Water and Wastewater Companies for Climate Mitigation

WaCCliM

Methodology Guide

Energy Performance and Carbon Emissions Assessment and Monitoring Tool - ECAM

Elaborated by: WaCCliM - Water and Wastewater Companies for Climate Mitigation

Authors:

Bruno Eduardo Silva*
Carolina Cabral*
Sebastian Rosenfeldt*
**Rotária do Brasil*

Reviewers:

Adriana Veizaga**, Martin Kerres**, David Moskopp**, Geraldine Canales**, Catherine Cardich Salazar**, Bianca Corona**, Nadine Ghantous**, Nooraldeen Balah**, Lisa Oberkircher**, Amalia Palacios*** and María Eugenia de la Peña***
***Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)*
**** Inter-American Development Bank (IDB)*

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The Water and Wastewater Companies for Climate Mitigation (WaCCliM) project is a joint initiative between the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the International Water Association (IWA). This project is part of the International Climate Initiative (IKI). The German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) supports this initiative on the basis of a decision adopted by the German Bundestag.

On behalf of: Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection of the Federal Republic of Germany

Implemented by: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH; the international water association

Water and Wastewater Companies for Climate Mitigation

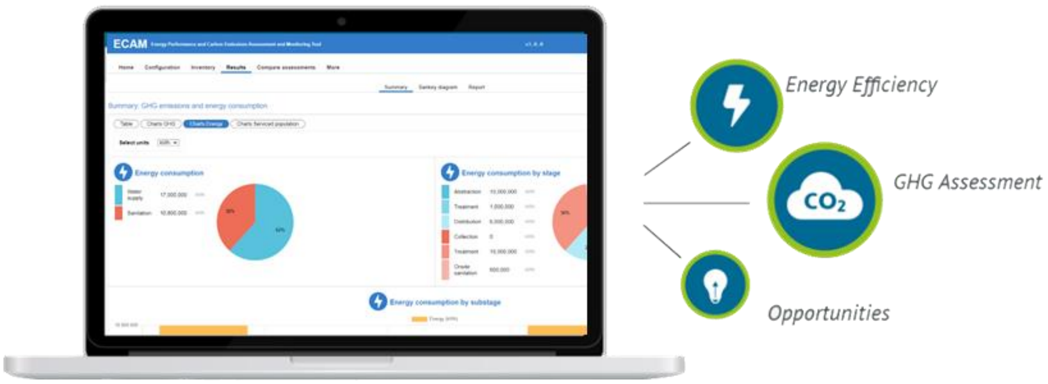
WaCCliM

Executive summary

The **ECAM Methodology Guide** was conceived in the context of **WaCCliM** (Water and Wastewater Companies for Climate Mitigation). WaCCliM is a global project implemented by the **Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)** GmbH in collaboration with the **International Water Association (IWA)**. The project seeks to contribute to low-carbon and climate-resilient water and sanitation sectors. In its scope, WaCCliM developed the ECAM tool (Energy Performance and Carbon Emissions Assessment and Monitoring) to measure and monitor greenhouse gas (GHG) emissions from the urban water sector.

This **Methodology Guide** was developed as an additional instrument to the **ECAM tool**. The guide presents the tool's methodological background which includes the principles, equations, sources, and assumptions. It can serve as a reference source and allow comparisons with other methodologies, making it suitable for users with all levels of experience.

The **ECAM tool** assists water utilities in using their own data to transform it into a source of valuable information on energy performance and GHG emissions. ECAM is the first of its kind to allow for a holistic approach of the urban water cycle to drive GHG emission reduction in water utilities, even those with limited data availability. It promotes transparency, comparability, and consistency. It is designed to assess the carbon emissions that utilities can control within the urban water cycle and prepares utilities for future reporting needs on climate mitigation.



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Abbreviations

BMUV	German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection
BOD	Biochemical Oxygen Demand
CC	Climate Change
CH_4	Methane
CO_2	Carbon Dioxide
$CO_{2\text{-}}$eq	Carbon Dioxide Equivalent
COD	Chemical Oxygen Demand
ECAM	Energy Performance and Carbon Emissions Assessment and Monitoring
EF	Emission Factor
EIB	European Investment Bank
ERSAR	Portuguese Water and Waste Services Regulation Authority (Abbreviation in Portuguese)
FS	Faecal Sludge
GHG	Greenhouse Gas
GWP	Global Warming Potential
ICRA	Catalan Institute for Water Research (Abbreviation in Catalan)
IKI	International Climate Initiative (Abbreviation in German)
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
ITA	Instituto Tecnológico del Agua
IWA	International Water Association
KPI	Key performance indicator
LCA	Life cycle assessment

Abbreviations

LNEC	Laboratório Nacional de Engenharia Civil
MCF	Methane correction factor
N	Nitrogen
N_2O	Nitrous oxide
NCV	Net calorific values
NO_2^-	Nitrite
NO_3^-	Nitrate
PI	Performance indicator
TN	Total nitrogen
UNFCCC	United Nations Framework Convention on Climate Change
UWC	Urban water cycle
VS	Volatile solids
WaCCliM	Water and Wastewater Companies for Climate Mitigation
WS	Water supply
WTP	Watert treatment plant
WWTP	Wastewater treatment plant

Glossary

Note: This glossary describes the terms as they are used in this methodology guide and ECAM.

Activated sludge	Flocs of sludge particles containing living microbes, mainly bacteria and protozoans, which are formed in the presence of oxygen in aeration tanks.
Activity data	Data on the magnitude of a human activity resulting in emissions or removals taking place during a given period. Data on energy use, metal production, land areas, management systems, lime and fertilizer use and waste arisings are examples of activity data.
Aerobic	Conditions with free oxygen in the wastewater.
Anaerobic	Conditions in which oxygen is not readily available. These conditions are important to produce methane emissions. Whenever organic material decomposes in anaerobic conditions methane is likely to be formed.
Anoxic	Conditions of oxygen deficiency or lacking sufficient oxygen as the electron acceptor in the wastewater. Other electron acceptors such as nitrate and nitrite (NO_x) would be used by microbes under these situations.
Assessment	Type of diagnosis that allows a utility to create an inventory over its activities within a defined period, of all its greenhouse gas emissions broken down by emission items
Base year	The starting year for the inventory.
Benchmark	Objective comparison of utilities or facilities.
Biogenic carbon	Carbon derived from biogenic (plant or animal) sources excluding fossil carbon.
Biological oxygen demand (five-day) BOD_5	Amount of oxygen which bacteria and other microorganisms consume in a water sample during the period of 5 days at a temperature of 20 °C to degrade the water contents aerobically. BOD_5 is thus an indirect measure of the sum of all biodegradable organic substances in the water.
Carbon footprint	Total greenhouse gas emissions caused by an individual, event, organization, service, or product, expressed as carbon dioxide equivalent.
Census	Data collected by interrogation or count of an entire population.
Chemical oxygen demand to nitrogen ratio (COD/N)	An index to reflect the carbon source availability during denitrification, which requires organic carbon to provide electrons for the reduction of nitrogenous compounds such as nitrate or nitrite in wastewater.

Glossary

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Chemical oxygen demand (COD)	Amount of oxygen equivalent consumed in the chemical oxidation of organic matter by strong oxidants such as potassium dichromate. An indication of the amount of organic material in wastewater.
Combined heat and power (CHP)	Combined heat and power (CHP), also known as cogeneration, is the simultaneous production of both electricity and useful heat for application by the producer or to be sold to other users with the aim of better utilisation of the energy used. Public utilities may utilise part of the heat produced in power plants and sell it for public heating purposes. Industries as auto-producers may sell part of the excess electricity produced to energy suppliers.
Country-specific data	Data for either activities or emissions that are based on research carried out on sites either in that country or otherwise representative of that country.
Direct emission	Emissions originated from sources owned (or controlled) by the utilities. Some examples are CO_2 emissions from in-situ engines and CH_4 and N_2O emissions from wastewater treatment plants.
Dissolved methane	Methane (CH_4) gas present in dissolved form in the water phase.
Dissolved oxygen	Molecular oxygen dissolved in wastewater.
Dropdown menus	Selectable list based on a reference table.
Emission factor	A coefficient that quantifies the emissions or removals of a gas per unit activity. Emission factors are often based on a sample of measurement data, averaged to develop a representative rate of emission for a given activity level under a given set of operating conditions.
Estimates	Input activity data that can be estimated by the tool or filled in by the user. The estimations are based on user input data.
Expert judgment	A carefully considered, well-documented qualitative or quantitative judgement made in the absence of unequivocal observational evidence by a person or persons who have a demonstrable expertise in the given field.
Fossil carbon	Carbon derived from fossil source.

