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Guidelines for performance evaluation of treatment technologies for water reuse systems —

Part 2: Methodology to evaluate performance of treatment systems on the basis of greenhouse gas emissions

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 282, *Water reuse*, Subcommittee SC 3, *Risk and performance evaluation of water reuse systems*.

A list of all parts in the ISO 20468 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The purpose of this document is to define a methodology more specifically for evaluating the environmental performance of treatment systems among treatment technologies for water reuse systems, which is covered in Clause 7 “Non-functional requirements” of ISO 20468-1:2018, *Guidelines for performance evaluation of treatment technologies for water reuse systems Part 1 General*.

Water reuse has been drawing attention for contributing to environmental protection, as well as providing solutions for water scarcity. For example, a water reclamation plant plays the additional role of removing pollutants such as emerging pollutants, pathogens, and toxic elements. Otherwise, water discharged into the environment can increase health risks and/or have negative impacts on ecosystems. Compared to conventional water supply systems, including waterworks consisting of dams and water conveyance facilities, water reuse systems can save operational energies and resources of constructions. In addition, water reuse can minimize environmental destruction during development.

In order to establish sustainable water reuse services, while protecting the environment, appropriate evaluation methods are needed. However, in the international community, there is no common approach to using parameters concerning the environment in evaluations of treatment technologies for water reuse systems. Although rules may be established for each region where water reuse systems are to be installed, having specialists work out rules and standardizing them through the ISO is more economical and convenient.

When discussing evaluations of environmental aspects, first of all, two aspects should be defined. One comprises boundary conditions that determine which areas are evaluated. The other is the evaluation parameter concerned.

Typical boundary conditions concerning environmental aspects in water reuse projects consist of intake, conveyance, treatment, reservoir, distribution, end-use, and final discharge into the environment. Taking into consideration the scope defined in Part 1, this document addresses treatment systems.

On the other hand, evaluation parameters concerning the environment attributable to treatment systems vary widely. For example, reclaimed water quality having adverse effects on a regional ecosystem and ground water can be one parameter for evaluation. Another can be the level of soil contamination caused by using reclaimed water. Moreover, the degree of noise and vibration from treatment systems can be utilized for evaluations because of the impacts on the environment. Greenhouse gas emissions in the course of plant operation should also be taken into consideration with more attention given to preventing global warming. Naturally, a treatment system should be evaluated by taking into account all of these parameters. However, an evaluation with so many parameters involves a great burden in terms of time and costs, and therefore lacks practicality at the moment.

In view of the conditions described above, this document provides guidelines for evaluating the performance of a treatment system using, as a parameter, greenhouse gas emissions in the course of system operation with the amount of reclaimed water produced. The reason why greenhouse gas emissions have been selected as a parameter is that it is a practical parameter on which many greenhouse-gas related standards have been established, such as ISO 14064-1. It is, however, important to note that this document is not intended to prevent evaluating other environmental parameters of treatment systems, including those described above, in water reuse projects. If such evaluations are necessary, other guidelines and/or expert judges should be referred.

The evaluation is also limited to the period during which the treatment system is being operated. This is because the systems are expected to operate for 20 years or more after construction, during which greenhouse gas emissions in the course of operation tend to be greater than the level at construction or when the system is being discontinued.

This document takes a simple and standard approach that can be applied anywhere. Therefore, this document includes how to estimate greenhouse gas emissions using typical activities, such as energy consumption or amount of consumables used in operations. In addition, CO_{2eq} emission intensity is defined to evaluate the environmental performance of a treatment system expressed as a value of the weight of greenhouse gas emissions divided by the amount of reclaimed water produced. As a result, there is no need to substantially change existing engineering duties. This will alleviate the burden on engineers.

It is expected that this document will contribute to the development of environmentally responsible treatment systems.

Guidelines for performance evaluation of treatment technologies for water reuse systems —

Part 2:
Methodology to evaluate performance of treatment systems on the basis of greenhouse gas emissions

1 Scope

This document provides guidelines for evaluating the performance of treatment systems on the basis of greenhouse gas (GHG) emissions.

In order to estimate greenhouse gas emissions from a treatment system, this document covers the estimate, types of GHG emission and sources, emission factor for each GHG, and global warming potential. The weight of greenhouse gases to be used in an evaluation is equivalent to emissions during operation of a treatment system.

This document also defines a method for calculating carbon dioxide equivalent (CO_{2eq}) emission intensity, in which GHG emissions are divided by the volume of reclaimed water. It also includes a method for evaluating the performance of a treatment system using CO_{2eq} emission intensity.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 20670, *Water reuse — Vocabulary*

3 Terms, definitions, and abbreviated terms

For the purposes of this document, the terms and definitions given in ISO 20670 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1 Terms and definitions

3.1.1
activity data
quantitative measure of activity that results in a GHG emission or removal

EXAMPLE The amount of imported electricity consumed, biologically treated sewage or water treatment chemicals consumed.

Note 1 to entry: See Reference [1].

3.1.2
anaerobic-aerobic activated sludge process
AO process
biological sewage treatment process with a sequence of anaerobic and aerobic (oxic) zones

3.1.3
anaerobic-anoxic-oxic activated process
A2O process
biological sewage treatment process with a sequence of anaerobic, anoxic and aerobic (oxic) zones

3.1.4
carbon dioxide equivalent
CO_{2eq}
conversion of individual GHG emissions or removals into climate impact, identified as tons equivalent of carbon dioxide (CO_{2eq})

Note 1 to entry: See Reference [2].

3.1.5
carbon dioxide equivalent (CO_{2eq}) emission intensity
value determined by dividing GHG emissions by amount of reclaimed water

3.1.6
emission factor
coefficient which quantifies emissions or removals per unit activity

Note 1 to entry: See Reference [2].

3.1.7
environmental performance
measurable results of treatment technologies in environmental aspects

3.1.8
greenhouse gas
GHG
carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)

Note 1 to entry: See Reference [1].

3.1.9
membrane bioreactor
MBR
treatment method in which bioreactor and membrane process are combined

3.1.10
recycled nitrification-denitrification process
RND process
biological nitrogen removal process utilizing nitrate recycle

3.2 Abbreviated terms

For the purposes of this document, the following abbreviated terms apply.

CO_2	carbon dioxide
CO_{2eq}	carbon dioxide equivalent
CH_4	methane
N_2O	nitrous oxide

GHG greenhouse gas

AO process anaerobic-aerobic activated sludge process

A2O process anaerobic-anoxic-oxic activated process

MBR membrane bioreactor

RND process recycled nitrification-denitrification process

N/A not applicable

ds dry solid

RO reverse osmosis

GWP global warming potential

STP sewage treatment plant

ID No. identification number

4 Symbols

The symbols used in this document are shown in Table 1.

