewater and uncollected wastewater (latrines and septic tanks)?
- Is the inventory of industrial wastewater complete? Has the Party identified the major industrial sectors with large potential for CH_4 emission from wastewater and estimated emissions for them? The 2006 IPCC Guidelines (vol. 5, chap. 6, p.6.22) indicate that usually three or four industrial sectors are key.

Box: Is the inventory consistent?

- Did the Party perform any recalculations and, if so, are they consistently applied across the entire time series?
- Are there any discontinuities in emissions or emission trends and, if so, are they properly explained in the NID?
- Has the Party applied the same methods and sources of AD and EFs over the time series?
- Are changes in the distribution over treatment and discharge pathways explained in the NID? Do the changes reflect the implementation of national policies?
- Is the coverage of industries (the three to four industrial sectors considered) consistent across the entire time series?

Box: Is the inventory comparable?

- When information on sludge removal is available and reported in category 5.D, does the NID explain where the sludge removed is subsequently treated, used or disposed (agriculture, SWDS or incinerated)? Are emissions from the treatment and disposal of sludge included in the emission estimate of these categories/sectors? Has the Party ensured that no omission or double counting occurs?
- If recovered CH_4 is used for energy, are the emissions from combustion correctly included under the energy sector? Has the Party provided a reference to the category in the energy sector where the emissions are included?

Is the inventory accurate?

Is the choice of methodology accurate?

- Is wastewater treatment and discharge a key category? This should be clearly mentioned in the relevant chapters in the NID and also specified in CRT 7.
- If wastewater treatment and discharge is a key category, do the methodologies comply with the guidance in the decision trees in the 2006 IPCC Guidelines (vol. 5, chap. 6, figures 6.2 and 6.3)? If it is a key category but the Party has made a methodological choice that is not in line with the corresponding decision tree (e.g. using tier 2 or higher methodologies and country-specific values for B_O and MCF for key pathways), did the Party clearly document in the NID why it made this choice?
- You may determine with developing countries if there is a capacity-building need. If a recommended method is not used, has the Party explained and justified its choice of an alternative method? If a recommended method is not used owing to lack of data or resources, has the Party adequately explained the national circumstances in the NID? Does the Party have plans to improve the situation?
- When a Party has predominantly advanced centralized WWTPs with controlled nitrification and denitrification steps, did the Party quantify its direct N_2O emissions using guidance from box 6.1 (2006 IPCC Guidelines, vol. 5, chap. 6)?

Are AD accurate?

- Some Parties have measured amounts of TOW available for all WWTPs. If the inventory is based on measured amounts of TOW in wastewater, are they based on influent measurements, not

effluent measurements? (Note that when industrial WWTPs report their environmental impact to local legislators, they are likely to report BOD/COD in the effluent because this is the information that is most valuable for the purposes of a legislator).

- If the Party reports CH_4 recovery/flaring, is the estimate well documented?
- If the Party includes sludge removal in its estimate of the emissions from wastewater, is it based on national sludge removal data and are the data consistently used across the sector?

The removal of sludge from well-managed WWTPs might not affect total emissions from 5.D. When MCF is 0, the product of MCF and (TOW-S) is 0 as well, independent of the value of S.

- When a Party calculates emissions from advanced centralized WWTPs using the 2006 IPCC Guidelines (vol. 5, chap. 6, box 6.1), does the Party correct N_{EFF} for the amount of nitrogen associated with N_{WWT} (as indicated in the note below Box 6.1)?
- When wastewater is treated predominantly in WWTPs, does the Party in the NID explain why WWTPs are assumed to be well managed or not well managed, and based on what definition of "well managed" was this categorization done?

Although MCF depends on the management of the aerobic treatment plants (e.g. MCF=0 for well-managed plants), the 2006 IPCC Guidelines (vol. 5, chap. 6) do not provide a clear definition of a well-managed/not well-management WWTP. Therefore, the reporting Party has to provide its own definitions of well-managed and not well managed WWTPs.

Also note that the 2006 IPCC Guidelines require an estimate to be accurate (neither an over- nor underestimate, as far as can be judged). This means that all assumptions used in the estimates should be well documented and justified in the NID.

