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Annex 1 Relating 2019 Refinement to the 2006 IPCC Guidelines

This annex provides a road map for relating sections, equations, tables, figures and boxes in the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Type of Refinement: U – Update, NG – New Guidance, NR – No Refinement, R – Removed

CHAPTER 2

This chapter presents an update of waste generation, composition and management data chapter of the *2006 IPCC Guidelines*. These refinements provide updated default waste generation and treatment data for the year 2010 using UN Classification at country and regional level. The updated waste composition in line with the *2006 IPCC Guidelines* are presented with the additional components of garden waste and nappies. Definition of sludge and estimation of degradable organic carbon (DOC) values are clarified. Default values of carbon content, nitrogen content and DOC of domestic and industrial sludge are presented. Guidance on DOC of sludge is also provided. New Annex 2A.2 with default values of waste composition by country and regional average is provided.

Sections

- Additional introduction has been provided in the introduction part to explain the refinement of this chapter.
- Updated regional default values of waste generation rate and their treatment presented in Section 2.2.1. Guidance on estimation of waste generation rate is clarified.
- Section 2.3.1 provides updated waste composition (in percentage) data. Guidance for countries without data for nappies and garden and yard waste is provided.
- Updated definition of sludge and default values of carbon content, nitrogen content and DOC of sludge from specific industry and domestic sludge and their uncertainties are provided. Clarification on domestic sludge in terms of treated sludge and untreated sludge including their default values are presented.
- New Annex 2A.2 has been added to provide waste composition default values by country and regional averages.

Sections

Section Title	Type of Refinement	2006 Guidelines Section Number	2019 Refinement Section Number
Introduction	U	2.1	2.1
Municipal Solid Waste (MSW): Default data	U	2.2.1	2.2.1
Municipal Solid Waste (MSW): Country specific data	NR	2.2.1	2.2.1
Municipal Solid Waste (MSW): Data from waste stream analysis	NR	2.2.1	2.2.1
Municipal Solid Waste (MSW)	U	2.3.1	2.3.1
Sludge	U/NG	2.3.2	2.3.2
Annex 2A.1 (Updated) MSW Generation and Management Data – by country and regional averages	U	Annex 2A.1	Annex 2A.1
Annex 2A.2 (New) Waste Composition – by country and regional averages	NG	-	Annex 2A.2

Tables

- Table 2.1 has been updated to present waste generation rate and treatment data by regional defaults to the most comparative year of 2010. New column of “Fraction of MSW open dumped” is added in the table to reflect available data on MSW open dumped in some regions.

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- Table 2.3 (Updated) presents the update of waste composition by regional defaults with new components of garden waste and nappies.
- Table 2.4a (New) has been added to present default values and uncertainties of carbon content, nitrogen content and DOC of domestic and industrial sludge and provides new default value for domestic sewage treated sludge.
- Table 2A.1 (Updated) presents waste generation and management data for some countries for which data were available to update applicable data for the year 2010. List of countries are according to UN classification by region. Table 2A.1 (Updated) also provides default values of regional averages derived from countries in the region presented in Table 2A.1 (Updated).
- Table 2A.2 (New) presents waste composition by country and region. Data on nappies, and garden and yard waste are provided to reflect the up-to-date waste composition.

Table Title	Type of Refinement	2006 Guidelines Table Number	2019 Refinement Table Number
MSW generation and treatment data – regional defaults	U	2.1	2.1
MSW composition data by percentage – regional defaults	U	2.3	2.3
Default value and uncertainty of carbon content, nitrogen content and DOC of domestic and industrial sludge (percent of dry matter)	NG	-	2.4a
MSW generation and management data – by country and regional averages	U	2A.1	2A.1
Waste composition by country and regional averages	NG	-	2A.2

Boxes

- Box in this chapter is not refined.

Box Title	Type of Refinement	2006 Guidelines Box Number	2019 Refinement Box Number
Example of activity data collection for estimation of emissions from solid waste treatment based on waste stream analysis by waste type	NR	2.1	2.1

CHAPTER 3

This chapter presents an update of the Solid Waste Disposal chapter of the *2006 IPCC Guidelines*. These refinements provide, to the extent of current knowledge, new categories of SWDS including semi-aerobic (managed poorly) and active aeration (well managed and poorly managed). MCF values for these new categories are provided. Default data on fraction of DOC_f by types of waste are updated. Guidance on estimation of DOC lost with leachate from SWDS is provided. The refinement also provides the information on N_2O from SWDS as well as information on the estimation of CH_4 emissions using measured data in the appendices. The IPCC Waste Model has been updated accordingly to the refinement.