Table 1 — Symbols

Symbol	Unit	Description
$E_{E,CO2,annual}$	tons of CO_2 per year	CO_2 emissions resulting from consumption of energy, including electricity, fuels, etc.
$E_{E,CH4,annual}$	tons of CH_4 per year	CH_4 emissions resulting from consumption of energy, including electricity, fuels, etc.
$E_{E,N2O,annual}$	tons of N_2O per year	N_2O emissions resulting from consumption of energy, including electricity, fuels, etc.
$E_{P,CH4,annual}$	tons of CH_4 per year	CH_4 emissions resulting from each biological treatment process
$E_{P,N2O,annual}$	tons of N_2O per year	N_2O emissions resulting from each biological treatment process
$E_{C,CO2,annual}$	tons of CO_2 per year	CO_2 emissions resulting from consumables and generation of waste
$E_{C,CH4,annual}$	tons of CH_4 per year	CH_4 emissions resulting from consumables and generation of waste
$E_{C,N2O,annual}$	tons of N_2O per year	N_2O emissions resulting from consumables and generation of waste
$E_{R,CO2eq,annual}$	tons of CO_{2eq} per year	Reduction of GHG emissions through the effective utilization of resources resulting from the production of reclaimed water (CO_2 equivalent)
$E_{T,CO2eq,annual}$	tons of CO_{2eq} per year	Total greenhouse gas emissions (CO_2 equivalent)
I_{CO2eq}	kg CO_{2eq} per m^3-reclaimed water	Carbon dioxide equivalent (CO_{2eq}) emission intensity
Q_{annual}	thousand m^3-reclaimed water per year	Annual volume of reclaimed water produced in a relevant water reclamation plant
$Q_{E,t}$	unit[a]	Amount of energy consumption, including electricity, fuels, etc.

[a] The unit varies according to the substance concerned. Definitions are given in Clause 7.

Table 1 *(continued)*

Symbol	Unit	Description
$Q_{P,t}$	unit[a]	Amount of treatment in each biological treatment process
$Q_{C,t}$	unit[a]	Amount of consumables and the weight of waste generated
$K_{E,CO2,t}$	tons of CO_2 per unit[a]	CO_2 emission factor resulting from consumed energy, including electricity, fuels, etc.
$K_{E,CH4,t}$	tons of CH_4 per unit[a]	CH_4 emission factor resulting from consumed energy, including electricity, fuels, etc.
$K_{E,N2O,t}$	tons of N_2O per unit[a]	N_2O emission factor resulting from consumed energy, including electricity, fuels, etc.
$K_{P,CH4,t}$	tons of CH_4 per unit[a]	CH_4 emission factor resulting from the biological treatment process
$K_{P,N2O,t}$	tons of N_2O per unit[a]	N_2O emission factor resulting from the biological treatment process
$K_{C,CO2,t}$	tons of CO_2 per unit[a]	CO_2 emission factor resulting from consumables and waste
$K_{C,CH4,t}$	tons of CH_4 per unit[a]	CH_4 emission factor resulting from consumables and waste
$K_{C,N2O,t}$	tons of N_2O per unit[a]	N_2O emission factor resulting from consumables and waste
$K_{GWP,t}$		Global warming potential (GWP)

[a] The unit varies according to the substance concerned. Definitions are given in Clause 7.

5 Principles

5.1 General

The following principles apply to evaluations of treatment systems using CO_{2eq} emission intensity.

5.2 Relevance

The activities of treatment systems, which are related to greenhouse gas emissions, should be extracted in a relevant manner and appropriately quantified.

5.3 Completeness

GHG emissions during production of reclaimed water should be calculated under conditions in which other environmental requirements (reclaimed water quality, noise and vibration, etc.) of the system comply with project requirements.

5.4 Consistency

In order to ensure an effective comparison, as much as possible, data should be acquired according to the same method from year to year. The method to be used should be established at the beginning of an evaluation for the same water reclamation plant.

5.5 Accuracy

Data acquisition should be free from bias, as much as possible, while minimizing uncertainty. For specified methods, refer to Clauses 6 and 7.

5.6 Transparency

The process for calculating the CO_{2eq} emission intensity and parameters used, such as emission factors and efficiency of equipment applied to a system, should be recorded and made available for clarification when requested.

6 Boundary conditions

6.1 General

When using this document in an evaluation of the environmental performance of a treatment system, the boundary conditions of the evaluation should be established according to the relevant project requirements. To facilitate a comparison of treatment systems, it is essential to define the boundary conditions of a performance evaluation, taking into consideration the processes of transforming raw water into reclaimed water and, if necessary, associated facilities inside the water reclamation plant. Unless otherwise specified, the boundary conditions should be defined referring to the example in Figure 1. To prevent the performance evaluation of the treatment system from being influenced by the location of a raw water intake point or distribution of reclaimed water, the boundary conditions of the performance evaluation should be limited to part of the treatment system and associated facilities inside the water reclamation plant. Then, tangible minimum boundary conditions should be established between the facility that receives the raw water to produce reclaimed water and the prescribed interface point to hand over reclaimed water produced through treatment processes. In addition, the relevant system, such as a sludge treatment system, may be included in the evaluation, taking into consideration project characteristics.