- Are all correction factors applied correctly when calculating emissions? Relevant add-on factors you need to check are:
    - The correction factor for additional industrial BOD discharged into sewers (I) in the calculation of the total amount of TOW (2006 IPCC Guidelines, vol. 5, chap. 6, equation 6.3). This factor increases BOD by 25 per cent for the fraction of the population whose wastewater is collected before treatment in WWTP. BOD for the fraction of the population that uses latrines or septic tanks should not be corrected;
    - The $F_{IND-COM}$ (2006 IPCC Guidelines, vol. 5, chap. 6, equation 6.8) corrects for the amount of nitrogen discharged into sewers by increasing it by 25 per cent, similarly to (I), as above which corrects the amount of BOD;
    - The factor $F_{NON-CON}$ for non-consumed protein added to wastewater corrects the amount of nitrogen in food wastes flushed away with the wastewater (2006 IPCC Guidelines, vol. 5, chap. 6, equation 6.8). According to the 2006 IPCC Guidelines, the factor $F_{NON-COM}$ is 1.4 in developed countries using garbage disposal. The common understanding of this is that in both developed and developing countries where the kitchen sink is not often used for garbage disposal (e.g. no large-scale implementation of electric sink grinders to facilitate disposal of green wastes), $F_{NON-COM}$ should be 1.1.

3.4. Case studies

The examples below, based on real submissions by Parties, show how the review approach may be applied when reviewing the category. For each question, select and/or draft your answer. Once you have submitted your answer, you will be able to see the suggested answer.

3.5. Case study 1 (sludge removal)

In the previous TERR, the following recommendation was made to the Party.

The TERT recommends that the Party clarify the way removal of sludge is taken into account in the estimation of emissions from wastewater treatment and discharge and provide information on the allocation of the emissions from treatment and disposal of sludge in other categories and sectors in the inventory.

In the NID section on wastewater (p.7.32), the Party reported the following:

In total 680,000 m^3 of sludge was removed from WWTPs in 2020. Assuming a specific weight of sludge of 1 t/m^3 and a moisture content of sludge of 10 per cent, this sludge amounts to 68 kt sludge (dry mass). In the calculation of CH_4 emissions (using equation 6.1 in the 2006 IPCC Guidelines (vol. 5, chap. 6)), S is assumed to be 68 kt.

The same value of 68 kt is also reported in the CRT 5.D.

In the NID, no additional information was provided on sludge treatment and disposal in chapters 5 (agriculture), 7.3 (solid waste disposal), 7.4 (biological treatment of solid waste) or 7.5 (incineration and open burning).

Question 1.1: Following up on previous recommendation

Assess the status of implementation of the previous recommendation in the NID and draft a rationale for the TERR:

A. Not resolved
B. Addressing
C. Resolved

Please provide your rationale in accordance with your choice of A, B or C above here:

Question 1.2: Assessing reported information (completeness)

When sludge removal is accounted for in 5.D (S>0), what implications should this have for other sectors or other categories in the waste sector?

A. To avoid double counting, sludge treatment and disposal should not be included in other sectors and categories.
B. To ensure completeness, sludge treatment and disposal should be included in other sectors and categories.
C. Neither of the above.

Question 1.3: Assessing reported information (accuracy)

According to p 7.32 in the NID (see quote in question 1.1), the total amount of sludge was estimated and reported in CRT 5.D as 68 kt sludge (dry mass). In the calculation of CH_4 emissions (using equation 6.1 in the 2006 IPCC Guidelines (vol. 5, chap. 6)), this value was used as a value for S. Is this correction in line with the 2006 IPCC Guidelines

A. Yes
B. No

Question 1.4: Drafting a question to the Party

Draft a question to the Party on its definition of S.

Please submit your question to the Party here:

Question 1.5: Drafting text for the TERR

In response to your question, the Party proposes a new method to calculate TOW removed as sludge. Again, the amount of dry sludge is calculated, assuming a density equal to 1 t/m^3 and a 75 per cent moisture content. TOW removed as sludge is calculated, assuming 50 per cent DOC in the dry sludge (2006 IPCC Guidelines, vol. 5, chap. 2.3.2) , 50 per cent decomposable carbon in the DOC (assumed to be equal to DOC_f in waste upon disposal in a SWDS from the 2006 IPCC Guidelines (vol. 5, chap. 3, p.3.13)) and an oxygen consumption of 32 g O_2 per 12 g carbon, the total amount of TOW removed as sludge is calculated as 50%*50%*32/12*170 kt=42.5 kt TOW removed as sludge.