Sections

- Section 3.2.1.1 provides information on aerobic management of SWDS including information on calculation of MCF for new categories of aerobic management.
- Section 3.2.3 provides additional information on DOC_f including updated default values and their uncertainties by different type waste (less, moderately and highly decomposable). Information on MCF including default MCF values and definition for new categories of aerobic management as well as information on effect of DOC leaching from SWDS are also provided.
- Additional information of N_2O emission from SWDS is provided in the Appendix 3A.1.
- Information of estimation of CH_4 emission from active aeration SWDS using locally available measured data are provided in the Appendix 3A.2.

Section Title	Type of Refinement	2006 Guidelines Section Number	2019 Refinement Section Number
First Order Decay	NG	3.2.1.1	3.2.1.1
Methane emissions	NR	3.2.1.1	3.2.1.1
Methane generation	NR	3.2.1.1	3.2.1.1
First order decay basics	NR	3.2.1.1	3.2.1.1
Simple FOD spreadsheet model	NR	3.2.1.1	3.2.1.1
CH_4 generated from decomposable DDOC_m	NR	3.2.1.1	3.2.1.1
Simple FOD Spreadsheet Model	NR	3.2.1.1	3.2.1.1
Modelling different geographical or climate regions	NR	3.2.1.1	3.2.1.1
Dealing with different waste categories	NR	3.2.1.1	3.2.1.1
Adjusting waste composition at generation to waste composition at SWDS	NR	3.2.1.1	3.2.1.1
Open burning of Waste at SWDS	NR	3.2.1.1	3.2.1.1
Choice of emission factors and parameters: Degradable organic carbon (DOC)	NR	3.2.3	3.2.3
Choice of emission factors and parameters: Fraction of degradable organic carbon which decomposes (DOC_f)	U/NG	3.2.3	3.2.3
Choice of emission factors and parameters: Methane correction factor (MCF)	U/NG	3.2.3	3.2.3

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Section Title	Type of Refinement	2006 Guidelines Section Number	2019 Refinement Section Number
Choice of emission factors and parameters: Fraction of CH ₄ in generated landfill gas (F)	NR	3.2.3	3.2.3
Choice of emission factors and parameters: Oxidation factor (OX)	NR	3.2.3	3.2.3
Choice of emission factors and parameters: Half-life	NR	3.2.3	3.2.3
Choice of emission factors and parameters: Methane recovery	NR	3.2.3	3.2.3
Choice of emission factors and parameters: Delay time	NR	3.2.3	3.2.3
Uncertainties associated with parameters	U	3.7.2.2.	3.7.2.2
Information on Nitrous Oxide Emission from Solid Waste Disposal Site	NG	-	Appendix 3A.1
Information on Estimation of CH ₄ Emission from Solid Waste Disposal Site Managed by Active Aeration Using Locally Available Measured Data	NG	-	Appendix 3A.2

Equations

- Equation 3A.1 was introduced to inform the estimation of CH₄ emission from active aeration SWDS using locally measured data.

Equation Title	Type of Refinement	2006 Guidelines Equation Number	2019 Refinement Equation Number
CH ₄ emission from SWDS	NR	3.1	3.1
Decomposable DOC from waste disposal data	NR	3.2	3.2
Transformation from DDOC _m to Lo	NR	3.3	3.3
DDOC _m accumulated in SWDS at the end of year T	NR	3.4	3.4
DDOC _m decomposed at the end of year T	NR	3.5	3.5
CH ₄ generated from decayed DDOC _m	NR	3.6	3.6
Estimates DOC using default carbon content values	NR	3.7	3.7
MCF for managed SWDS (active aeration)	NG	-	3A.1

Tables

- Table 3.0 (New) provides DOC_f for waste types with different degree of decomposition (less, moderately and highly decomposable).
- Table 3.1 (Updated) was introduced to update MCF by SWDS classification. New MCF values for managed poorly semi-aerobic as well as managed well and managed poorly active aeration landfills are presented.
- Table 3.5 (Updated) updates uncertainties associated with the default DOC_f and MCF values.