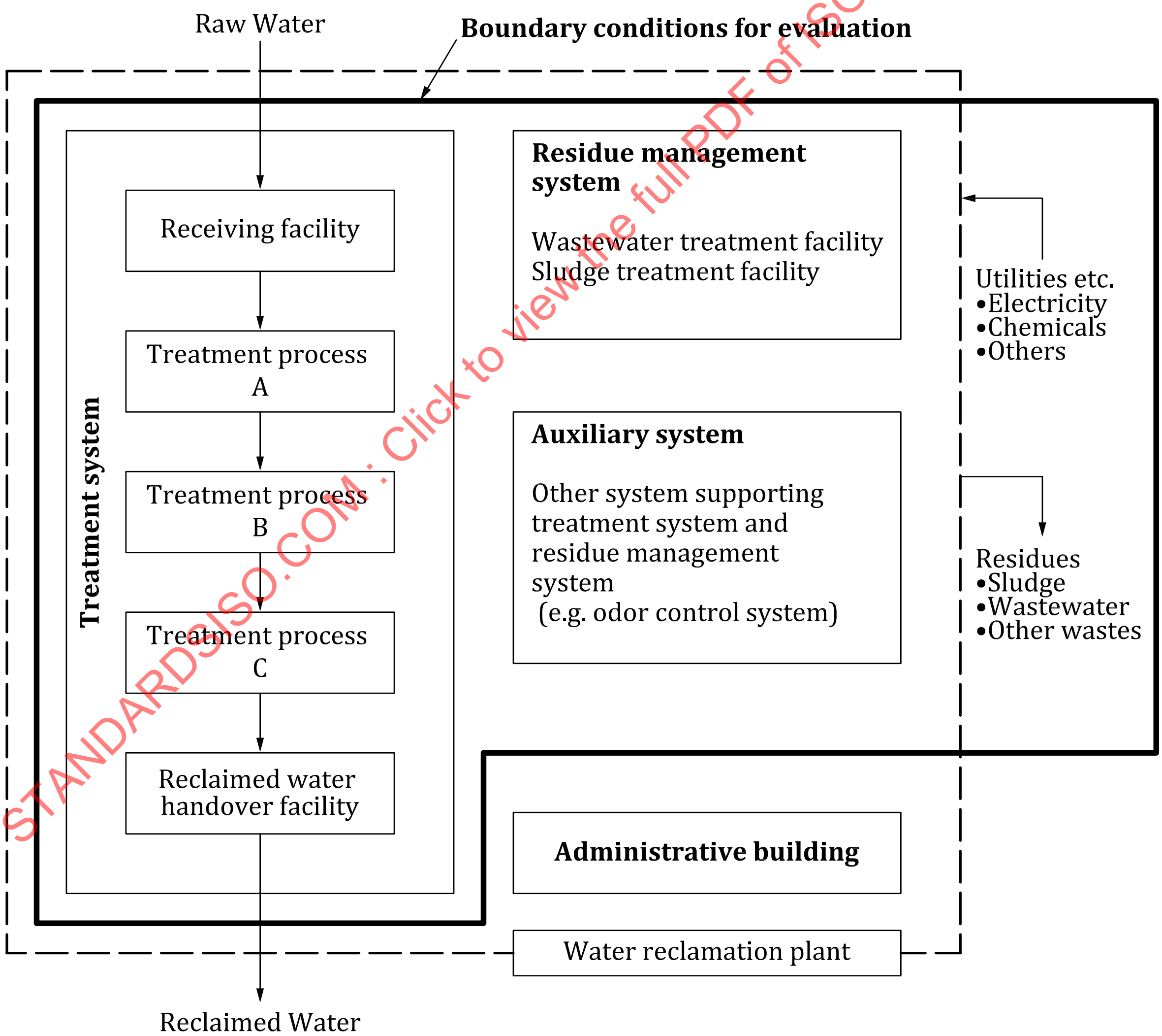


Figure 1 — Example of the boundary conditions of evaluation

6.2 Treatment system

An example of treatment system refers to a set of water treatment processes inside a water reclamation plant, in which raw water, such as raw sewage, preliminary, primary, or secondary treated wastewater, is transformed into reclaimed water. Normally, the treatment system consists of multiple treatment processes using physical, biological and/or chemical means. Because this document is not intended to specify the type and order of treatment processes such as A, B, and C in Figure 1, they are to be replaced with adequate treatment processes according to the relevant project requirements. When evaluating the environmental performance of the treatment system by applying this document, a treatment system should at least be included in the boundary conditions.

6.3 Residue management system

Generally, treatment systems generate wastewater or sludge. The following facilities are needed to handle them:

— Wastewater treatment facility(s);

— Sludge treatment facility(s).

These facilities may be provided as a part of the project, or treatment work may be assigned to nearby plants already in service. GHG emissions from a residue management system may be included in the boundary conditions of an evaluation as required. It is essential to specify clearly whether or not such GHG emissions are included.

6.4 Auxiliary system

Systems not included in the treatment system or the residue management system, but relate to producing reclaimed water are taken as an auxiliary system. The example is an odor control system. They may be included in the boundary conditions of the evaluation as required.

In principle, however, power consumed for lighting, air conditioning, etc. not directly connected to the production of reclaimed water is not counted in the performance evaluation of this document.

7 Calculation

7.1 Calculation procedure

This clause describes how to calculate CO_{2eq} emission intensity. The steps are as follows (see Figure 2):

— Step 1: Establish boundary conditions of evaluation (see 7.2);

— Step 2: Calculate annual amount of reclaimed water (see 7.3);

— Step 3: Calculate GHG emissions resulting from energy consumption, including electricity, fuels, etc. (see 7.5);

— Step 4: Calculate GHG emissions resulting from biological treatment processes (see 7.6);

— Step 5: Calculate GHG emissions resulting from consumables and generation of wastes (see 7.7);

— Step 6: Calculate GHG emissions reduced through the effective utilization of resources resulting from the production of reclaimed water (see 7.8);

— Step 7: Calculate total GHG emissions (see 7.9);

— Step 8: Calculate CO_{2eq} emission intensity (see 7.10).

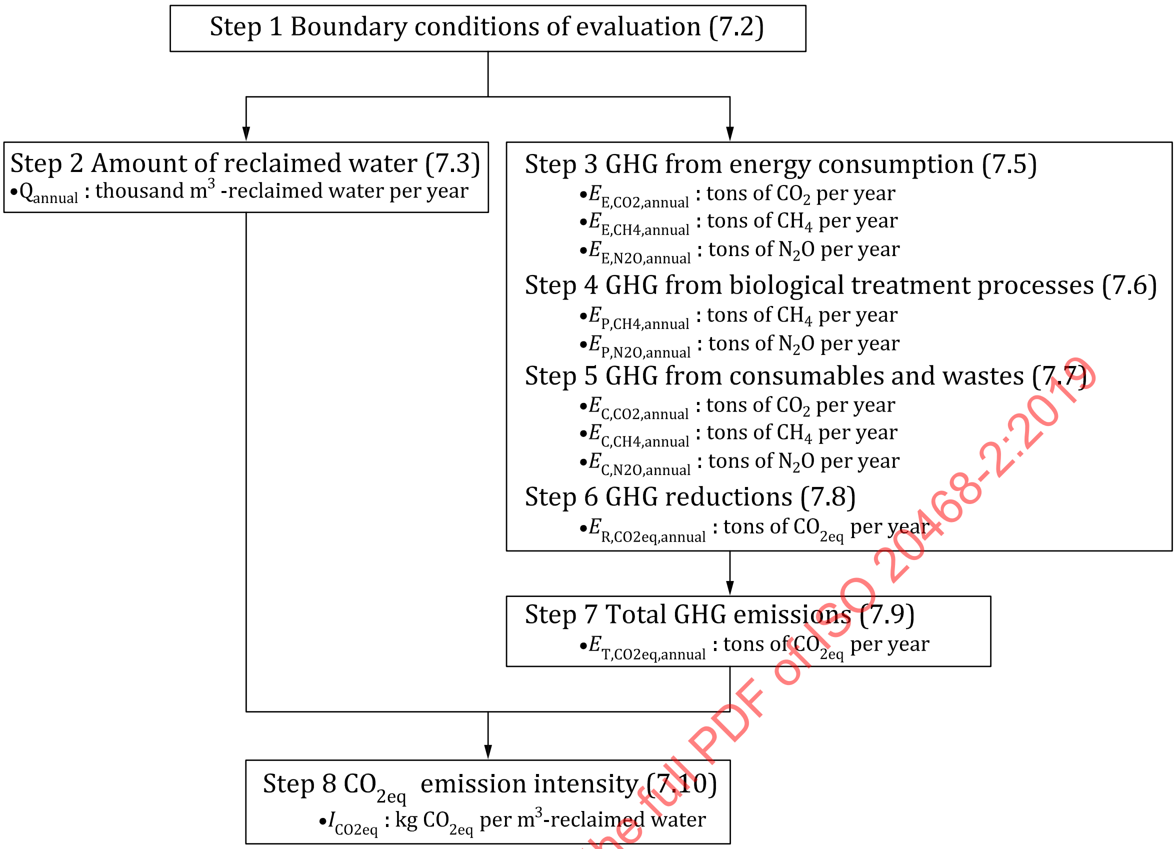


Figure 2 — Calculation procedure

7.2 Step 1: Establish boundary conditions of evaluation

Step 1 is to establish boundary conditions for evaluating environmental performance, while referring to Clause 6. The GHG emissions and reductions within the boundary conditions are calculated based on 7.5, 7.6 7.7, and 7.8. As a rule, activities to be included for the calculation and the GHGs concerned are as follows:

— GHG emissions and reduction are divided into four: 1) to 4) of Table 2;

— Types of GHG include CO_2, CH_4, and N_2O;

— To evaluate the environmental performance of a treatment system, it is recommended to select only emission sources related to the treatment system, excluding administrative buildings.

Table 2 — Activities to be calculated

GHG emissions, reduction, and type		Example of principal emissions and reduction in reclaimed-water production	Related Subclauses
1) Step 3 GHG emissions resulting from energy consumption, including electricity, fuels, etc.	CO_2 CH_4 N_2O	— Emissions resulting from consumption of electricity supplied by a third party — Emissions resulting from heat supplied by a third party — Emissions from diesel engines	7.5
2) Step 4 GHG emissions resulting from biological treatment processes	CH_4 N_2O	— Emissions resulting from biological water treatment — Emissions resulting from landfill of sludge — Emissions resulting from composting of sludge	7.6
3) Step 5 GHG emissions resulting from consumables and generation of wastes	CO_2 CH_4 N_2O	— Emissions resulting from consumption of chemicals	7.7
4) Step 6 GHG emissions reduced through the effective utilization of resources resulting from the production of reclaimed water	CO_2	— Reduction through effective utilization of resources (biogas, algae, nutrients, etc.)	7.8
Item 1) is categorized as Direct GHG emissions and removals and/or Energy indirect GHG emissions in ISO 14064-1 (see Reference [1]). Items 2) is categorized as Direct GHG emissions and removals in ISO 14064-1(see Reference [1]). Items 3) is categorized as Other indirect GHG emissions and removals in ISO 14064-1(see Reference [1]). Items 4) is categorized as Other indirect GHG emissions and removals in ISO/TR 14069 (see Reference [3]).			