Glossary

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Fuel	Any substance burned as a source of energy such as heat or electricity.
Fuel combustion	Oxidation of fuel materials usually used to provide heat or mechanical work to a process.
Fugitive emissions	Emissions that are not emitted by an intentional release. This can include leaks from pipes or biogas flaring.
Global Warming Potential (GWP)	Ratio of the radiative forcing of one kilogramme greenhouse gas emitted to the atmosphere to that from one kilogramme CO_2 over a given period (e.g., 100 years).
Greenhouse gas	Gas that absorbs and emits radiant energy within the thermal infrared range and contributes to the global warming effect.
Indirect emission	Emissions derived from the acquisition of electrical or thermal energy consumed by a utility. It also includes emissions that the utility considers that are not part of its operations, such as CH_4 emissions from wastewater generated by the population not connected to the sewer system.
Input	It includes both the activity data that must be added by the user and the estimates calculated by the software (or calculated by the user). It also includes data chosen from dropdown menus.
Input variable	Variable belonging to the inputs section of ECAM.
Inventory	List of emission sources and the associated emissions quantified using standardized methods.
Nutrient	Substances such as nitrogen or phosphorous compounds and organic carbon that can be assimilated by microbes to promote their metabolism and growth.
Organic matter	Organic waste of plant or animal origin in households or industries, or originated from storm water run-offs.
Output	Results of calculations performed by ECAM
Output variable	Variable belonging to the outputs section of ECAM.
Oxidation	Addition of an oxidizing agent, removal of hydrogen, or the removal of electrons from an element or compound. In wastewater treatment,

Glossary

Note: This glossary describes the terms as they are used in this methodology guide and ECAM.

	organic matter is oxidized to more stable substances. Oxidizing agents can aldo breakdown harmful substances in wastewater (ozonation).
Scope	Setup of the boundaries of a system to determine the GHG assessment. It may include defining which emissions will be considered, or which stages will be accounted for.
Sewer	A network of artificial underground conduits that convey and transport wastewater and/or stormwater from its origin to its treatment point.
Stage	Refers to "Water Abstraction", "Water Treatment", "Water Distribution", "Wastewater Collection", "Wastewater Treatment", and "Onsite Sanitation".
Substage	Refers to the facilities that are to be evaluated in each of the stages. Example: Pumping station number 1; or WWTP number 3.
Survey data	Survey data is derived from random sampling of a population and does not include real data for the whole population.
System	Systems designed to meet human demands related to drinking water supply and sanitation.
Tier (level of information)	A tier represents a level of methodological complexity. Usually, three tiers are provided. Tier 1 is the basic method, Tier 2 intermediate and Tier 3 most demanding in terms of complexity and data requirements. Tiers 2 and 3 are sometimes referred to as higher tier methods and are generally considered to be more accurate.
Uncertainty	Lack of knowledge of the true value of a variable that can be described as a probability density function characterizing the range and likelihood of possible values. Uncertainty depends on the analyst's state of knowledge, which in turn depends on the quality and quantity of applicable data as well as knowledge of underlying processes and inference methods.
Urban water cycle	It is the hydrological cycle within an urban environment, which covers the engineered systems that provide essential and safe drinking water and ensure wastewater and sewage removal. In ECAM, those are the "Water Supply" and "Sanitation" systems, which are composed of six stages: "Water Abstraction", "Water Treatment", "Water Distribution", "Wastewater Collection", "Wastewater Treatment", and "Onsite Sanitation".

Glossary

Note: This glossary describes the terms as they are used in this methodology guide and ECAM.

Urban Water Sector	Refers to utilities, facilities, and urban water activities.
Urban water services	Refers to activities provided by urban water utilities.
Urban water utilities	Refers to the institutions (public or private) responsible for carrying out the urban water services of a municipality or state.
Variable	Field name of an element used for ECAM calculations, whether in the input section or output section. Example: serviced population with wastewater treatment.
Variable code	In ECAM, a variable code is the name associated with a variable, which is used by the tool's algorithm for calculations. Example: "wwt_serv_pop" is the code for serviced opulation with wastewater treatment
Wastewater	The used water including solids discharged from communities, businesses, industry, or agriculture that flows into a wastewater treatment plant. Storm water, surface water, and groundwater infiltration also may be included.

Introduction

About ECAM Tool

The Energy Performance and Carbon Emissions Assessment and Monitoring Tool (ECAM) is the first greenhouse gas (GHG) emissions calculation tool focused on the urban water sector. It is designed for utilities with both high-quality data as well as limited data availability. The advantage over the isolated use of empirical formulas is the possibility of evaluating different systems in parallel, in addition to involving more variables in the calculations, increasing their precision, and facilitating the handling of emissions information by the urban water utilities.

The tool was developed within the framework of the Water and Wastewater Companies for Climate Mitigation (WaCCliM) project, which is a joint initiative between the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the International Water Association (IWA). WaCCliM is commissioned by the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) as part of the International Climate Initiative (IKI).

ECAM has the purpose of evaluating and monitoring GHG emissions from water and wastewater utilities. ECAM is available online, it has an open source and is free to use and tailor. Together with IWA and GIZ, the web interface and features were developed by the Institut Català de Recerca de l'Aigua (ICRA). The tool was first developed for WaCCliM project in 2015 as a spreadsheet tool by the consortium Urban Water Commons (LNEC and ITA, Universitat Politècnica de València) in collaboration with Cobalt Water Global. The spreadsheet tool laid the foundation and basic equations for the web-tool.

To cover all utilities, including those that have limited data on their processes, the tool proposes default values based on the literature, which can be modified by the user to better illustrate local conditions. ECAM also allows to incorporate more data as the utility´s data management capacity grows. Methodologically, ECAM is based on the *Intergovernmental Panel on Climate Change* (*IPCC) Guidelines for National Greenhouse Gas Inventories,* including their 2019 refinement (IPCC, 2019).

Based on the GHG estimations generated by the tool, the utility can identify areas with GHG reduction potential and operating expenses, also strengthening performance monitoring and decision-making.

The tool's functionalities include:

- GHG emissions assessment,
- energy performance assessment,
- identification of opportunities for reducing GHG emissions and energy consumption,
- developing scenarios when investigating possible measures to improve performance,
- monitoring the results after the implementation of improvement measures.

In terms of data security and privacy, no information is stored in fixed memory on a server, but available as a downloadable file with the assessment. Therefore, all data entered is processed locally and stored solely on the user's computer.

As first of its kind, ECAM follows a holistic approach to the urban water cycle, as it is designed to calculate GHG emissions at all stages of the cycle, enabling integrated comparisons and assessments. Thus, the user can create assessments accounting only some stages of a system, the complete system, or even all the systems of a utility.

It is also possible to include energy performance and service level analyses calculated by the tool, such as: topographic energy use; electromechanical efficiency; sludge management; treatment performance; biogas production; and more.

About the Methodology Guide

The **Methodology Guide** has the aim of providing to the complete methodological background of ECAM, which includes:

- Context on GHG and emissions accounting,
- principles, boundaries, and limitations of the tool,
- explanation of formulas and tables,
- presentation of sources and scientific bases,
- debate on limitations and approaches of the tool,
- detailed explanation of terms and expressions.

Note that this methodology document may be used in conjunction with the **ECAM User Manual**, which describes the different functionalities and features of the tool.

Who should use this document?

The target group is composed by water utility managers and technicians, consultants, climate change professionals, academics, and policy makers who are interested in understanding the conceptual background of the ECAM tool.

In addition, anyone interested in the urban water cycle, particularly the energy consumption and GHG emissions from the urban water cycle and how this could be tackled to advance the system towards improved sustainability and efficiency could benefit from this guide.

Conceptual framework

Context overview

How are climate change and the urban water sector related?