Table Title	Type of Refinement	2006 Guidelines Table Number	2019 Refinement Table Number
Fraction of degradable organic carbon which decomposes (DOC_f) for different waste types	NG	-	3.0
SWDS classification and Methane Correction Factors (MCF)	U/NG	3.1	3.1
Oxidation factor (OX) for SWDS	NR	3.2	3.2
Recommended default methane generation rate (k) values under Tier 1	NR	3.3	3.3
Recommended default half-life ($t_{1/2}$) values (yr) under Tier 1	NR	3.4	3.4
Estimates of uncertainties associated with the default activity data and parameters in the FOD method for CH_4 emissions from SWDS	U	3.5	3.5

Boxes

- Box 3.0a (New) provides definition of aerobic active management of SWDS and information on calculation of MCF for different types of aerobic SWDS including managed poorly semi-aerobic, managed well active aeration and managed poorly active aeration.
- Box 3.0b (New) presents information on effect of DOC leachate from SWDS.

Box Title	Type of Refinement	2006 Guidelines Box Number	2019 Refinement Box Number
Information on calculation of MCF for new category of aerobic management of SWDS (Managed poorly-semi-aerobic, Managed well-active aeration, Managed poorly-active aeration)	NG	-	Box 3.0a
Information on effect of DOC leaching from SWDS	NG	-	Box 3.0b

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CHAPTER 5

This chapter presents an update of Incineration and Open Burning of Waste chapter of the *2006 IPCC Guidelines*. These refinements present updated information on definition of thermal technology including pyrolysis, gasification and plasma to guide understanding of thermal technology. The refinements provide, to the current knowledge, CH₄ and N₂O emission factors by operation condition and technologies of specific plant. Guidance on reporting of emission is also provided. The default value of oxidation factor in percent of carbon input of MSW open burning is updated. To be consistent with updated information on sludge in Chapter 2, carbon content of sewage sludge was also updated.

Sections

- Section 5.1 provides definition of and information on pyrolysis, gasification and plasma technology.
- Section 5.4.1.3 presents an updated oxidation factor of MSW open burning
- Sections 5.4.2 and 5.4.3 provide default emission factors of CH₄ and N₂O for pyrolysis-melting and gasification-melting for specific plant types.

Section Title	Type of Refinement	2006 Guidelines Section Number	2019 Refinement Section Number
Introduction	U/NG	5.1	5.1
Methodological issues	U	5.2	5.2
Choice of emission factor	NR	5.4	5.4
CO ₂ emission factors	U	5.4.1	5.4.1
Oxidation factor	U	5.4.1.3.	5.4.1.3
CH ₄ emission factor	U/NG	5.4.2	5.4.2
N ₂ O emission factor	U/NG	5.4.3	5.4.3

Tables

- Table 5.2 was updated to provide updated oxidation factor of MSW open burning and carbon content of domestic sludge
- Table 5.3a (New) presents new default CH₄ emission factor by wet weight of specific pyrolysis and gasification plant
- Table 5.4a (New) presents new default N₂O emission factor by wet weight of specific pyrolysis and gasification plant

Table Title	Type of Refinement	2006 Guidelines Table Number	2019 Refinement Table Number
Default data for CO ₂ emission factors for incineration and open burning of waste	U	5.2	5.2
CH ₄ emission factors for incineration of MSW	NR	5.3	5.3
CH ₄ emission factors for pyrolysis-melting and gasification-melting plant of MSW	NG	-	5.3a
N ₂ O emission factors for incineration of MSW	NR	5.4	5.4
N ₂ O emission factor for pyrolysis-melting and gasification-melting plant of MSW	NG	-	5.4a

Boxes

- Box 5.0a (New) was introduced to present the basic information on pyrolysis including process and emission.
- Box 5.0b (New) was introduced to present the basic information on gasification including process and emission.
- Box 5.0c (New) was introduced to present the basic information on plasma technology including process and emission
- Box 5.2 (New) presents the information on CH₄ emission from pyrolysis and gasification at laboratory scale to inform dependency on some process factors including types of technology and operation condition related to emission.
- Box 5.3 (New) was introduced to guide the understanding of combined process.