7.3 Step 2: Calculate annual amount of reclaimed water

The annual amount of reclaimed water produced in a water reclamation plant is calculated (Q_{annual}). This calculation is conducted not to obtain the amount of raw water, but to obtain the amount of available reclaimed water that meets water quality requirements. The reason for using the amount of the available reclaimed water in the calculation is that the accurate calculation of CO_{2eq} emission intensity defined in 7.10 can be achieved even though the water recovery ratio of the relevant treatment system is lower. In principle, the following amounts are calculated:

— Design reclaimed-water amount in the plan stage of treatment system;

— The amount of reclaimed water integrated by the flow meter or the amount of reclaimed water calculated on the basis of measured flow at the operation stage of a treatment system.

The unit of Q_{annual} is thousand m^3-reclaimed water per year (1 000 m^3-reclaimed water per year).

7.4 General descriptions of methodological issues when calculating GHG emissions for Step 3 to Step 6

7.4.1 Choice of method to determine GHG emissions

The first step is that the amount of GHG emissions is calculated using activity data multiplied by corresponding emission factors as follows.

GHG emissions = activity data × emission factor

Details are described in 7.5, 7.6, 7.7, and 7.8.

The second step is to total all GHG amounts calculated above using the corresponding global warming potential, referring to 7.9.

7.4.2 Choice of activity data

For the convenience, Tables 3, 5, and 7 of this document provide typical activities related to water reuse projects. However, as they are not exclusive and non-exhaustive, the tables should be finalized by adding any necessary activities and/or deleting unrelated activities from them as needed. In addition, the units may be changed while matching them with units of corresponding emission factors. This work may be conducted by engineers and/or experts appointed in the project.

In principle, activity data are calculated based on the amount of water fed to the treatment system while Q_{annual} defined in 7.3 for CO_{2eq} emission intensity is the amount of reclaimed water. This is because the consumption of electricity and chemicals, which are examples of GHG sources, is basically determined from the amount of feed water.

7.4.3 Choice of emission factors

Although this document is not intended to set priorities for emission factors to be used, for the convenience, some reference values of emission factors are listed in Table A.1, A.2, and A.3 corresponding to Tables 3, 5, and 7. Other sources of emission factors may be used such as IPCC guideline (see Reference [2]), guideline for area concerned, and survey to manufactures regarding special equipment. It is entrusted to decide which emission factors are used for a relevant project as long as they are reliable. However, when two candidate treatment systems for the same project are compared using this document, the same emission factors should be used. Otherwise, the two systems cannot be compared accurately.

7.5 Step 3: Calculate GHG emissions resulting from energy consumption

7.5.1 Data acquisition

Within the selected boundary conditions, types of energy, including electricity, fuels, etc., used are identified, their consumption is calculated on an annual basis, and results are summarized using Table 3. This work should be completed before calculating GHG emissions described in 7.5.2. As a rule, the amount of consumption should be calculated as indicated below.

— Design energy consumption at the planning stage of a treatment system.

— The amount integrated on a watthour meter (or any other instrument appropriate for the type of energy) or value calculated based on measured amounts at the operation stage of a treatment system.

If the consumption calculation method is determined in another way, the method should be clarified.

Table 3 — Activity data resulting from energy consumption

ID No. t[a]	Activity	Unit	Amount of consumption $Q_{E,t}$
1	Imported electricity	MWh/year	$Q_{E,1}$
N	Other energy	Specified by user	$Q_{E,N}$

[a] Suffix "t" refers to numbers from 1 to N.

7.5.2 Calculate GHG emissions

GHG emissions resulting from energy consumption, including electricity, fuels, etc, are calculated using Formulae (1) to (3), with the acquired data ($Q_{E,t}$) shown in Table 3 and the corresponding emission factors ($K_{E,CO2,t}$, $K_{E,CH4,t}$, $K_{E,N2O,t}$), which are entered in Table 4 in advance.

$$E_{E,CO2,annual} = \sum_{t=1}^{N} K_{E,CO2,t} \times Q_{E,t} \text{ [tons of CO}_2\text{ per year]} \quad (1)$$

$$E_{E,CH4,annual} = \sum_{t=1}^{N} K_{E,CH4,t} \times Q_{E,t} \text{ [tons of CH}_4\text{ per year]} \quad (2)$$

$$E_{E,N2O,annual} = \sum_{t=1}^{N} K_{E,N2O,t} \times Q_{E,t} \text{ [tons of N}_2\text{O per year]} \quad (3)$$

Table 4 — GHG emission factors resulting from energy consumption

ID No. t[a]	Activity	CO_2 emission factor $K_{E,CO2,t}$ tons of CO_2/unit[b]	CH_4 emission factor $K_{E,CH4,t}$ tons of CH_4/unit[b]	N_2O emission factor $K_{E,N2O,t}$ tons of N_2O/unit[b]
1	Imported electricity	$K_{E,CO2,1}$	N/A	N/A
N	Other energy	$K_{E,CO2,N}$	$K_{E,CH4,N}$	$K_{E,N2O,N}$

[a] Suffix "t" refers to numbers from 1 to N.

[b] Unit refers to the unit in Table 3.

7.6 Step 4: Calculate GHG emissions resulting from biological treatment processes

7.6.1 Data acquisition

Within the selected boundary conditions, each biological treatment process is identified, and the annual amount treated is summarized using Table 5. This work should be completed before calculating GHG emissions described in 7.6.2. When GHG emissions are calculated from the amount of biodegradable carbon in raw water, the contents of Table 5 may be modified, referring to other suitable guidelines such as IPCC guideline. Data acquisition is omitted if no biological treatment processes are utilized in the selected boundary conditions.

Table 5 — Activity data in each biological treatment process

ID No. t[a]	Activity	Unit	Amount treated $Q_{P,t}$
1	Biological sewage treatment	thousand m^3-feed/year	$Q_{P,1}$
2	Landfill of sewage sludge	ds-tons/year	$Q_{P,2}$

[a] Suffix "t" refers to numbers from 1 to N.

Table 5 *(continued)*

ID No. t[a]	Activity	Unit	Amount treated $Q_{P,t}$
3	Composting	ds-tons/year	$Q_{P,3}$
N	Others	Specified by user	$Q_{P,N}$

[a] Suffix “t” refers to numbers from 1 to N.

7.6.2 Calculate GHG emissions

GHG emissions resulting from biological treatment processes are calculated using Formulae (4) and (5), with the acquired data ($Q_{P,t}$) shown in Table 5 and the corresponding emission factors ($K_{P,CH4,t}$, $K_{P,N2O,t}$), which are entered in Table 6 in advance.

For the process of decomposing organics into CO_2, the CO_2 generated is not included in this calculation according to the carbon neutral concept (see Reference [2]).