Assess the response and draft a conclusion and, if needed, a recommendation for the TERR.

Please submit your draft here:

3.6. Case study 2 (discharge pathways)

In the NID, a Party from Africa quantifies emissions from category 5.D.1, as follows:

The distribution of waste water over the various treatment and discharge pathways is calculated, assuming available statistics on urbanization (rural, urban low and high-income) and assuming the distribution over treatment and discharge pathways for each income group, as listed for Nigeria in table 6.5 in the 2006 IPCC Guidelines (vol. 5, chap. 6). The information is listed in table 7.18 of the NID (as below). For each treatment and discharge pathway, the default MCF is assumed from the 2006 IPCC Guidelines (vol. 5, chap. 6, table 6.3).

Table 7.18: Urbanization (U_i) and distribution of wastewater over treatment and discharge pathways ($T_{i,j}$).

Urbanization (U_i)	fraction population	Septic tanks	Latrines	Other	Sewer	None
rural	16%	2%	28%	4%	10%	56%
urban high income	25%	32%	31%	0%	37%	0%
urban-low income	59%	17%	24%	5%	34%	20%

Question 2.1: Assessing provided information (transparency)

Does this information suffice to get a full understanding of the quantification of domestic wastewater by the Party? Is it clear what values of MCF are used for each fraction of wastewater treatment and discharge?

A. Yes
B. No

Question 2.2: Drafting a question to the Party

Draft a question to the Party to clarify what MCFs are used in the estimates.

Please submit your question here:

Question 2.3: Assessing the Party's response

In response to your question, the Party indicates that:

- All latrines are considered wet climate latrines with an MCF=0.7;
- Others are assumed to be bucket latrines/nightsoil collection systems and vault latrines. The MCF for this wastewater is assumed to be the same as for latrines;
- All rural collected wastewater is assumed to be discharged into rivers without treatment;
- All high-income urban wastewater is assumed to be treated in well-managed aerobic wastewater treatment plants;
- All low-income urban wastewater is assumed to remain untreated in stagnant sewers;
- Wastewater pathways indicated as 'none' are direct discharge from household to rivers or to soil. In rural areas a 50:50 distribution is assumed between both. In urban areas, none is assumed to be discharged in rives. Wastewater added to soil is assumed to have negligible emissions owing to the close proximity of wastewater with air.

The assumptions are listed in the table below:

Urbanization (U_i)	fraction population	Septic tanks	Latrines	Other	Sewer			None	
			Wet climate	'latrines'	untreated river	stagnant sewers	to WWTP	to rivers	to soil
MCF		0.5	0.7	0.7	0.1	0.7	0	0.1	0
rural	16%	2%	28%	4%	10%			28%	28%
urban high income	25%	32%	31%	0%			37%	0%	
urban-low income	59%	17%	24%	5%		34%		10%	10%

Based on the information received, calculate the total share of the population whose wastewater is treated in septic tanks.

A. 17.0 per cent
B. 18.3 per cent
C. 33.3 per cent
D. 51.0 per cent

3.7. Answers to case study exercises

Question 1.1
The correct answer is B. The Party provided information in the NID on sludge removal in estimating emissions from category 5.D, but provides no explanation of how the emissions from sludge are accounted for and allocated in other parts of the inventory.

A possible text for the TERR might read:

Addressing. The Party provided in the NID (p.7.32) information on the amount of sludge removed from WWTPs (680.000 m^3) and the assumptions used to estimate this amount of sludge. However, it did not provide information on how emissions from sludge removed from category 5.D are accounted for and allocated in other parts of the inventory.

Question 1.2
The correct answer is B. When removal of TOW as sludge is accounted for in 5.D, emissions from sludge are not covered by equation 6.1. To ensure completeness of emissions, the Party should include the amount of sludge removed from category 5.D under the sectors where this sludge is treated/disposed, it means, in their AD for calculating emissions from other categories in the waste sector.

In addition, you need to consult with the agriculture expert on the TERT to evaluate whether use of sludge as a fertilizer is included in the agriculture inventory.