Box Title	Type of Refinement	2006 Guidelines Box Number	2019 Refinement Box Number
Pyrolysis	NG	-	5.0a
Gasification	NG	-	5.0b
Plasma	NG	-	5.0c
Information of CH ₄ emission factors in laboratory scale	NG	-	5.2
Combined system	NG	-	5.3

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CHAPTER 6

This chapter presents an update of the Wastewater Treatment and Discharge chapter of the *2006 IPCC Guidelines*. The refinements laid out in this chapter provide clarity over how to apply the *2006 IPCC Guidelines* and definitions of treatment systems presented and introduce new and improved default values and emission factors based on further scientific research into the mechanisms associated with GHG emissions from wastewater treatment (including sludge treatment that occurs within the WWTP). In addition, these refinements present an updated section on N₂O emissions to better address emissions from domestic wastewater, including centralised treatment plants, and to include emissions from industrial wastewater.

Sections

- New subsections have been added to the Introduction to provide a discussion of technical topics related to new guidance presented in the chapter.
- Sections that discuss CH₄ emissions from domestic and industrial wastewater, as well as N₂O emissions from domestic wastewater have been updated to reflect the refinements presented throughout the chapter.
- A new section, Section 6.4, has been added to provide new guidance on estimating N₂O emissions from industrial wastewater.
- A series of annexes have been included to provide additional details related to new or revised emission factors and default activity data.
- An appendix has been added to provide a discussion of abiogenic CO₂ emissions from wastewater treatment and discharge.

Section Title	Type of Refinement	2006 Guidelines Section Number	2019 Refinement Section Number
Introduction	U	6.1	6.1
Centralised treatment systems	NG	-	6.1.1
Decentralised treatment systems of domestic wastewater (onsite sanitation)	NG	-	6.1.2
Emissions from receiving waters	NG	-	6.1.3
Changes compared to 1996 Guidelines and Good Practice Guidance	U (only Section number)	6.1.1	6.1.4
Changes compared to 2006 Guidelines	NG	-	6.1.5
Methodological issues	U	6.2.1	6.2.1
Choice of method (CH ₄ emissions from domestic wastewater)	U, NG	6.2.2.1	6.2.2.1
Choice of emission factors (CH ₄ emissions from domestic wastewater)	U	6.2.2.2	6.2.2.2
Choice of activity data (CH ₄ emissions from domestic wastewater)	U, NG	6.2.2.3	6.2.2.3
Uncertainties (CH ₄ emissions from domestic wastewater)	U	6.2.2.5	6.2.2.5
Choice of method (CH ₄ emissions from industrial wastewater)	U	6.2.3.1	6.2.3.1
Choice of emission factors (CH ₄ emissions from industrial wastewater)	U	6.2.3.2	6.2.3.2
Nitrous oxide emissions from domestic wastewater	U, NG	6.3	6.3
Methodological issues (N ₂ O emissions from domestic wastewater)	U, NG	6.3.1	6.3.1
Choice of method (N ₂ O emissions from domestic wastewater)	U, NG	6.3.1.1	6.3.1.1

Section Title	Type of Refinement	2006 Guidelines Section Number	2019 Refinement Section Number
Choice of emission factors (N ₂ O emissions from domestic wastewater)	U, NG	6.3.1.2	6.3.1.2
Choice of activity data (N ₂ O emissions from domestic wastewater)	U, NG	6.3.1.3	6.3.1.3
Uncertainties (N ₂ O emissions from domestic wastewater)	U	6.3.3	6.3.3
Nitrous oxide emissions from industrial wastewater	NG	-	6.4 (and all subsections)
Abiogenic (fossil) CO ₂ emissions from wastewater treatment and discharge	NG	-	Appendix 6A.1
Summary data for pit latrine use, no sanitation facility, and groundwater use by country	U, NG	-	Annex 6A.1
Derivation of the maximum CH ₄ producing potential (B ₀) for domestic wastewater	U	-	Annex 6A.2
Estimation of default methane conversion factors for CH ₄ in centralised wastewater treatment plants treating domestic wastewater	U	-	Annex 6A.3
Calculation of MCF for methane emissions from sewage discharges	U, NG	-	Annex 6A.4
Estimation of default emission factors for N ₂ O in domestic wastewater treatment plants	U, NG	-	Annex 6A.5
Estimation of default emission factors for N ₂ O in effluent	U, NG	-	Annex 6A.6
List of countries by region included in Table 6.10a	NG	-	Annex 6A.7