Although only biodegradable substances in sewage sludge may be counted in order to calculate GHG emissions, identifying the amount of biodegradable substances is not practical because it varies in the landfill over time. Therefore, in this document, the total amount of sludge generated is utilized for the calculation, assuming that all sludge sent to the landfill decomposes.

$$E_{P,CH4,annual} = \sum_{t=1}^{N} K_{P,CH4,t} \times Q_{P,t} \text{ [tons of } CH_4 \text{ per year]} \quad (4)$$

$$E_{P,N2O,annual} = \sum_{t=1}^{N} K_{P,N2O,t} \times Q_{P,t} \text{ [tons of } N_2O \text{ per year]} \quad (5)$$

Table 6 — GHG emission factors resulting from biological treatment processes

ID No. t[a]	Activity	CH_4 emission factor $K_{P,CH4,t}$ tons of CH_4/unit[b]	N_2O emission factor $K_{P,N2O,t}$ tons of N_2O/unit[b]
1	Biological sewage treatment	$K_{P,CH4,1}$	$K_{P,N2O,1}$
2	Landfill of sewage sludge	$K_{P,CH4,2}$	N/A
3	Composting	$K_{P,CH4,3}$	$K_{P,N2O,3}$
N	Others	$K_{P,CH4,t}$	$K_{P,N2O,t}$

[a] Suffix “t” refers to numbers from 1 to N.

[b] Unit refers to the unit in Table 5.

7.7 Step 5: Calculate GHG emissions resulting from consumables and generation of wastes

7.7.1 Data acquisition

Within the selected boundary conditions, consumables and wastes resulting from system operation are identified, and the amount of consumables and wastes generated are calculated and summarized using Table 7. This work should be completed before calculating GHG emissions described 7.7.2. The chemicals transported into the water reclamation plant, as well as waste residues transported out of the plant, may also be considered whenever relevant. Emissions due to waste generation of consumables used over years, such as membranes, may be amortized by the designated replacement period. Note that, among the wastes, sludge counted in 7.5 is excluded from this data acquisition.

Table 7 — Activity data of consumables and waste generated

ID No. t[a]	Activity	Unit	Consumption or the amount generated $Q_{C,t}$
1	Water treatment chemicals	tons/year	$Q_{C,1}$
2	Filter media	tons/year	$Q_{C,2}$
3	Membrane	m^2/year	$Q_{C,3}$
N	Others	Specified by user	$Q_{C,N}$

[a] Suffix "t" refers to numbers from 1 to N.

7.7.2 Calculate GHG emissions

GHG emissions resulting from consumables and wastes generated during system operation are calculated using Formulae (6) to (8), with the acquired data ($Q_{C,t}$) shown in Table 7 and the corresponding emission factors ($K_{C,CO2,t}$, $K_{C,CH4,t}$, $K_{C,N2O,t}$), which are entered in Table 8 in advance.

$$E_{C,CO2,annual} = \sum_{t=1}^{N} K_{C,CO2,t} \times Q_{C,t} \text{ [tons of CO}_2\text{ per year]} \tag{6}$$

$$E_{C,CH4,annual} = \sum_{t=1}^{N} K_{C,CH4,t} \times Q_{C,t} \text{ [tons of CH}_4\text{ per year]} \tag{7}$$

$$E_{C,N2O,annual} = \sum_{t=1}^{N} K_{C,N2O,t} \times Q_{C,t} \text{ [tons of N}_2\text{O per year]} \tag{8}$$

Table 8 — GHG emission factors resulting from consumables and wastes

ID No. t[a]	Activity	CO_2 emission factor $K_{C,CO2,t}$ tons of CO_2/unit[b]	CH_4 emission factor $K_{C,CH4,t}$ tons of CH_4/unit[b]	N_2O emission factor $K_{C,N2O,t}$ tons of N_2O/unit[b]
1	Water treatment chemicals	$K_{C,CO2,1}$	N/A	N/A
2	Filter media	$K_{C,CO2,2}$	N/A	N/A
3	Membrane	$K_{C,CO2,3}$	N/A	N/A
N	Others	$K_{C,CO2,t}$	$K_{C,CH4,t}$	$K_{C,N2O,t}$

[a] Suffix "t" refers to numbers from 1 to N.

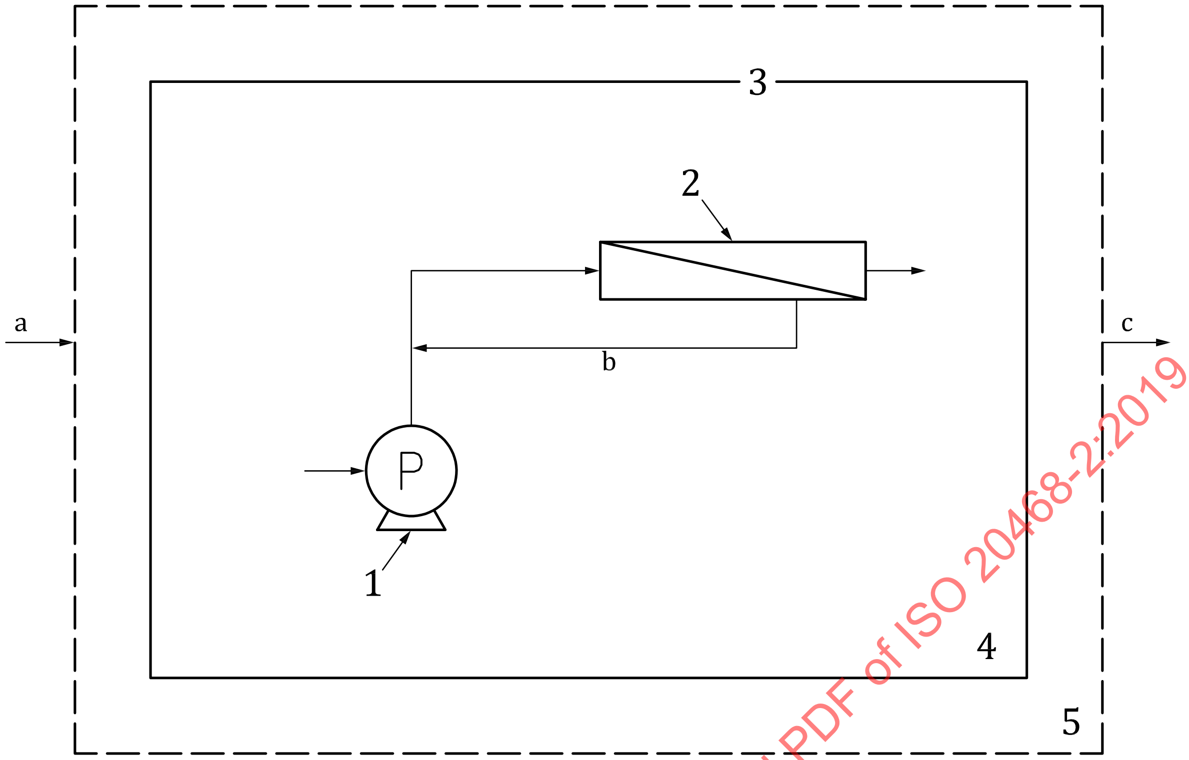
[b] Unit refers to the unit in Table 7.

7.8 Step 6: Calculate GHG emissions reduced through the effective utilization of resources resulting from the production of reclaimed water

The calculation methods to be used when GHG emissions can be reduced by means of resources resulting from the production of reclaimed water are shown in Table 9. This calculation may be omitted if it is expected that no useful resources, such as energy, are produced.