Question 1.3
The correct answer is B. The approach is not consistent with the method in equation 6.1. S in equation 6.1 is defined as “TOW removed as sludge”. This is not the same as sludge removed. The 2006 IPCC Guidelines do not provide a method to back-calculate S from the amount of sludge removed. In order to use S, the Party should correct its estimate or may assume no sludge removal in the calculation (default assumption for tier 1).

Question 1.4
A possible question to the Party might read:

In the NID (p.7.32), the Partyprovided information on sludge removal. In total, 68 kt sludge (dry mass) was removed in 2020. This amount was subsequently used as S in the calculation of CH_4 emissions using equation 6.1 in the 2006 IPCC Guidelines (vol. 5, chap. 6).

The TERT notes that according to the 2006 IPCC Guidelines, S in equation 6.1 is defined as TOW removed as sludge. This is not the same as sludge removed (dry mass). Can you explain why you assume TOW removed as sludge to be the same as sludge removed (dry mass)?

Question 1.5

A possible text in the TERR might read:

In the NID (p.7.32), the Party provided information on the amount of sludge removed from WWTPs. In total, 68 kt sludge (dry mass) was removed in 2020. This amount was subsequently used as S in the calculation of CH_4 emissions under category 5.D, using equation 6.1 in the 2006 IPCC Guidelines (vol. 5, chap. 6). The TERT noted that according to the 2006 IPCC Guidelines, S in equation 6.1 is defined as TOW removed as sludge and not as dry mass of sludge removed.

During the review, the Party proposed a new method to calculate TOW removed as sludge, assuming 50 per cent DOC in the dry sludge (2006 IPCC Guidelines, vol. 5, chap.2.3.2), 50 per cent decomposable carbon in the DOC (assumed to be equal to DOC_f in waste upon disposal in a SWDS from the 2006 IPCC Guidelines (vol. 5., chap. 3, p.3.13)) and an oxygen consumption of 32 g O_2 per 12 g carbon. Therefore, the total amount of TOW removed as sludge is calculated as 50%*50%*32/12*170 kt=42.5 kt TOW removed as sludge. The TERT agreed with this new method to calculate TOW, removed as sludge.

The TERT recommends that the Party recalculate CH_4 emissions for the entire time series under category 5.D by reflecting the correct amount of S (based on TOW removed as sludge). The TERT also recommend that the Party explain in the NID the method used for the calculation of TOW removed as sludge

Question 2.1

The correct answer is B. The Party provides the information that used MCF values from the 2006 IPCC Guidelines (vol. 5, chap. 6, table 6.3). However, the exact MCFs are not provided. In order to fully understand how, for example, collected wastewater is treated and what MCFs should be used, additional information is required to identify the pathways and MCFs in table 6.3 (2006 IPCC Guidelines, vol. 5, chap. 6). For example, table 7.18 in the NID specifies that 37 per cent of wastewater from the high-income urban population is collected in sewers. However, it remains unclear how this sewered wastewater is treated and whether sewers are open or closed. It is therefore unclear which MCF is selected from table 6.3. MCFs also differ for wastewater treated in latrines depending on the type of latrine as demonstrated in table 6.3. The Party could solve this transparency issue by adding the MCFs in table 7.18 for each treatment pathway.

Question 2.2
A possible question might read:

The TERT noted the information on the distribution of wastewater over treatment and discharge pathways provided in the NID and in table 7.18. However, the NID does not include the MCF values used in the estimates, only a reference to table 6.3 in the 2006 IPCC Guidelines (vol. 5, chap. 6). The TERT would like some additional clarifications to fully understand the emission estimates from category 5.D.1, namely:

C. What types of latrines are used in the country based on the classification in table 6.3 in the 2006 IPCC Guidelines (vol. 5, chap. 6)?
D. What pathways are covered under 'others' reported in table 7.18 and what MCFs are used for them?
E. How is wastewater collected by sewers, treated and discharged (from the options in 2006 IPCC Guidelines (vol. 5, chap. 6), e.g. discharged into open waters without treatment, treated in a wastewater treatment plant, etc.)?
F. How is the wastewater under column 'none' in table 7.18 treated in the emission estimates, if at all?

Question 2.3
The correct answer is B.