Equations

- Equation 6.1 in *2006 IPCC Guidelines* was divided to Equations 6.1 (Updated), 6.1a (New), and 6.3a (New) to emphasize calculation by individual pathways.
- Equation 6.3 was updated to remove the correction factor for additional industrial BOD, as it was added to Equation 6.3a (New).
- Equations 6.3b (New) was introduced to allow conversion on sludge (t/yr) to organic component removed as sludge (S in updated Equation 6.1).
- Equation 6.3c (New) was introduced to estimate the organic component removed as sludge from septic systems (S in updated Equation 6.1).
- Equation 6.3d (New) was introduced to estimate the organic component discharged to aquatic environments in treated domestic wastewater effluent.
- Equation 6.9 was updated to reflect the calculation of N₂O emissions from domestic wastewater treatment and expanded to cover all wastewater treatment plants.
- Equation 6.7 was updated to reflect the calculation of N₂O emissions from the domestic wastewater effluent discharged to aquatic environments.
- Equation 6.10 (New) was introduced to better reflect the calculation of total nitrogen in domestic wastewater.
- Equation 6.10a (New) was introduced to estimate the amount of protein consumed when national statistics on protein consumed are not available.
- Equation 6.8 was updated to reflect the calculation of nitrogen in effluent from domestic wastewater treatment.
- Equations 6.11 (New) through 6.14 (New) were introduced to allow for calculation of N₂O emissions from industrial wastewater treatment.

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Equation Title	Type of Refinement	2006 Guidelines Equation Number	2019 Refinement Equation Number
Total CH ₄ emissions from domestic wastewater for each treatment/discharge pathway or system	U	6.1	6.1
Total CH ₄ emissions from domestic wastewater treatment and discharge	U	6.1	6.1a
CH ₄ emission factor for each domestic wastewater treatment/discharge pathway or system	NR	6.2	6.2
Total organically degradable material in domestic wastewater	U	6.3	6.3
Total organics in domestic wastewater by treatment/discharge pathway or system	NG	6.1	6.3a
Organic component removed as sludge from aerobic treatment plants	NG	-	6.3b
Organic component removed as sludge from septic systems	NG	-	6.3c
Total organics in treated domestic wastewater effluent	NG	-	6.3d
Total CH ₄ emissions from industrial wastewater	NR	6.4	6.4
CH ₄ emission factor for industrial wastewater	NR	6.5	6.5
N ₂ O emissions from domestic wastewater treatment plants	U	6.9	6.9
N ₂ O emissions from domestic wastewater effluent	U	6.7	6.7
Total nitrogen in domestic wastewater by treatment pathway	NG	-	6.10
Protein consumed	NG	-	6.10a
Total nitrogen in domestic wastewater effluent	U	6.8	6.8
N ₂ O emissions from industrial wastewater treatment plants	NG	-	6.11
N ₂ O emissions from industrial wastewater effluent	NG	-	6.12
Total nitrogen in industrial wastewater	NG	-	6.13
Total nitrogen in industrial wastewater effluent	NG	-	6.14

Tables

- Table 6.1 was updated to reflect refinements to the overall wastewater treatment systems and discharge pathways covered in this chapter.
- Tables 6.3, 6.7, 6.8, and 6.11 have been updated, and Tables 6.8a (New) and 6.13 (New) introduced, to reflect updated or new emissions factors for CH₄ and N₂O emissions and the resulting uncertainty ranges. An alternate set of emission factors is provided for CH₄ and N₂O emissions from wastewater after disposal of untreated wastewater or wastewater treatment effluent into aquatic environments when the country has activity data to differentiate the conditions of the waterbody receiving the discharge.
- Tables 6.6a (New) and 6.6b (New) have been introduced to provide default values for the removal of organic component from wastewater as sludge (K_{REM}) and wastewater treatment organics removal fractions (TOW_{REM}), according to treatment type.
- Table 6.10a (New) provides regional default factors for sources of nitrogen in domestic wastewater.
- Table 6.10b (New) has been added to provide additional country-specific information on the use of food waste disposals if needing to calculate a country-specific value for the fraction of protein not consumed.
- Table 6.10c (New) has been introduced to provide default values for the removal of nitrogen from wastewater (N_{REM}).
- Table 6.12 (New) has been added to provide default values for use in estimating N₂O emissions from industrial wastewater.