Table 9 — Methods for calculating GHG emissions reduced in various scenarios when effectively utilizing resources resulting from the production of reclaimed water

Place of use	Considerations in calculating GHG reduction
Resource utilization in a treatment system	Generally, the GHG reduction achieved by effective resource utilization appears within the set boundary conditions. However, it is suggested to confirm how and where the reduction is counted for accuracy. Example (see Figure 3): This example shows that double counting of the GHG reduction should be avoided. When energy recovered in the RO process makes up for energy used to operate RO feed pumps, the reduction of power consumed by the RO feed pumps is consequently counted as a reduction of GHG emissions. Accordingly, this reduction should not be subtracted from emissions in boundary conditions.
Resource utilization in a residue management system	Counting the GHG reduction achieved by effective resource utilization depends on the boundary conditions set for a residue management system. As a result, it is necessary to identify how and where the reduction is implemented. Two examples are shown as follows. Example (see Figure 4): This example shows that double counting of the GHG reduction should be avoided. When biogas from anaerobic process, which was installed in the same water reuse project, is used as the source to heat the anaerobic digesters, the reduction of heat amount is counted as the reduction of GHG emissions. Accordingly, this reduction should not be subtracted from emissions in boundary conditions. Note that CO_2 resulting from combustion of methane derived from biomass is not included in this calculation according to the carbon neutral concept. Example (see Figure 5): When the residue management system is not included in the boundary conditions of an evaluation, the benefit is quantified as the reduction of GHG emissions ($E_{R,CO2eq,annual}$) and may be subtracted from GHG emissions.
Resource utilization in an auxiliary system	Based on the concept of a residue management system
Resource utilization at locations other than the above	The benefit of effective utilization does not appear in the GHG reduction in the boundary conditions. Accordingly, the benefit may be quantified as the reduction of GHG emissions ($E_{R,CO2eq,annual}$) and subtracted from GHG emissions. Example (see Figure 6): When energy recovered during production of reclaimed water is used in businesses other than reclaimed water production, the amount of greenhouse gases equivalent to the amount of supplied energy may be estimated and subtracted from the emissions from the boundary conditions.

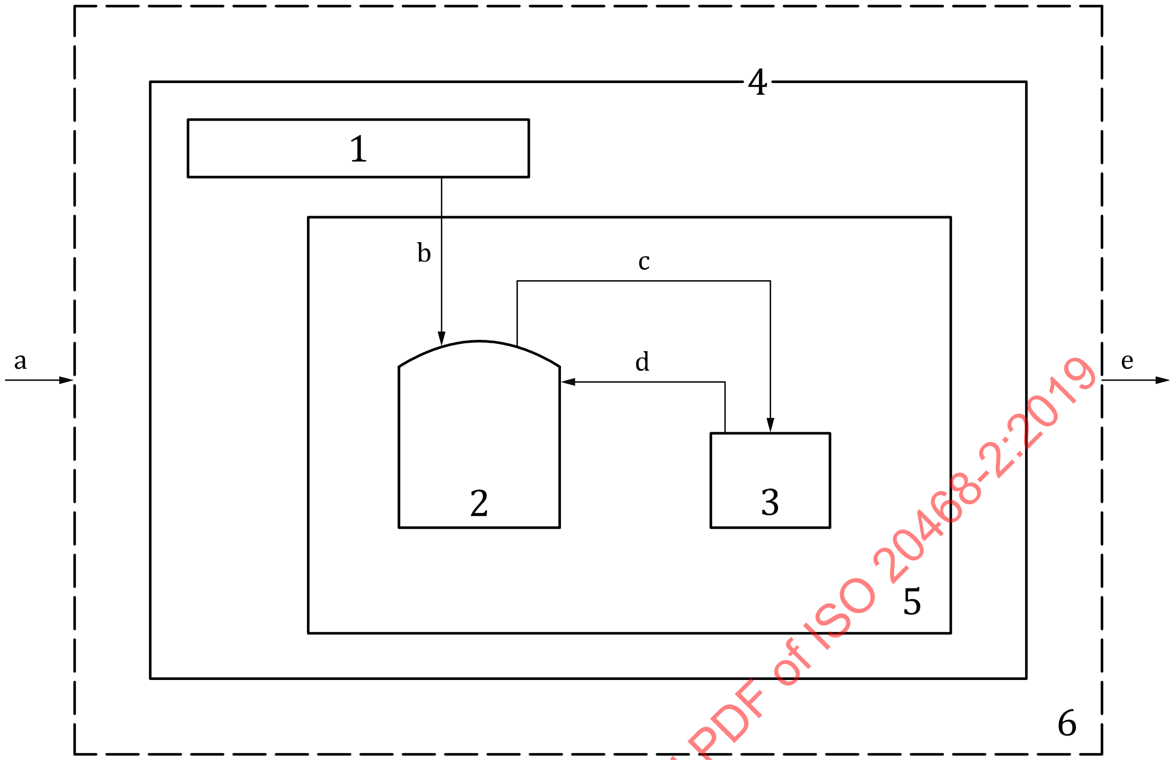


Key

1 RO feed pump
2 RO membrane
3 boundary conditions
4 treatment system
5 water reclamation plant
a Raw water.
b Recovered energy.
c Reclaimed water.

NOTE In this case, $E_{R,CO2eq,annual}$ is not counted in the calculation due to the recovered energy effectively utilized in the boundary conditions and the corresponding GHG reduction computed in RO feed pump.