- 2 per cent of the rural population uses septic tanks. 16 per cent of the total population lives in rural areas. So, 2%*16% of the total population lives in rural areas and uses septic tanks.
- 25 per cent of the total population lives in high-income urban areas. 32 per cent of the high-income urban population uses septic tanks. So, 25%*32% of the total population living in high-income urban areas uses septic tanks.
- 59 per cent of the total population lives in low-income urban areas. 17 per cent of the low-income urban population uses septic tanks. So, 59%*17% of the total population living in low-income urban areas uses septic tanks.
- Total share of the population using septic tanks is 0.02*0.16+0.25*0.32+0.59*0.17=0.183 or 18.3%

4. Practical exercises

In the following section, some additional exercises are provided to practice your skills as a review expert.

4.1. Exercise 1: Emissions from domestic wastewater

See Appendix Lesson 6 -1 for a section of NID from a Party from Central Asia. You may download the document here: https://unfccc.int/resource/tet/bw/bw6-01_app_6.1.pdf

Question 1.1:

Based on the information in the NID (section 7.5.2.2, p. 342) for domestic wastewater, do you think that the assumptions made for BOD and the use of the correction factor 'I' are in line with the 2006 IPCC Guidelines?

A. Yes
B. No

Question 1.2:

When reading the information provided in the NID, do you see a potential issue with the distribution of wastewater over treatment and discharge pathways for domestic wastewater?

A. Yes
B. No

Question 1.3:

What question would you ask the Party on the transparency issues detected in the previous exercise? Please submit your question here:

Question 1.4

In response to your question regarding the lack of clarity on how the 26.8 per cent of households that lacks wastewater disposal points are considered in the inventory, the Party indicates that this 26.8 per cent of the population has a more nomadic lifestyle and discharges wastewater into nature without further facilities. For this type of people, table 6.3 in the 2006 IPCC Guidelines (vol. 5, chap. 6) does not provide guidance. The Party assumes that wastewater produced will most likely seep into the soil, while solid materials in the wastewater will degrade in the soil under aerobic conditions with no CH_4 emissions.

What is your assessment of the response of the Party on wastewater from nomadic people? What recommendation, if any, might you include in the TERR?

4.2. Exercise 2: N_2O emissions from domestic wastewater

A Party from South-East Asia describes in the NID its quantification of indirect N_2O emissions from domestic wastewater after disposal of effluent into waterways, lakes or sea, as follows:

N_2O emissions from wastewater treatment effluent have been calculated using the tier 1 methodology proposed by the 2006 IPCC Guidelines.

The population estimate was taken from Statistical Yearbooks and Statistical First Releases. Annual per capita protein intake value is calculated from annual nutrient supply and an estimate of protein consumption, as a fraction of protein supply (FPC) of 96 per cent (see 2019 Refinement to the 2006 IPCC Guidelines, vol. 5, chap. 6, table 6.10A). Default values of factors and parameters proposed by the 2006 IPCC Guidelines (vol. 5, table 6.11) were used for emission calculation.

- *Population size = 18,567,829;*
- *Per capita protein supply = 68.63 g per capita per day;*
- *FPC = 96 per cent (see 2019 Refinement to the 2006 IPCC Guidelines);*
- *EF ($EF_{EFFLUENT}$) = 0.005 kg N_2O-N/kg - N;*
- *Fraction of nitrogen in protein (F_{NPR}) = 0.16 kg N/kg protein;*
- *Factor for non-consumed protein added to the wastewater ($F_{NON-CON}$) = 1.1;*
- *Factor for industrial and commercial co-discharged protein into the sewer system ($F_{IND-COM}$) = 1.25;*
- *Nitrogen removed with sludge (N_{SLUDGE}) = 0 kg N/year.*

The resulting N_2O emissions are = 0.77 kt per year.

Reproduce N_2O emissions from the data provided. Is the estimate correct?

A. Yes, the estimate of 0.77 kt N_2O per year is correct.
B. No, the estimate of N_2O emissions is incorrect. Emissions are 0.49 kt N_2O per year.
C. No, the estimate of N_2O emissions is incorrect. Emissions are 98.24 kt N_2O per year.
D. No, the estimate of N_2O emissions is incorrect. Emissions are 491.21 kt N_2O per year.