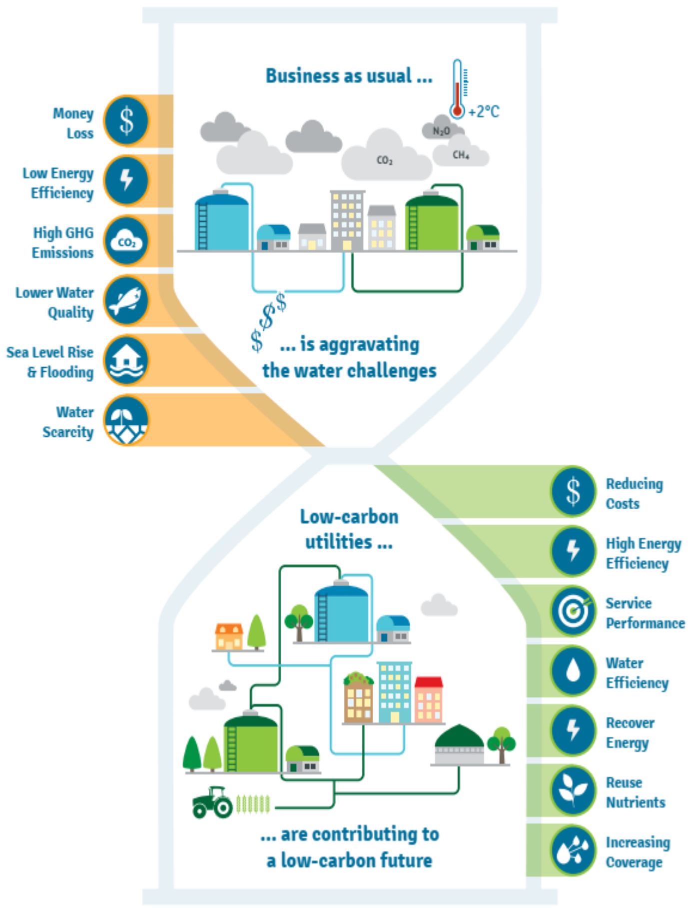
The impacts caused by climate change should be considered during design, construction, operation, and maintenance of the urban water sector infrastructure. These **impacts include**:

- Increased variability and uncertainty in hydrological cycles,
- prolonged droughts and frequent flooding,
- extreme hydrometeorological phenomena,
- sea level rise,
- increased evaporation and decreased precipitation rates accompanied by higher water extraction rates.

Along with pollution, the effects of climate change fall on the availability and quality of water sources for human consumption. In this sense, urban water utilities face increasing treatment requirements, while having to deal with structural damage caused by extreme weather.

Additionally, the operation of urban water systems contributes to the generation of GHG emissions, either directly or indirectly. These gases are the main drivers of climate change, which increases the occurrence of extreme events and hinders the availability of natural resources. Therefore, **the relationship between climate change and urban water utilities is cyclical and mutually impacting**.

In this context, *business-as-usual* is no longer a viable option: utilities are challenged to adapt to impacts of climate change but also to champion the transition to a carbon-neutral future, to avoid compounding their challenges.



There is a great opportunity to promote better planning of urban water services. This also means creating GHG emissions mitigation strategies within the operation of facilities, ensuring the sustainability of services and benefiting human life.

Which GHG are generated in urban water services?

The three main GHGs emitted from urban water services are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

Carbon dioxide (CO_2)

Carbon dioxide is mainly associated with the burning of fossil fuels in stationary and mobile combustion engines. In the urban water sector, it is the main GHG associated with the consumption of electrical energy from the grid (Smith et al., 2016). It was estimated that energy-intensive processes associated with abstracting, supplying and treating water and wastewater accounted for around 4% of global electricity consumption in 2014 (IEA, 2016). In many cases, the energy consumed is obtained from a fossil fuel source, such as coal, oil or natural gas. Energy production from these sources generates carbon dioxide emissions. Water and wastewater utilities encompass energy-intensive processes, making this a significant emission to consider (Rothausen; Conway, 2011).

In addition, CO_2 can also be emitted from biogenic sources, i.e., emissions related to the natural carbon cycle, as well as from the combustion, harvesting, digestion, fermentation, decomposition, or processing of bio-based materials. These emissions are not considered in the ECAM tool, and further discussion is given in this document´s topic **CO2 emissions from biological degradation.**

Methane (CH_4)

Methane formation occurs from the degradation of organic matter under anaerobic digestion conditions, which can be present in wastewater and sludge. Anaerobic digestion usually occurs in two stages. In the first stage, facultative and anaerobic bacteria convert complex organic compounds into simpler organic materials such as fatty acids and alcohols by hydrolysis and fermentation processes.

In the second stage, called methanogenesis, part of the simpler organic materials is converted into methane and carbon dioxide by methanogenic archaea (Chernicharo, 2015).

As it is generated from a basic degradation process, methane is present in several stages of the urban water sector. In wastewater treatment, the CH_4 emissions can make up a significant portion of a wastewater treatment plant's (WWTP) carbon footprint, and in cases such as an anaerobic lagoon (>2m) it can be even much greater (Daelman et al., 2013; Foley, 2015; Hwang et al., 2016; Delre et. Al, 2017).

Methane can also be emitted from sludge handling processes, mainly from sludge anaerobic stabilization and long-term sludge drying processes (Daelman et al., 2012; Hwang et al., 2016; Tauber et al., 2019). Significant amounts of methane can leak from anaerobic digestion process due to improper maintenance and operation of sludge anaerobic digesters (Duan, 2019).

Methane could also be generated in flowing closed sewer and released in the treatment process, however, insufficient data exist to quantify emission factors that address the variation in sewer type and operational conditions (Foley, 2015; Liu et al., 2015; Guisasola et al., 2008). Further discussion is given in section **CH4 emissions from closed sewers**.

Nitrous oxide (N_2O)

Nitrous oxide is associated with the degradation of nitrogenous compounds present in wastewater, such as urea, nitrate, and proteins. Its production is associated with nitrification and denitrification processes (Duan et al., 2015). Both processes can occur in a WWTP and in the water body into which the treated and untreated wastewater is discharged.

Nitrification is an aerobic process that converts ammonia and other nitrogenous compounds to nitrate (NO_3^-), while denitrification occurs under anoxic conditions (without free oxygen) and involves the biological conversion of nitrate to di-nitrogen gas (N_2) (Von Sperling, 2015). Nitrous oxide can be an intermediate product of both processes (Foley, 2015).

These processes typically occur in aerobic reactors designed for nitrification and/or denitrification. In nitrification, the N_2O produced is immediately stripped into the atmosphere. Its generation is mainly influenced by high values of nitrite and ammonia at this stage. In denitrification, it can be either diffused into the atmosphere within the same reactors, and/or stripped in downstream aerobic reactors. In this second case, its generation is influenced by a low concentration of dissolved oxygen (< 1mg/L), nitrites and a low chemical oxygen demand (COD) to nitrogen ratio (Kampschreur et al., 2009; Foley, 2015).

In WWTPs, the highest production of nitrous oxide is associated with aeration processes (up to 90%), predominantly from activated sludge units, but it also occurs in other units, such as sludge recirculation, digester sludge, pre-treatment, effluent, and secondary clarifiers. (Ahn et al., 2010; 2009 ; Czepiel et al, 1995; Kampschreur et al., 2009; Mello et. al, 2013)

Estimating and quantifying N_2O from the urban water sector is a complex process. In the past, the United Nations Framework Convention on Climate Change (UNFCCC) did not consider WWTPs as relevant sources and further research is still being conducted to properly determine oxide nitrous emissions from wastewater treatment plants (Foley, 2015; Valkova et al., 2021).

Which activities in the urban water cycle release GHG emissions? Which influencing factors exist at each activity?

The emissions of GHG occur in several stages of the urban water cycle (UWC).