Figure 3 — Example of resource utilization in the treatment system

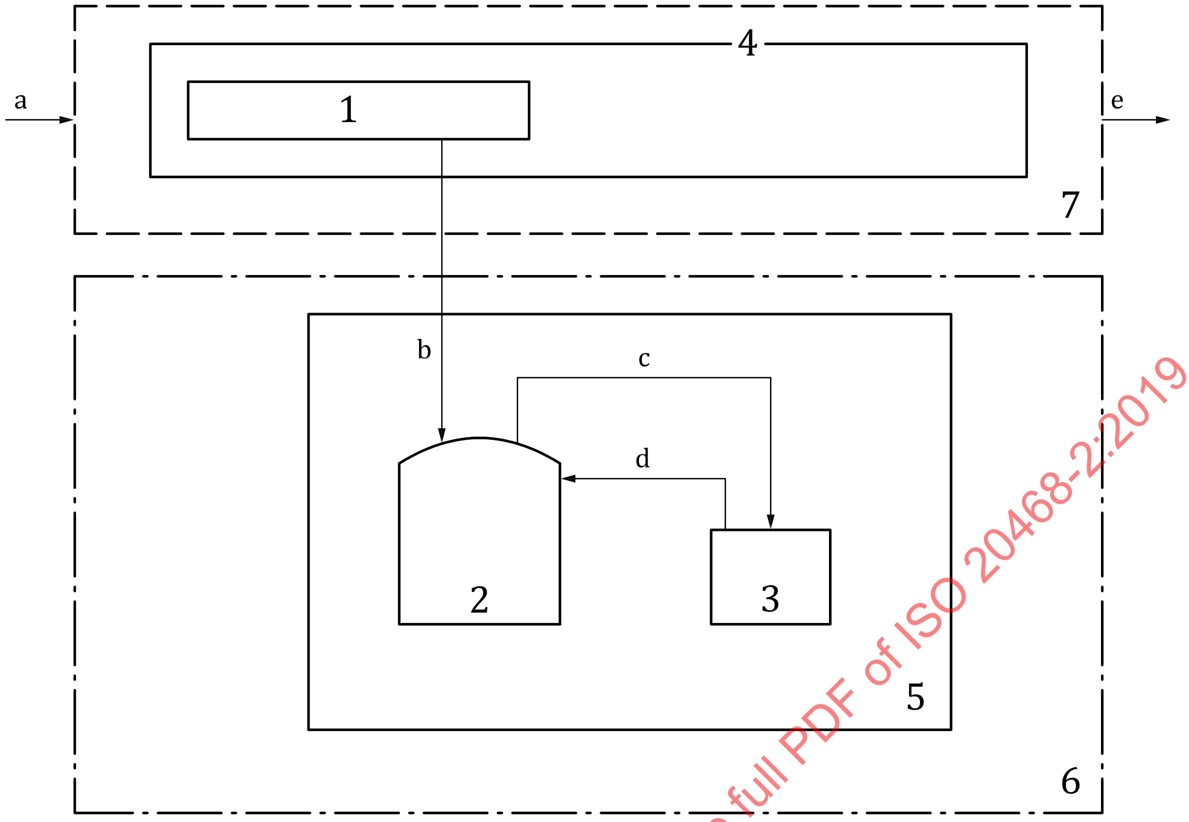


Key

1	treatment system	a	Raw water.
2	anaerobic digester	b	Sludge.
3	boiler	c	Biogas.
4	boundary conditions	d	Steam.
5	residue management system	e	Reclaimed water.
6	water reclamation plant		

NOTE In this case, $E_{R,CO2eq,annual}$ is not counted in the calculation due to biogas effectively utilized in the boundary conditions and the corresponding GHG reduction computed in the residue management system.

Figure 4 — Example of resource utilization in the residue management system within the boundary conditions

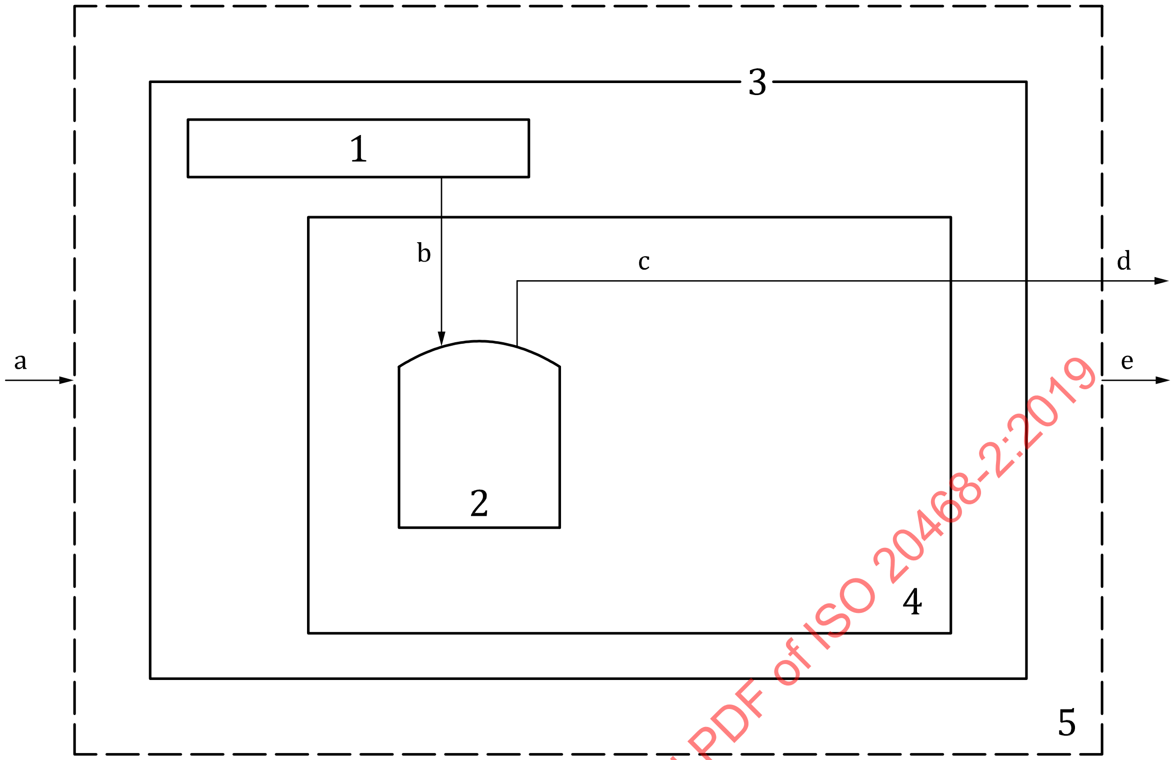


Key

1 treatment system
2 anaerobic digester
3 boiler
4 boundary conditions
5 residue management system
6 other plant (e.g. existing STP)
7 water reclamation plant
[a] Raw water.
[b] Sludge.
[c] Biogas.
[d] Steam.
[e] Reclaimed water.

NOTE In this case, $E_{R,CO2eq,annual}$ can be counted in the calculation due to biogas effectively utilized out of the boundary conditions and the corresponding GHG reduction not appearing in the boundary conditions.

Figure 5 — Example of resource utilization in the residue management system outside the boundary conditions



Key

1 treatment system
2 anaerobic digester
3 boundary conditions
4 residue management system
5 water reclamation plant

a Raw water.
b Sludge.
c Biogas.
d To other facilities.
e Reclaimed water.

NOTE In this case, $E_{R,CO2eq,annual}$ can be counted in the calculation due to biogas effectively utilized out of the boundary conditions and the corresponding GHG reduction not appearing in the boundary conditions.

Figure 6 — Example of resource utilization at locations other than above

7.9 Step 7: Calculate total GHG emissions

Each amount of greenhouse gas (CO_2, CH_4, N_2O) is multiplied by the respective global warming potential (Table 10), and total emissions are determined. However, if the effective utilization of generated resources is achieved within the boundary conditions of the evaluation of a treatment system, due care should be taken to prevent duplication when counting the reduction resulting from effective utilization and the reduction of GHG emissions resulting from energy consumption. An example of a worksheet for calculating total GHG emissions is available in Annex B.

Total GHG emissions ($E_{T,CO2eq,annual}$) are calculated from Formula (9):

$$E_{T,CO2eq,annual} = (E_{E,CO2,annual} + E_{C,CO2,annual}) \times K_{GWP,CO2} + (E_{E,CH4,annual} + E_{P,CH4,annual} + E_{C,CH4,annual}) \times K_{GWP,CH4} + (E_{E,N2O,annual} + E_{P,N2O,annual} + E_{C,N2O,annual}) \times K_{GWP,N2O} - E_{R,CO2eq,annual} \left[\text{tons of } CO_{2eq} \text{ per year}\right] \quad (9)$$

Table 10 — Global warming potential of each greenhouse gas

ID No. t[a]	Parameter	Global warming potential $K_{GWP,t}$[b]
CO_2	Carbon dioxide	1
CH_4	Methane	25
N_2O	Nitrous oxide	298

[a] Suffix “t” refers to CO_2, CH_4 and N_2O.

[b] See Reference [3].

7.10 Step 8: Calculate CO_{2eq} emission intensity

CO_{2eq} emission intensity (I_{CO2eq}) is calculated from Formula (10) using $E_{T,CO2eq,annual}$ and Q_{annual}:

$$I_{CO2eq} = E_{T,CO2eq,annual} / Q_{annual} \text{ [kg } CO_{2eq} \text{ per } m^3\text{- reclaimed water]} \tag{10}$$

A calculation example is shown in Annex C.

8 Application of CO_{2eq} emission intensity in evaluating the environmental performance of a treatment system

The environmental performance of a treatment system increases as CO_{2eq} emission intensity (I_{CO2eq}) decreases.