4.3. Answers to practical exercises

Exercise 1:

Question 1.1
The correct answer is B. The Party mentioned in last paragraph of page 342 that "the IPCC default correction factor for additional industrial BOD discharged into sewers was used for emission calculations" and the value of 'I' mentioned of 1.25 is in agreement with the default in the 2006 IPCC Guidelines (see p. 6.14 in chap 6, vol 5).

However, the value is applied to all wastewater from the urban high-income and urban low-income population and not to collected wastewater. The factor "I" should not be applied to the urban population that treats wastewater in septic tanks or latrines. For rural areas I is assumed to be 1, however, a small part of rural wastewater is collected and treated in a WWTP, for this fraction I should be also 1.25. For BOD values, the Party correctly apply the default from table 6.4 (vol 5, chap 6 of the 2006 IPCC Guidelines) for Asian countries

Question 1.2
The correct answer is A. The text in the second paragraph and table 7.13 refer to the distribution of wastewater over its treatment and discharge pathways. However, the information in the second paragraph seems to be inconsistent with that in table 7.13. For example, the second paragraph indicates that 25.19 per cent of the population are connected to WWTP. Table 7-13 indicates 24.7 per cent (urban high-income population, connected to WWTP) + 8.2 per cent (urban low-income population, connected to WWTP) + 1.45 per cent (rural population, connected to WWTP) = 34.35 per cent of the total population is connected to WWTP.

In addition, it is mentioned that 26.8 per cent of the population lacks wastewater disposal points. It is unclear how this group of people is considered in table 7.13.

Question 1.3
A possible question might read as follows:

In the NID (second paragraph in p. 342 and table 7.13 describe the distribution of wastewater over its treatment and discharge pathways. The TERT noted some inconsistencies in the reported information:

- Paragraph 2 mentions that 25.19 per cent of the population is connected to WWTP. Table 7-13 indicates that 24.7 per cent (urban high-income population connected to WWTP) + 8.2 per cent (urban low-income population connected to WWTP) + 1.45 per cent (rural population connected to WWTP) = 34.35 per cent of the total population is connected to WWTP.
- Paragraph 2 also mentions that 26.8 per cent of the population lacks wastewater disposal points. It is unclear how this group of people is considered in table 7.13.

Could the Party clarify how data in table 7-13 (rural, high-income urban and low-income urban) are used to present the overall percentages in the text in paragraph 2, page 342, in the NID? Could the

Party also clarify whether the emissions calculated for the 26.8 per cent of households that lack disposal points are considered in the NID and also the assumption used for these wastewater flows?

Question 1.4

You might decide to accept this explanation as reasonable based on your experience and judgment and the Party's national circumstances but include a transparency recommendation in the review report. This finding and recommendation might read:

The Party described in the NID (section 7.5.2.2, p.342) the distribution of wastewater treatment and discharge pathways and includes the fact that 26.8% of the population lacks wastewater disposal points. It was not clear in the NID whether the wastewater generated by this part of the population was included in the inventory (i.e. in table 7.13). During the review, the Party explained that 26.8% of the population has a more nomadic lifestyle and discharges wastewater into nature without further facilities. The Party assumes that wastewater produced will most likely seep into the soil, while solid materials in the wastewater will degrade on the soil under aerobic conditions with no CH_4 emissions. The TERT agrees with the Party's explanation that this wastewater will degrade under aerobic conditions and will not result in CH_4 emissions.

The TERT recommends that the Party improve the transparency of the NID by explaining clearly that 26.8% of households lack wastewater disposal points because this share of population has a more nomadic lifestyle and discharges wastewater into nature without further facilities and therefore it is assumed that wastewater produced will most likely seep into the soil, while solid materials in the wastewater will degrade on the soil under aerobic conditions with no CH4 emissions. The TERT also recommend that the Party include the share of the nomadic population in tables 7-12 and 7-13 and mention in table 7-14 that the MCF for wastewater disposal without wastewater disposal points is assumed to be 0.

Exercise 2:

The correct answer is A. The estimate of 0.77 kt N_2O per year is correct.