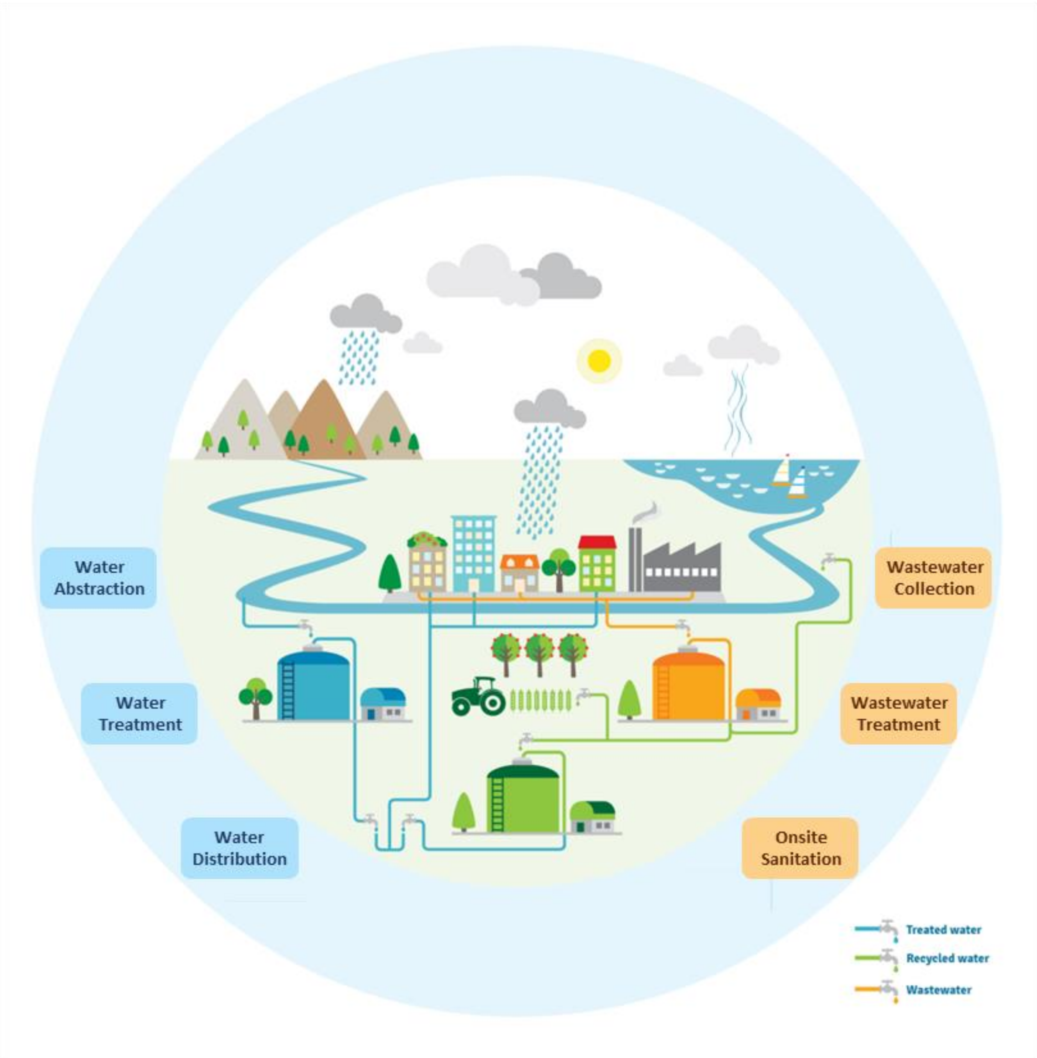


Figure 1- Stages of the Urban Water Cycle as presented in the ECAM tool

The UWC begins at the water source of a city, which can be surface water (lakes, reservoirs, rivers), groundwater, seawater, rainwater, reclaimed water, or any combination thereof. From the source, water is abstracted for potable water supply (**Water Abstraction** stage). Then it is conveyed to the **Water Treatment** stage, which, depending on the water source quality and treatment standards, will involve a wide range of treatment techniques from chemical addition or disinfection to conventional

filtration and even reverse osmosis. After the drinking water treatment stage, the water is delivered to end users during the **Water Distribution** stage.
After being used by the final consumer, the water is converted into wastewater, which must be collected (**Wastewater Collection Stage**) and sent for appropriate treatment. The **Wastewater Treatment** stage comprises all the techniques and technologies needed to treat the influent of a treatment plant and includes the discharge or reuse of clarified effluent. An additional stage also includes the decentralized sanitation (**Onsite sanitation** stage), where faecal sludges must be treated and routed for final disposal.

In this context, urban water utilities contribute with *direct* and *indirect* GHG emissions at each of these stages.

- **Direct emissions** arise from sources owned (or controlled) by the utilities. Some examples are CO_2 emissions from in-situ engines and CH_4 and N_2O emissions from wastewater treatment plants.

- **Indirect emissions** are those derived from the acquisition of electrical or thermal energy, consumed by the utility. In other words, they are emissions that occurred elsewhere, but were stimulated by energy consumption within the sector. For example, the CO_2 emissions from the consumption of electricity to power electromechanical equipment which were produced at the power plant. Indirect emissions can also be related to the utility activities, but that are produced from sources that do not belong to or are not controlled by the utility (for example, CH_4 emissions from wastewater that is generated by the population that is not connected to the sewer system).

The following chapters approach the potential sources of emissions from each of the UWC stages, and the factors that can influence the volume of emissions at each stage.

Water abstraction and treatment stages

In the water abstraction stage, GHG emissions are mainly associated with the consumption of electricity from the public power grid to operate pumping stations; however, there are also direct GHG emissions from the use of fuel or combustion to power pump engines or equipment through emergency generators.

In the water treatment stage, emissions depend on the type of treatment adopted in a water treatment plant (WTP) and the electromechanical equipment used in the facilities. They include:

- Emissions of CO_2 related to energy consumption in equipment such as: blowers, mixers, flocculators, dosing pumps.

- Emissions of CO_2 related to energy consumption in treatment technology such as: filter backwashing, membrane processing, ultraviolet light disinfection.

- CO_2, CH_4, and N_2O direct GHG emissions from fuel use or combustion from engines or emergency generators that drive pumps.


Figure 2 - Drinking water treatment plant (Tratamento de Água e Efluentes, 2022)

The following aspects have a great influence on the generation of GHG emissions at this stage: water losses; pumping efficiency; drinking water demand by final consumers; and treatment technology.

- Drinking water systems must maintain certain pressures or volumes in storage tanks. Any loss of water in the system will require additional energy to recover and ensure proper pressure. Therefore, the lower the loss of water in the entire drinking water system, the less water will have to be withdrawn and the less GHG emissions will be generated during the abstraction stage.

- Assuming that the pumping head conditions, and the volume of water are optimal, the pumping efficiency determines the energy consumption and GHG emissions of the abstraction system. Therefore, the higher the pumping efficiency, the less GHG emissions will be generated in this stage.

- The greater the demand for drinking water, the greater the need to extract water resources and the greater the GHG emissions. This results in potentially higher energy consumption due to pumping and transporting the water to the drinking water treatment facility.

- Treatment technologies and the way they are operated also influence the generation of GHG:
    - In the case of filter backwashing, the more times that filters are backwashed, the more energy consumed during the process. Therefore, it is critical to optimize the backwashing sequence, such that filters are not excessively backwashed. The *more optimal the sequence*, the *less GHG emissions generated* from the treatment stage.

    - For membrane processes, the type of membranes used, and the control of the processes define the emission of GHG. The optimized the process, the less GHG emissions generated from the treatment stage.

    - In the case of ultraviolet disinfection, the aspects with the greatest impact on the generation of GHG are its operation, control and maintenance. In general, the higher the volume of water treated, and the higher the ultraviolet disinfection dose, the higher GHG emissions generated from the ultraviolet disinfection process. However, the dose (as impacted by water turbidity), control and maintenance can be optimized to minimize these emissions, while still meeting minimum disinfection requirements.

Water distribution stage

In the water distribution stage, most GHG emissions will depend on the energy consumption associated with the transport of drinking water from the facilities to the final consumers. In most cases, GHG emissions are:

- CO_2 indirect emissions from the consumption of electricity from the public grid to run the pumps.
- CO_2, CH_4, and N_2O direct GHG emissions from fuel use or combustion from engines or emergency generators that drive pumps.

Figure 3 - Water booster system (Metropolitan Industries, 2019)

The following aspects have a great influence on the generation of GHG emissions at this stage: water losses; pumping efficiency; and demand for drinking water by final consumers.

- As for the water collection stage, any loss of water from the system will require additional energy for its recovery and distribution to final consumers. Therefore, the lower the water loss from the system, the less emissions will be generated during the distribution stage.
- Assuming that the pumping head conditions and the volume of water are optimal, the pumping efficiency can condition the energy consumption and GHG emissions of the distribution system. Therefore, the higher the pumping efficiency, the less emissions will be generated in the distribution stage.

- Finally, as well as in the water collection stage, the demanded amount of drinking water affects the GHG emissions generated during the drinking water distribution stage. The *greater* the *demand* for drinking water, the *more quantity must be distributed and pumped* to customers, and *more GHG emissions* are generated.

Wastewater collection stage

In the wastewater collection stage, emissions include:

- CO_2 indirect emissions from the consumption of electricity from the public grid to pump wastewater using electric motors.
- CO_2, CH_4, and N_2O direct GHG emissions from fuel use or combustion from engines or emergency generators that drive pumps.
- CH_4 and N_2O direct emissions from sewers.
- CH_4 and N_2O direct emissions from collected wastewater discharge without treatment.
- CH_4 and N_2O indirect emissions from population not connected to the sewers.

Figure 4 - Sewer system construction (Designing Buildings, 2022)

The following aspects have a great influence on the generation of GHG emissions at this stage: pumping efficiency; drinking water demand by final consumers; infiltration and influx; direct wastewater discharge.

- If the pumping head conditions and the volume of water are optimal, the pumping efficiency can determines the energy consumption and GHG emissions of the collection system. Therefore, the higher the pumping efficiency, the less GHG emissions will be generated in the wastewater collection stage.

- The higher the drinking water demand and use by households, the more wastewater will be dumped into sewerage networks and, in some cases, will have to be pumped out afterwards. On the other hand, the more wastewater is discharged into the sewer, the greater the possibility that methane will be produced and emitted. Therefore, the *lower the demand* for drinking water, the *less GHG emissions* will be generated during the wastewater collection stage.