EXAMPLE 1

A water reclamation plant needs to compare the environmental performance of multiple treatment systems at the planning stage.

When there are two (X and Y) candidate treatment systems, CO_{2eq} emission intensity (I_{CO2eq}) is calculated for each system and compared. For example, “CO_{2eq} emission intensity (I_{CO2eq}) of treatment system X” less than “CO_{2eq} emission intensity (I_{CO2eq}) of treatment system Y” means that the environmental performance of system X is higher. Accordingly, the system X should be selected from the aspect of environmental awareness.

The same emission factors for treatment systems to be compared should be used for this application to avoid an evaluation that is adversely influenced by the emission factors used.

EXAMPLE 2

A water reclamation plant needs to develop a benchmark for the environmental performance of a treatment system already in service.

The CO_{2eq} emission intensity (I_{CO2eq}) in FY 2016 for a treatment system already in service may be used as the numerical target for more eco-friendly operation in FY 2017.

Annex A
(informative)

Examples of emission factors

For reference, Table A.1 to Table A.3 illustrates emission factors to be used in the calculation of GHG emissions.

Table A.1 — GHG emission factors resulting from energy consumption

ID No. t[a]	Activity	CO_2 emission factor $K_{E,CO2,t}$	CH_4 emission factor $K_{E,CH4,t}$	N_2O emission factor $K_{E,N2O,t}$
1	Imported Electricity	0,5[b] ton of CO_2/MWh	N/A	N/A

[a] Suffix “t” refers to 1.

[b] This value is the world average electricity emission factor from the International Energy Agency (IEA). (See Reference [4])

Table A.2 — GHG emission factors resulting from biological treatment processes

ID No. t[a]	Activity	CH_4 emission factor $K_{P,CH4,t}$	N_2O emission factor $K_{P,N2O,t}$
1	Sewage treatment (conventional activated sludge process)[b]	0,000 528 7[d] ton of CH_4/thousand m^3-feed	0,000 142[e] ton of N_2O/thousand m^3-feed
2	Sewage treatment (AO process)	0,000 528 7[d] ton of CH_4/thousand m^3-feed	0,000 029 2[e] ton of N_2O/thousand m^3-feed
3	Sewage treatment (A2O process and RND process)[c]	0,000 528 7[d] ton of CH_4/thousand m^3-feed	0,000 011 7[e] ton of N_2O/thousand m^3-feed
4	Sewage treatment (RND type MBR)	0,000 528 7[d] ton of CH_4/thousand m^3-feed	0,000 000 5[e] ton of N_2O/thousand m^3-feed
5	Anaerobic landfill of digested sewage sludge	0,100 ton of CH_4/ds-ton	N/A
6	Semi-aerobic landfill of digested sewage sludge	0,050 ton of CH_4/ds-ton	N/A

[a] Suffix “t” refers to numbers from 1 to 9.

[b] Includes all biological sewage treatment processes other than those indicated above.

[c] Includes all biological sewage treatment processes which remove nitrogen to the same level or greater than Anaerobic-anoxic-oxic process and recycled nitrification-denitrification process, but excludes recycled nitrification-denitrification membrane bioreactor.

[d] In case the sewage sludge treatment is counted in the boundary conditions, the total emission factor for both sewage and sludge treatment may be utilized for the calculation. The total emission factor is 0,000 876 7 by adding 0,000 348 (ton of CH_4/1 000 m^3-feed) for sludge treatment into 0,000 528 7 for the sewage treatment listed above.

[e] In case the sewage sludge treatment is counted in the boundary conditions, the total emission factor for both sewage and sludge treatment may be utilized for the calculation. The total emission factor is calculated as follows using 0,000 000 6 (ton of N_2O/1 000 m^3-feed) for sludge treatment. e.g. Conventional activated sludge process with the sludge treatment: 0,000 142 + 0,000 000 6 = 0,000 142 6 ton of N_2O/1 000 m^3-feed for the total emission factor.

NOTE See Reference [5].

Table A.2 *(continued)*

ID No. t[a]	Activity	CH_4 emission factor $K_{P,CH4,t}$	N_2O emission factor $K_{P,N2O,t}$
7	Anaerobic landfill of other sewage sludge	0,133 ton of CH_4/ds-ton	N/A
8	Semi-aerobic landfill of other sewage sludge	0,067 ton of CH_4/ds-ton	N/A
9	Composting	0,01 ton of CH_4/ds-ton	0,000 6 ton of N_2O/ds-ton

a Suffix “t” refers to numbers from 1 to 9.

b Includes all biological sewage treatment processes other than those indicated above.

c Includes all biological sewage treatment processes which remove nitrogen to the same level or greater than Anaerobic-anoxic-oxic process and recycled nitrification-denitrification process, but excludes recycled nitrification-denitrification membrane bioreactor.

d In case the sewage sludge treatment is counted in the boundary conditions, the total emission factor for both sewage and sludge treatment may be utilized for the calculation. The total emission factor is 0,000 876 7 by adding 0,000 348 (ton of CH_4/1 000 m^3-feed) for sludge treatment into 0,000 528 7 for the sewage treatment listed above.

e In case the sewage sludge treatment is counted in the boundary conditions, the total emission factor for both sewage and sludge treatment may be utilized for the calculation. The total emission factor is calculated as follows using 0,000 000 6 (ton of N_2O/1 000 m^3-feed) for sludge treatment. e.g. Conventional activated sludge process with the sludge treatment: 0,000 142 + 0,000 000 6 = 0,000 142 6 ton of N_2O/1 000 m^3-feed for the total emission factor.

NOTE See Reference [5].

Table A.3 — GHG emission factors resulting from consumables and wastes

ID No. t[a]	Activity	CO_2 emission factor $K_{C,CO2,t}$	CH_4 emission factor $K_{C,CH4,t}$	N_2O emission factor $K_{C,N2O,t}$
1	Sodium hypochlorite	0,321[b] ton of CO_2/ton	N/A	N/A
2	Polymer coagulant	6,534[b] ton of CO_2/ton	N/A	N/A
3	Ferric chloride	0,318[b] ton of CO_2/ton	N/A	N/A
4	PACL (Polyaluminum chloride)	0,405[b] ton of CO_2/ton	N/A	N/A
5	Sodium hydroxide	0,938[b] ton of CO_2/ton	N/A	N/A
6	Granular activated carbon	7,768[b] tons of CO_2/ton	N/A	N/A
7	Natural silica sand (Filter media)	0,029[b] ton of CO_2/ton	N/A	N/A
8	Membrane main body (organic membrane)	0,0108[c] ton of CO_2/m^2	N/A	N/A

a Suffix “t” refers to numbers from 1 to 8.

b See Reference [6].

c See Reference [7].

Annex B
(informative)

Example of a worksheet for calculating total GHG emissions

Table B.1 provides an example of a worksheet used for calculating total GHG emissions.

Table B.1 — Example of a worksheet used for calculating total GHG emissions

	Greenhouse gas emissions reference			CO_2-converted emissions for each gas			Emissions
	CO_2 tons of CO_2/year	CH_4 tons of CH_4/year	N_2O tons of N_2O/year	CO_2 tons of CO_2/year	CH_4 tons of CO_{2eq}/year	N_2O tons of CO_{2eq}/year	CO_2-converted value tons of CO_{2eq}/year
Emissions resulting from energy consumption (see 7.5)							
Emissions from biological treatment processes (see 7.6)							
Emissions resulting from consumables and generation of wastes (see 7.7)							
Reduction of emissions through effective utilization of resources resulting from the production of reclaimed water (see 7.8)							
Total GHG emissions (see 7.9)							