As annual per capita protein consumption in table 6.11 in the 2006 IPCC Guidelines (vol. 5, chap. 6) is indicated to be coutry-specific, falls a Party does not have this data (and in the absence of default value in the 2006 Guidelines), it can use updated data from the 2019 refinements to calculate it. In this case the Party calculated its annual protein consumption using default factor from table 6.10A (FPC = 96 per cent) and applying equation 6.10A from the 2019 refinements.

Annual per capita protein consumption (Protein) = Daily protein supply * days per year* fraction of protein supply (FPC)

= 68.63 g/day *365 days/year *96% = 24.05 kg per capita per year

Applying equation 6.8 of the 2006 IPCC Guidelines (vol. 5 chap. 6) and the default values indicated by the Party in its NID:

$$N_{EFFLUENT} = P * Protein * F_{NPR} * F_{NON-CON} * F_{IND-COM} - N_{SLUDGE}$$

= 18,567,829 people * 24.05 kg/cap/year * 0.16 * 1.1 * 1.25 - 0 = 98.24 kt per year

N_2O emissions are calculated using equation 6.7 from the 2006 IPCC Guidelines (vol. 5, chap. 6):

$$\text{Emissions} = N_{EFFLUENT} * EF_{EFFLUENT} * 44/28 =$$

98.24 *0.005*44/28 = 0.77 kt per year.

5. Self-check quiz

The questions set out below will allow you to check your knowledge of the sector. Please be aware that you can use the information in the 2006 IPCC Guidelines when answering these questions.

Question 1

For domestic wastewater, only the part of the population with access to wastewater treatment infrastructure needs to be taken into account.

A. Always true
B. Sometimes true, but not always
C. False

Question 2

When larger shares of the population get connected to a sewer system and simultaneously the management of WWTPs improves owing to improvements in domestic wastewater treatment policies, you can expect a gradual decrease in per capita emissions of CH_4 from the category.

A. Always true
B. Sometimes true, but not always
C. False

Question 3

When no further information is available on the quality of a WWTP, a Party should assume as a conservative assumption that all WWTPs are not well managed in the estimate of CH_4 emissions.

A. Always true
B. Sometimes true, but not always
C. False

Question 4

When all major industrial installations collect and treat wastewater separately, the correction factor 'I' for additional industrial BOD discharged into sewers to calculate emissions in domestic wastewater can be assumed to be 1.

A. Always true
B. Sometimes true, but not always
C. False

Question 5

A Party has accurately measured data on TOW in its WWTP. The total amount of BOD entering the WWTP is 140 kt BOD per year. The amount of sludge removed is 50 kt (dry mass) per year. The Party can calculate its emissions, based on (TOW-S) as AD, being 140 - 50=90 kt.

A. Always true
B. Sometimes true, but not always
C. False

Question 6

When a Party discharges part of its wastewater into open surface waters (e.g. rivers or lakes), open waters can become a source of CH_4. If this happens, a country-specific value for the MCF needs to be developed.

A. Always true
B. Sometimes true, but not always
C. False

Question 7

When wastewater treated in advanced WWTPs with biological nitrogen removal (nitrification and denitrification) is included in the inventory, direct N_2O emissions will increase and indirect N_2O emissions will decrease.

A. Always true
B. Sometimes true, but not always
C. False

5.1. Answers to self-check quiz

Question 1

The correct answer is C. The entire population needs to be taken into account. Where, for certain disposal pathways (direct disposal of wastewater on surface), no default MCF is defined and CH_4 emissions are assumed to be negligible, this should be specified in the NID. AD need to be given, even in cases where the MCF is assumed to be zero and the wastewater pathway does not result in emissions. This facilitates a check on completeness.

Question 2

The correct answer is A. The population which is not connected to a sewer system will either discharge wastewater directly into open waters or treat its wastewater in latrines or septic tanks. All these treatment options have a higher MCF than the treatment of collected wastewater in well-managed plants. When these high-MCF treatment routes decreases and wastewater is treated in well management WWTP (less-MCF route), per capita emissions will reduce.

Question 3

The correct answer is C. The inventory needs to be accurate, resulting in neither over- nor underestimation of emissions. Any assumption used should be as accurate as possible. Where statistical data are not available, an estimate of the share of WWTPs that are well managed can be made based on expert judgment. First estimates can be improved by conducting follow-up surveys.