- For sewer systems that require pumping, the *greater the infiltration and inflow* of water into the collection system, the *greater the energy consumption required* to pump the additional water, which leads to *increased GHG emissions*.

- Finally, the *direct discharge* of untreated wastewater can *generate methane and nitrous oxide* emissions in receiving water bodies. This happens when not all the wastewater is collected and transporting a larger volume of wastewater to the wastewater treatment plant can reduce or eliminate these GHG emissions.

Wastewater treatment and onsite sanitation

In wastewater treatment the GHG emissions are generally related to:

- CO_2 indirect emissions from the consumption of electricity from the public grid to supply the electromechanical equipment necessary for the operation of the WWTP: pumps, aerators, mixers, and grit traps. Generally, the aeration process is the most energy consuming. Therefore, opportunities to optimize the aeration system and control should be explored wherever possible, assuming that air intake can be controlled, and dissolved oxygen measured at short intervals throughout the day.

- CO_2, CH_4, and N_2O direct GHG emissions from fuel use or combustion from engines or emergency generators that drive pumps.

- CH_4 direct emissions from wastewater treatment, incomplete biogas combustion during anaerobic digestion, improper management of activated sludge systems, and pipeline leaks of biogas.

- CH_4 and N_2O direct emissions from discharge of treated wastewater.

- N_2O direct emissions generated from the biological processes of nitrogen elimination, which has its greatest production in aeration tanks.

- CH_4 and N_2O direct and indirect emissions from sludge management and transport.
    - Sludge is a product resulting from wastewater treatment, and its characteristics depend on the conditions of the raw sewage and the wastewater treatment technology employed. Sludge is produced in three possible stages of treatment (primary, secondary, tertiary), and can be managed through different techniques, such as aerobic and anaerobic stabilization (digestion), composting and drying.

- CH_4 is generated mainly in sludge holding tanks and transport lines, which are areas with high COD levels and low oxygen concentration. In the form of dissolved methane, it is also generated in digesters, sludge thickeners and tanks. (Guisasola et al., 2008; Foley et al., 2009)

- N_2O is generated most significantly in aerobic stabilization techniques, such as composting, incineration and landfilling.

In onsite sanitation, direct emissions are generated in fecal sludge containment, treatment, and disposal.

Figure 5 - Münchehofe wastewater treatment plant (Berliner Wasserbetriebe, 2022)

The following aspects have a great influence on the generation of GHG emissions at this stage: pumping efficiency; drinking water demand by final consumers; infiltration and influx; treatment requirements; ammonia load and aeration control; COD/N ratio; biogas valorization; water reuse.

- Assuming that the conditions of pumping head and the volume of water are optimal, the pumping efficiency can condition the energy consumption and greenhouse gas emissions of the WWTP pumping system. Therefore, the higher the pumping efficiency, the less emissions will be generated in the wastewater collection stage.

- The more water is demanded and used, the more wastewater the system must treat. End consumers impact GHG emissions from the wastewater treatment stage because of how much drinking water they consume and how they consume it. Therefore, the lower the demand for drinking water, the less emissions will be generated during the wastewater treatment stage.

- The greater the infiltration and inflow of water into the collection system and the collection of wastewater to WWTP, the more energy is used to process the additional water that has entered the system. Therefore, the lower the infiltration and inflow of water, the less GHG emissions will be generated during the wastewater treatment stage.

- Depending on the quality of the received wastewater quantities, the more treatment that is required, the more GHG emissions will be generated, mainly because of energy consumption required by aeration systems in wastewater treatment plants.

- The daytime charges of ammonia reaching the wastewater treatment plant and how aeration is controlled to remove ammonia (when necessary) can have a significant impact on both energy consumption and nitrous oxide emissions. Depending on ammonia concentrations or charges, excess or lack of dissolved oxygen required to carry out the chemical reaction, can lead to the production and emission of large amounts of nitrous oxide. Control of the oxygen dissolved in biological reactors is essential. Therefore, an adequate concentration of dissolved oxygen can reduce GHG emissions generated in the wastewater treatment stage.

- The COD/N ratio in wastewater can influence nitrous oxide emissions from denitrification. A low COD/N ratio, derived from carbon-limited wastewater, can inhibit the steps necessary to reduce nitrate to nitrogen gas during denitrification. In these cases, nitrous oxide, which is an intermediate product in this process, can accumulate and be emitted instead of being reduced to nitrogen gas. The external addition of carbon can simultaneously contribute to the nitrogen removal process and minimize nitrous oxide emissions.

- The biogas produced can be recovered and used as an energy source to reduce the consumption of electricity from the grid or the fuel of the engines. Consequently, the more biogas that is used as energy, the less GHG will be produced at the wastewater treatment stage.

- The higher the demand on water reuse, the greater the need for treating and/or distributing wastewater effluent. The end users impact the GHG emissions of the discharge/reuse stage by how they use water. Therefore, the less reuse water demanded, the less GHG emissions generated from the discharge/reuse stage. However, there are generally more offsetting benefits if water is reused in terms of water security and/or reduced GHG emissions.

Attention: despite the wide range of stages and emissions existing in the UWC, the ECAM tool addresses these aspects in its own way, not considering some emissions and merging some stages of the UWC. This is addressed in the next topic: **ECAM Boundaries**.

ECAM Boundaries

Which emissions can be calculated with ECAM?

In the ECAM tool, emissions are generated from 2 main systems: **Water Supply** and **Sanitation**. They are also sub-categorized into 3 water supply stages: **Abstraction**, **Treatment**, and **Distribution**; and 3 sanitation stages: **Collection**; **Treatment**[1]; and **Onsite sanitation**[2].

When referring to the IPCC Guidelines, emissions related to electricity are addressed in **Volume 2 Energy**, while those referring to biological degradation processes and sludge disposal are addressed in **Volume 5 Waste**.

In the tool, the user is free to select which stages and emissions to consider in the assessment. The choice of which emissions and stages and substages will and will not be considered is called *scoping*. A scope of a GHG emissions inventory may include, for example: only one specific WWTP that needs diagnosis; a specific water distribution zone; or a set of systems belonging to the same urban water utility.

Table 1 shows the emissions that **CAN** be included in the user's scope and are calculated by ECAM.

[1] This stage also includes wastewater discharge.
[2] The ECAM tool addresses onsite sanitation, i.e., decentralized solutions, separately.

Table 1 - List of emissions that can be calculated with ECAM

	Water supply			Sanitation		
Emissions calculated by ECAM	**Abstraction**	**Treatment**	**Distribution**	**Collection**	**Treatment**[3]	**Onsite Sanitation**
Direct emissions						
CO_2, CH_4, and N_2O from onsite engine stationary fossil fuel combustion	●	●	●	●	●	●
CH_4 from sewers or biological wastewater treatment				●	●	
N_2O from sewers or biological wastewater treatment				●	●	
CH_4 and N_2O from collected wastewater discharge without treatment				●		
CH_4 and N_2O from collected treated wastewater discharge					●	●
CH_4 and N_2O from sludge digestion					●	●
CH_4 from faecal sludge containment						●
CH_4 and N_2O from faecal sludge treatment						●
N_2O from open defecation						●
Indirect emissions						
CO_2 from grid electricity usage	●	●	●	●	●	●
CO_2, CH_4, and N_2O from the combustion of fossil fuels in vehicles			●		●[4]	●
CH_4 and N_2O from sludge and faecal sludge management[5]					●	●

[3] In ECAM, it includes emission from wastewater treatment and discharge.
[4] It includes sludge transport, but which is accounted in "sludge management", and truck transport of reused water.
[5] In the case of wastewater treatment, it includes storage at WWTP (direct emission), transportation, and off-site final disposal. In the case of onsite sanitation, it includes transportation and final disposal.

Some emissions cannot be calculated by ECAM due to boundaries of the software's base methodology, or because they fall outside of the boundaries of urban water utilities.

In the topic **IPCC Compliance** of this document, the limitations of the base methodology are discussed, mainly regarding not considering some issues that may be significant in a utilities inventory.

The following emissions **ARE NOT** calculated by the ECAM tool:

- **Emissions related to the electrical consumption of the utilities' administrative units**, which are considered irrelevant in the context of a scope that assesses the technical performance of urban water utilities. However, these emissions can be manually calculated by the user using an *emissions grid factor*, as done by ECAM for the calculation of energy grid emissions by motors and equipment using energy from an external source. If the users wish to understand more about the selection of an energy grid factor, they can consult the UNFCCC's IFIs - Harmonization of Standards for GHG accounting (UNFCC, 2022).