Table Title	Type of Refinement	2006 Guidelines Table Number	2019 Refinement Table Number
CH ₄ and N ₂ O emission potentials for wastewater and sludge treatment and discharge systems	U	6.1	6.1
Default maximum CH ₄ producing capacity (B ₀) for domestic wastewater	NR	6.2	6.2
Default MCF values and resultant EFs for domestic wastewater	U	6.3	6.3
Estimated BOD ₅ values in domestic wastewater for selected regions and countries	NR	6.4	6.4
Suggested values for urbanisation (U) and degree of utilisation of treatment, discharge pathway or method (Ti,j) for each income group for selected countries	NR	6.5	6.5
Example of the application of default values for degrees of treatment utilization (T) by income groups	NR	6.6	6.6
Removal of organic component from wastewater as sludge (K _{REM}) according to treatment type	NG	-	6.6a
Wastewater treatment organics removal fractions (TOW _{REM}) according to treatment type	NG	-	6.6b
Default uncertainty ranges for domestic wastewater	U	6.7	6.7
Default MCF values and resultant EFs for industrial wastewater	U	6.8	6.8
Default EF values for domestic and industrial wastewater	NG	6.11	6.8a
Default factors for domestic wastewater	NG	-	6.10a
Estimate on use of food waste disposal in sewer	NG	-	6.10b

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Table Title	Type of Refinement	2006 Guidelines Table Number	2019 Refinement Table Number
Wastewater treatment nitrogen removal fractions (N _{REM}) according to treatment type	NG	-	6.10c
N ₂ O methodology default data	U	6.11	6.11
Examples of industrial wastewater data	NG	-	6.12
Default uncertainty ranges for industrial wastewater	NG	-	6.13
Summary of literature investigating fossil organic carbon in wastewater	NG	-	Appendix 6A.1
Summary data for pit latrine use, no sanitation facility, and groundwater use by country	NG	-	Annex 6A.1
MCFs based on measured CH ₄ in full-scale domestic wastewater treatment plants	NG		Annex 6A.2
Summary of literature investigating CH ₄ emissions from wastewater discharge	NG	-	Annex 6A.3
Default N ₂ O emission factors for domestic wastewater treatment plants	NG	-	Annex 6A.4
N ₂ O emission factors in full-scale domestic wastewater treatment plants	NG	-	Annex 6A.5
List of countries by region included in Table 6.10a (New)	NG	-	Annex 6A.6

Figures

- Figure 6.1 was updated to reflect refinements to the overall wastewater treatment systems and discharge pathways covered in this chapter.
- Figure 6.1a (New) was introduced to present information on the use of pit latrines by low-income country populations.
- Figures 6.2 and 6.3 were updated to reflect refinements to the tier methodologies for CH₄ emissions, particularly related to emissions from discharge.
- Figures 6.4 (New) and 6.6 (New) were introduced to reflect refinements to the tier methodologies for N₂O emissions.
- Figure 6.5 (New) was introduced to show the sources of nitrogen in domestic wastewater.
- Figure 6A.1 (New) presents information on the correlation of influent nitrogen load entering wastewater treatment plants to N₂O emissions.

Figure Title	Type of Refinement	2006 Guidelines Figure Number	2019 Refinement Figure Number
Wastewater treatment systems and discharge pathways	U	6.1	6.1
Percentage of low-income country populations using pit latrines as a primary sanitation facility	NG	-	6.1a
Decision tree for CH ₄ emissions from domestic wastewater	U	6.2	6.2
Decision tree for CH ₄ emissions from industrial wastewater	U	6.3	6.3

Figure Title	Type of Refinement	2006 Guidelines Figure Number	2019 Refinement Figure Number
Decision tree for N ₂ O emissions from domestic wastewater	NG	-	6.4
Nitrogen in domestic wastewater treatment	NG	-	6.5
Decision tree for N ₂ O emissions from industrial wastewater	NG	-	6.6
Correlation between influent N load and N ₂ O emission	NG	-	6A.1