Question 4

The correct answer is C. For major industries installations that collect and treat wastewater separately, normally there are statistics and data to estimate their emissions under category 5.D.2 (industrial waste). When there is no data available and industrial wastewater is released into domestic sewer systems it is necessary to apply the correction factor 'I'. The correction factor 'I' does not only apply to major industries, but also to smaller industrial activities and establishments (e.g. restaurants, butchers, grocery stores). Wastewater from such activities and establishments will be discharged into sewers along with wastewater from households. Therefore, the 'I' value of 1.25 is still applicable.

Question 5

The correct answer is C. 'S' in equation 6.1 refers to the amount of TOW removed as sludge, not to the amount of sludge itself. In order to correct for sludge, the Party has to make an assumption on the amount of BOD removed with a tonne of sludge (dry mass).

Question 6

The correct answer is B. Table 6.3 (2006 IPCC Guidelines, vol. 5, chap. 6) provides a default MCF for wastewater discharged into open waters. Therefore, in principle, no country-specific MCF is required to quantify emissions. However, when wastewater treatment and discharge is a key category, the decision tree in figure 6.2 (2006 IPCC Guidelines, vol. 5, chap. 6) indicates that the Party should develop a

country-specific B_O and MCF for the key pathways. When discharge into open waters is considered a key pathway, a country-specific MCF for direct discharge into open waters may be needed to reflect the Party's national circumstances.

Question 7

The correct answer is A: N_2O is generated due to nitrification and denitrification. At advanced WWTPs, these processes occur at the WWTP itself. As a result, the emissions from the WWTP itself (direct emissions) increase. When nitrification and denitrification occur, the amount of nitrogen discharged with the effluent into open waters decreases and therefore indirect N_2O emissions (from spontaneous nitrification and denitrification in open waters) also decrease.

6. Key points to remember

- Chapter 6, volume 5, of the 2006 IPCC Guidelines provides the methodology to estimate CH_4 and N_2O emissions from wastewater treatment and discharge.
- In the Party's submission, the major elements to check for the category are included in chapter 7.5 of the NID (if the outline for the NID is followed by the Party) and CRT 5.D, along with all cross-cutting sections of the NID and cross-cutting and summary tables of CRTs.
- For each subcategory estimated, assess whether the Party is in compliance with the TACCC principles.
- The category should also be assessed focusing on its interlinkages with other sectors (e.g. energy and agriculture) and other categories in the waste sector (e.g. solid waste disposal or incineration). The reviewer should check emission allocation and any possible omission or double counting of emissions.
- For CH_4 emissions from domestic wastewater production, a distribution of wastewater over all discharge and treatment pathways needs to be presented in the NID, even if no MCF is defined in the 2006 IPCC Guidelines, or when no emissions are expected.
- Treatment of industrial wastewater refers to wastewater treated on-site. Experience has shown that usually three or four industrial sectors are key. Smaller industries might discharge wastewater via the communal sewer system (these emissions are included in domestic wastewater and are covered by the correction factor 'I' in equation 6.3) (2006 IPCC Guidelines, vol. 5, chap. 6).
- The MCF values for aerobic plants depend on their management. However, the 2006 IPCC Guidelines do not provide a clear definition of well-managed and not well managed WWTPs. The decision on well-managed/not well managed aerobic WWTP used in the estimates should be well documented and justified in the NID to ensure accuracy of the estimates.
- Where statistics on sludge removal are available, they will refer to the amount of sludge (in dry mass) removed. The parameter 'S' in equation 6.1 refers to the amount of TOW (BOD) removed as sludge. When a Party corrects TOW for sludge removal, it needs to explain how it calculates 'S' from statistics on the amount of sludge removed.
- When TOW is not corrected for sludge, emissions from the treatment, disposal and use of this sludge are implicitly included in the calculation of emissions from wastewater treatment and discharge (category 5.D). This sludge should therefore not be included in the estimates of emissions from solid waste disposal (category 5.A), incineration of waste (category 5.C) or use of sludge as fertilizer in the agriculture or LULUCF sectors.

When the majority of wastewater is treated in advanced WWTPs, direct N_2O emissions need to be calculated using box 6.1. The amount of nitrogen associated with direct emissions needs to be subtracted from the effluent. As a result, indirect N_2O emissions are reduced.