- **Methane emissions generated in flowing closed sewers**, released only in the wastewater treatment stage, which are not considered in the IPCC methodology. The boundaries associated with the lack of calculation of these emissions are discussed in the topic **CH4 emissions from closed sewers** of the ECAM Methodology Guide.

- **Emissions of carbon dioxide associated with biological degradation of wastewater**, whether biogenic or non-biogenic, which are not considered in the IPCC methodology. The boundaries associated with the lack of calculation of these emissions are discussed in the topic **CO2 emissions from biological degradation** of the ECAM Methodology Guide.

- **Emissions referring to the population not connected to the sewage system**, which are not considered as they are not related to the urban water utility's activities. In the case of using the ECAM tool to assess emissions from the sanitation sector of a municipality, for example, it may be interesting to consider them.

- **Emissions from a Life Cycle Assessment (LCA) perspective (e.g., energy consumption for production of equipment, chemicals; emissions related to construction materials; etc.)**. The losses and limitations associated with the lack of calculation of these emissions are discussed in the topic **IPCC vs LCA approach** of this Methodology Guide.

Source of uncertainties

The uncertainties associated with the ECAM tool calculations are explained by one or more of the following aspects:

- Uncertainties associated with the base *methodology*, that is, the *boundaries of the IPCC*. These uncertainties are discussed in the **IPCC Compliance** chapter of this document.

- Uncertainties associated with the factors that make up the *equations and formulas*, that is, the *emission factors adopted* and the *used global warming potentials*.

- Uncertainties associated with *activity data.* in this case, these *uncertainties are associated with limited knowledge* about the parameters needed to fill in the ECAM tool.

It is recommended that uncertainties be pointed out and critically analyzed by an expert when carrying out an Inventory of GHG emissions.

IPCC Compliance

The ECAM tool is based on the **Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories**. In this sense, this topic discusses the principles and boundaries associated with this methodology.

The IPCC methodology is often used as a standard, but not the only international method to calculate GHG emissions. Therefore, the user can also choose to follow another methodology that is more aligned with their needs in the elaboration of a GHG inventory. **The IPCC method is under constant discussion and evolution, as is the continuous development of new methods and ways of calculating emissions**.

GHG accounting and reporting principles

All countries that are part of the United Nations Framework Convention on Climate Change (UNFCCC) must periodically report national inventories of greenhouse gases. The results of the inventories are a way to identify: which GHGs are emitted in the country; the amount of emissions generated annually; the main emitting activities; and the historical trend of these emissions. This information facilitates decision-making regarding mitigating actions for the country, guiding the implementation of strategic actions to reduce emissions.

The IPCC develops and updates the practical guidelines for the preparation of these inventories, establishing the methodologies to estimate the emissions generated by the different human activities.

ECAM was developed to be consistent with the IPCC Guidelines for National Greenhouse Gas Inventories, including the IPCC 2019 refinement. The guidelines were used as the main reference for the equations within the tool. The IPCC is also the leading international source on **global warming potential** values, which are used in ECAM for the conversion of GHG emissions into the equivalent CO_2 equivalent (CO_2eq) unit.

In addition to the IPCC guidelines, the ECAM tool also considers the accounting and reporting principles of the 2015 Paris Agreement (UNFCCC, 2015), an international treaty on climate change. These principles include **transparency**, **accuracy**, **completeness**, **consistency and comparability**, as well as the promotion of environmental integrity and the avoidance of double counting.

- **Transparency** is achieved through a factual and coherent approach, based on references that clarify the calculation methods and data sources.

- **Accuracy** is ensured by the systematization of the tool's calculations, which assure that the quantification of emissions is not significantly below or above the real ones, reducing the possibility of errors and allowing users to decide with reasonable assurance as to the integrity of the reported information.

- **Completeness** is provided to the user while the tool makes available the possibility of considering all relevant emissions within the delimited scope and boundaries.

- **Consistency and comparability** refer to the use of robust methodologies, which allow the monitoring and comparison of emissions over time. The operation of the tool allows the user to check for each inventory what were the considerations regarding data, scope, GWP sources, among others.

Boundaries of the IPCC methodology: non-accounted emissions

CO_2 emissions from biological degradation

The IPCC Guidelines assume that most of the organic carbon present in wastewater derives from biogenic organic matter in human excreta or food waste. Consequently, CO_2 emissions from wastewater treatment according to those Guidelines are also considered wholly biogenic and are discounted from international greenhouse gas accounting inventories, since they do not represent a transfer of carbon from the lithosphere to the atmosphere.

However, another part of the carbon dioxide emissions present in wastewater is of non-biogenic sources since they come from organic contaminants with fossil carbon origin. This fossil carbon is derived from the use of petroleum-based products (domestically and commercially). These products include cosmetics, pharmaceuticals, surfactants, detergents, and food additives. They can account for up to 14% of total chemical oxygen demand (COD) in influent sewage into wastewater treatment plants (Law et al. 2013).

The non-biogenic CO_2 emissions may increase in the future due to population growth and changes in wastewater quality, which makes this a point of weakness in the methodology.

Additionally, another source of carbon emissions that is not considered are those caused by dosing products from the wastewater treatment stage. This includes direct dosing of synthetic, fossil-derived organic substrates (e.g., methanol), which can occur at wastewater treatment plants to enhance denitrification performance (Schneider et al. 2015).

Based on the IPCC, the ECAM tool does not account the emission of carbon dioxide by biological degradation processes. This carbon has two origins: biogenic and non-biogenic.

Biogas flaring emissions

The IPCC methodology does not account for emissions from biogas flaring, since most CO_2 emissions are of biogenic origin, and the CH_4 and N_2O emissions are irrelevant (IPCC, 2019).

In ECAM, these emissions are also not account for. The biogas emissions considered in the tool are the ones related to leaks.

CH_4 emissions from closed sewers

Sewer systems may consist of networks of open channels or closed underground pipes. Occasional stagnant conditions and heat provide favorable anaerobic condition for methane generation in closed and open sewers. In urban areas in developing countries and some developed countries, sewer systems may consist of networks of open canals, gutters, and ditches, which are referred to as open sewers. These systems are subject to heating from the sun and the sewers may be stagnant allowing for anaerobic conditions to emit CH_4. Emissions from stagnant channels are accounted for by the IPCC and the ECAM tool in the **Wastewater Collection** stage.

In most developed countries and in high-income urban areas in other countries, sewers are usually closed and underground. Although methane emissions have been measured in both gravity (Foley et al., 2011; Foley, 2015), and pressure sewers (Guisasola et al., 2008), the risk of production tends to be greater in pressure sewers since there is generally no air/water interface to diffuse oxygen into the liquid phase and promote aerobic conditions. IPCC (2019a, b) indicates that closed underground sewers, which are predominant, do not contribute significantly to CH_4 emissions. However, some studies provide different insights. Guisasola et al. (2008) found sewage methane to contribute to the addition of 12 – 100% GHG emissions of those from a WWTP itself. Foley et al. (2011) showed that methane emissions in pipes contributed around 18% of the total GHG in wastewater collection and treatment stages in Australia. Discussions on this topic are still incipient, and there are not yet any conventional methods for estimating these emissions that can easily be implemented by a water utility.

Whilst generated in the collection stage, emissions in closed sewers would be released to the atmosphere in the wastewater treatment stage. This is an important boundary of the IPCC methodology, which is also reflected in the ECAM tool. Despite this, the user can, based on studies of their choice, define an emission factor for closed sewers manually.

CH_4 dissolved emissions from anaerobic to aerobic reactors

The emission of dissolved methane to the atmosphere occurs through two processes: diffusion and air stripping. These processes are facilitated by aeration.

The IPCC methodology (and ECAM as well) does not consider that there are relevant methane emissions from aerobic reactors, since anaerobiosis is a condition for the generation of this gas.

However, for cases of multi-stage treatment processes, it is noted that methane can be formed in anaerobic reactors, or in anaerobic phases of batch reactors, before entering the main aerobic reactor (Hwang et al., 2016). Part of this methane remains in dissolved form and, as it enters the aerobic reactor, it can be airstripped by the aeration process (Foley, 2015; Guisasola et al., 2018).

N_2O emissions from sewers

Although some studies have reported N_2O emissions from sewers to be significant, the conditions leading to N_2O emissions in sewers are still not well understood (Short et al., 2014). The IPCC does not consider sewers as a source of N_2O emissions, hence, they are not considered in ECAM.

Boundaries of the IPCC methodology: other relevant aspects

Emission Factors for CH_4 and N_2O in Multi-stage wastewater treatment plants

In the IPCC, the GHG emission factors adopted for the **Wastewater Treatmen**t stage depend on the wastewater treatment technology used in a treatment plant. In ECAM, the user can select this factor in a dropdown menu by selecting the WWTP technology.

This procedure is quite simple for users who are evaluating only one specific technology (e.g. anaerobic lagoon). In the case of more than one treatment technology (e.g., anaerobic lagoon followed by facultative lagoon) the procedure can become more complex, since the IPCC does not suggest EF related to multi-stage systems, but it gives the equation to calculate it.

In this sense, it becomes inevitable that users look for additional EF, or that they calculate a personalized EF for their treatment system. This case is addressed, in practice, in the complementary document to this guide, the **ECAM User Manual**, in the subtopic **"Wastewater Treatment stage: how to choose the best option for the Dropdown Menus"**.

Temperature impacts on wastewater emissions

The emission factors suggested by the IPCC and other sources adopted by ECAM are an average of several studies. In this sense, some important variables for the generation of GHG may end up being "suppressed". One of these variables is **temperature**.

The water temperature varies according to the location of the facilities and seasonally. This variable impacts the kinetics of the reactions involved in anaerobic digestion, which means that it also impacts the production of CH_4 from wastewater.

In this sense, CH_4 production varies not only with the type of technology adopted for wastewater treatment (IPCC methodological basis), but there is also a variety of emission related to the location of operation of that technology. Masuda et al. (2015), for example, noted significant changes in methane production throughout the seasons, when summer (higher temperatures) provided conditions for greater CH_4 production. Therefore, there is clearly a relationship between temperature and CH_4 that must be expressed in "temperature-dependent" emission factors (Leverenz et al. 2010), but which have not yet been developed on a large scale due to the lack of baseline studies.

In this sense, if the user of the ECAM tool wants to use it to inventory the emissions of a location with large temperature changes in the seasons, the IPCC suggests using local emission factors.

IPCC vs LCA approach

Life Cycle Assessment (LCA) is a methodology that evaluates the environmental impacts of a product or service from the extraction of its raw material to its destination. The conceptual framework of an LCA is defined by standards from the International Organization for Standardization (ISO): ISO 14040 and ISO 14044.

In the context of GHG emissions in the urban water sector, using a LCA approach can include a multitude of new emissions to be calculated, depending on the scope to be defined by the user. Some of these would be emissions related to:

- Construction materials involved in the construction and operation phases of urban water facilities,
- production and delivery of chemical products used in the operation of WWTPs,
- production and transport of equipment used in the facilities,
- demolition of units and disposal of consumables,
- Maintenance of water and sewage networks.

In addition to these mentioned emissions, an LCA would also include the emissions calculated by the ECAM tool.

In general, the ECAM calculations represent most of the emissions from the urban water sector, considering that the operation and maintenance phases of the facilities represent most of the environmental impacts of utilities, and that ECAM calculates a large part of the emissions of the operation phase (Li et al. 2013). Special attention should be given to the consumption of chemicals, which could represent significant emissions in large WWTPs, or in WWTPs that have physic-chemical processes as the treatment base.

However, there are some exceptions when it is stated that most emissions from the urban water sector are associated with the operation of the systems. In some types of WWTPs, it is observed that most of the emissions are in the construction phase, that is, if the user of the tool wants to evaluate the exchange of one treatment system for another. Such conditions should be considered to develop a full picture of GHG emissions from the utilities, i.e. wetlands and membrane bioreactors (Corominas et al. 2013).

Methodology

The calculation of GHG emissions from the ECAM tool is mostly based on the IPCC methodology (2006; 2019), however for some factors additional sources are used. This topic presents what's behind the GHG emissions calculations for each system and stage of the tool's inventories.

First, the key concepts that must be known to understand the description of formulas and benchmarks[6] are presented. Next, the methodology is explained following the same structure as the ECAM tool, so that the user can quickly resolve specific doubts or retrieve information.

Note:

The Methodology topic was developed so that the user can search for additional information about any variable in ECAM **by using the "locate" tool** in a .doc or .pdf software. For this reason, some definitions may seem repetitive when comparing variables that are essentially the same, but with different nomenclatures and codes because they are part of a different stage. As an example, the variable "Energy consumed from the grid" will be repeated in all topics, but with different codes (Example: wsa_nrg_cons, wsd_nrg_cons, wst_nrg_cons, etc.)

Introduction

Key concepts

Some key concepts used by the IPCC need to be further clarified so that the user has an adequate understanding of the ECAM methodology.

Activity data

The quantification of GHG emissions defined by the IPCC are based on activity data (AD) and emission factors (EF):

$$\textit{Emissions} = \textit{Activity data} \cdot \textit{Emission factor}$$

The **activity data** is information that can be related to the magnitude of a human activity resulting in emissions or removals taking place during a given period.

In ECAM, activity data can be **(1) provided directly by the user**, or it could be **(2) estimated from preset formulas given in the tool**.

[6] Benchmark tables can be consulted in Annex 2 – Benchmark table.

Some *examples* of **activity data** are:

- Human population
- Energy consumption from the grid
- Fuel consumption
- Per capita consumed protein
- BOD_5 load in the wastewater
- Amount of sludge removed from wastewater treatment
- Volume of reused effluent
- Amount of CH_4 recovered or flared

The collection of activity data is part of the user´s job when using ECAM. The procedures include finding and processing existing data, (i.e., data that are compiled and stored for other statistical or administrative uses than the inventory), as well as generating new data by surveys or measurement campaigns.

Therefore, possible sources of activity data are:

- **Existing official data:** national statistics; international statistics; other data sources including remote sensing, industrial associations, and academia.
  For example: adopting population data according to national statistics.

- **Local data**: historical monitoring data; census and local survey data; operational reports; energy bills.
  For example: defining the Influent BOD load based on continuous monitoring carried out by WWTP, paying attention to unit conversion.

- **Surrogate/Correlated data**: using data correlated with the desired activity data.
  For example: The water utility does not have the electricity bills to fill in the energy consumption, for this reason it could choose to use estimates based on calculations using the number of hours of operation of the equipment; or even extrapolated values based on the operation of pumps with frequency inverters.

- **Expert judgment**: A last resort for filling in activity data in ECAM is expert judgment. This process consists of consulting the specialists to fill in data gaps, based on other data or based on the professional's previous experience.

Attention: it is important that the users consider the origin and consistency of their activity data whilst using ECAM. For example, using two different sources for data that compose the same equation could result in negative emissions.

For a more in-depth approach to data collection and data gap filling, it is recommended to consult **Chapter 2, Volume 1 of the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006a).**

Emission factors

GHG emissions are not usually measured directly but obtained through models that relate emissions to activity data. Emission factors (EF) are coefficients which quantify the emissions or removals per unit of activity data.

Some examples of **emission factors** are:

- Amount of CH_4 (methane) emitted by the amount of BOD effluent load discharged into aquatic environments [kgCH$_4$/kg BOD]

- Amount of CO_2 emitted by fuel consumption [kgCO$_2$/L]

- Amount of CO_2 associated with the consumption of each kWh of a water supply stage [kgCO$_2$/kWh]

- Amount of N_2O (nitrous oxide) nitrogen emitted by the ammonium nitrogen converted [kgN$_2$O-N/kg N]

In ECAM, EF can be defined in two ways: (1) from IPCC-based tables; or it is also possible for the user (2) to add their own emission factor, based on calculations, on their own investigations, or on local studies. Expert judgment is recommended to use own or local data.

The IPCC tabulated emission factors are defined based on the average of available data from a series of investigations. These factors facilitate the estimation of emissions from different sources of GHG.

Tier (Level of Information)

Associated with activity data and emission factors, "tier" is a concept that also needs to be aligned with the user of the ECAM tool.

In the IPCC (2006; 2019), a *tier* represents a level of *methodological complexity*. Usually, three tiers are mentioned in the methodology. Tier 1 is the basic method, tier 2 intermediate and tier 3 most demanding in terms of complexity and data requirements. Tiers 2 and 3 are sometimes referred to as higher tier methods and are generally considered to be more accurate.

In practice with the ECAM tool, the tier concept will be used for the selection of emission factors related to wastewater discharge (see in the annex **Table 11** and **Table 16**), that is, it will be used in the **Wastewater Collection**, **Treatment**, and **Onsite sanitation** stages. In this case, tier can be understood as "level of information" related to:

1. Level of activity data that make up the equation for which the emission factor will be applied.

2. Level of information that the utility has about the water body where the discharge is taking place.

Table 2 presents the tier options to be chosen when selecting the wastewater discharge EF, based on the activity data and water body level of information. To select the tier of the first column, **all requirements** of the columns in the corresponding row must be met.

Table 2 - Choosing Wastewater Discharge emission factors based on Tiers (Level of Information)

	Level of Information	
Chosen Tier	**When defining CH_4 emission factors for wastewater discharge:**	**When defining N_2O emission factors for wastewater discharge:**
Tier 1 Methodologically, the data is scaled from a particular source, which will not respond to local changes. No information about the water body is known.	**Effluent BOD_5 load:** Defined from ECAM estimates, that is, based on the extrapolation of a series of studies carried out. **Water body:** There is no need for the utility to know which type of water body the wastewater is discharged.	**Effluent total itrogen load:** Defined from ECAM estimates, that is, based on the extrapolation of a series of studies carried out. **Water body:** There is no need for the utility to know which type of water body the wastewater is discharged nor if this body is impacted by nutrients or it is in hypoxic conditions.
Tier 2 Methodologically, the data are scaled from country-specific calculations or from local monitoring. No information about the water body is known.	**Effluent BOD_5 load:** Defined based on country-specific studies or on local monitoring by the utility (in this second case, the utility must consider uncertainties such as gaps in data sets). **Water body:** The utility must know to what type of water body is discharged the wastewater, i.e., if it is a river, estuary, lake, etc.	Not applicable, because the selection of the N_2O emission factors does not include a Tier 2.
Tier 3 Methodologically, the data are scaled from country-specific calculations or local monitoring. The necessary information about the water body is known.	Not applicable, because the selection of the CH_4 emission factors does not include a Tier 3.	**Effluent total nitrogen load:** Defined based on country-specific studies or on local monitoring by the utility (in this second case, the utility must consider uncertainties such as gaps in data sets). **Water body:** The utility must know the water body and know if it is impacted by nutrients and/or in hypoxic conditions.

Benchmarks and performance indicators

The performance indicators (PIs) used in ECAM are based upon the IWA PI frameworks that have been broadly and successfully used worldwide (Alegre et al., 2016; Cabrera et al., 2011). A performance indicator is a measure of the efficiency and effectiveness related to specific issues of the delivery of the services by a utility. A PI can be dimensionless (-, %) or intensive (e.g. kWh/m^3).

There are 3 types of performance indicators:

1. *Key performance indicators* (kPIs). Provide global picture of stage's performance – energy or GHG.
2. *Context PIs*. Provide context information about the stage (e.g., sludge quality is related to energy consumption)
3. *Service level PIs*. Provide more information on service level. Limited number of key quality of service indicators that need to be considered when interpreting monitoring results of direct and indirect emissions. For instance, emissions per m^3 of treated water may increase if the level of treatment increases; emissions per m^3 of authorized consumption may also increase if there were insufficient pressure in the baseline and the situation is fixed during the project. If these aspects were not included in the assessment system, improvement measures might appear to have not worked. The same rational reversely applies for tracing decreases in the levels of service.

Two examples are provided below on how energy performance outcomes can be interpreted. Both examples correspond to pressurized water transport (pumping):

- The energy required to elevate 1 m^3 one hundred meters (or, to increment its pressure into 9.81 bar), is exactly 0.2725 kWh/m^3. Assuming a global inefficiency (mainly pump and electric motor drive) of 0.70, a reasonable value is 0.4 kWh/m^3. If water is pumped in a well, an elevation of 100 m and the calculated value of the indicator results in 0.70 kWh/m^3, it is evident that there is room for improvement.

- At the distribution stage the evaluation is a bit more complex because inefficiencies can be due to not just only the poor performances of the pumping station, but also due to leaks, pipe friction or other losses such as, for instance, pressure break tanks. As before, indicators to measure the ideal (theoretical) and the real global efficiencies (this last one to be determined based on specifics of the utility) are required to calculate the difference (that is to say, the improvement margin).

When using indicators, it is common practice to have reference values, which are called *benchmarks*[7]. When significant differences between the measure performance and the benchmark value are observed, an energy audit to understand the origin of the inefficiencies should be performed. The table benchmarks are presented in **Annex 2 – Benchmark table**.

[7] ***Important:*** *Users should analyse the performance indicators and benchmarks applied cautiously, keeping in mind the specific characteristics of the system lay-out and operating conditions as well as considering the quality of input data and potential uncertainties involved.*

How to use the "Section" topics: formula sheets

The next topics in this document are named with the prefix "**Section**" because they refer to a specific section of the ECAM tool, following the same structure of the software. The intention of this procedure is to facilitate the consultation of specific variables and formulas for each stage.

Each of the sections will present the relevant formulas in a "sheet" format (Figure 6). You can also use your document editor's **search tool** to look for a specific code (example: *ws_run_cost*), which will take you directly to the associated equation.

1 **Total running costs**

2 *ws_run_cost [$]*

Total operations and maintenance net costs and internal manpower net costs (i.e. not including the capitalised cost of self constructed assets) related to water supply within the service area managed by the undertaking during the entire assessment period 3

$$wsa\_KPI\_GHG\_fuel = wsa\_nrg\_cost + wsd\_nrg\_cost + wst\_nrg\_cost$$

Equation xx.xx 4

With: 5 6

wsa_run_cost [$]	Total operations and maintenance net costs and internal manpower net costs (i.e. not including the capitalised cost of self constructed assets) related to water supply within the service area managed by the undertaking during the entire assessment period
wsd_run_cost [$]	Total operations and maintenance net costs and internal manpower net costs (i.e. not including the capitalised cost of self constructed assets) related to water supply within the service area managed by the undertaking during the entire assessment period
wst_run_cost [$]	Total operations and maintenance net costs and internal manpower net costs (i.e. not including the capitalised cost of self constructed assets) related to water supply within the service area managed by the undertaking during the entire assessment period

Sources: 7

EIB Methodologies for the Assessment of Project GHG Emissions and Emission Variations, 2020
• frontend/docs/eib_project_carbon_footprint_methodologies_en_v11.1.pdf#page=34

UNFCCC IFI TWG - List of harmonized GHG accounting standards/approaches and guidelines developed
• https://unfccc.int/climate-action/sectoral-engagement/ifis-harmonization-of-standards-for-ghg-accounting/ifi-twg-list-of-methodologies

Figure 6 - How to use the Formula Sheets

1 Variable name.
2 Variable code [unit].
3 Description of the variable.
4 Equation/formula used to calculate the variable.
5 List of other variable codes used to calculate it [unit].
6 Description of the related variables.
7 List and link of sources.

Section 1: Configuration

This section refers to the elements in the Configuration tab[8] in ECAM (**Figure 7**).

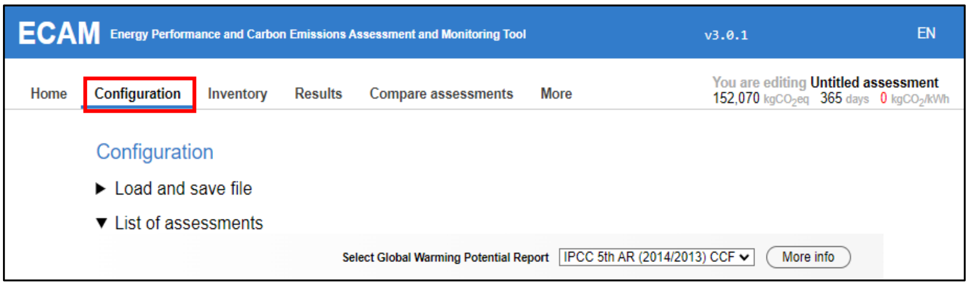


Figure 7 - Configuration tab

Selection of the Global Warming Potential Report

GHGs have different levels of ability to trap heat in the atmosphere, and this ability is called the global warming potential (GWP). Thus, the GWP is the ratio of how many times the specific gas emitted is more potent than carbon dioxide (CO_2) in the ability to generate global warming. It is expressed as the ratio of its heat trapping ability relative to that for CO_2, that is, in units of "CO_2 equivalent ($CO_{2\text{-eq}}$)".

The GWP of CO_2 equals one. This means that a gas with GWP 25 has its radiative forcing 25 times that of CO_2, that is, a ton of the reference gas can also be expressed as 25 tons of $CO_{2\text{-eq}}$.

In the ECAM tool, users must select the IPCC Global Warming Potential Report that they would like to use as a reference for their inventory.

Table 3 - List of IPCC GWP Reports that can be selected in ECAM

Global warming potential for 100-year horizon				
Report (Reference)	**CO_2 (CO_2 equivalents)**	**CH_4 (CO_2 equivalents)**	**N_2O (CO_2 equivalents)**	**Comments**
IPCC 5th AR (2014/2013) CCF	1	34	298	with climate-carbon feedbacks[9]
IPCC 5th AR (2014/2013)	1	28	265	without climate-carbon feedbacks
IPCC 4th AR (2007)	1	25	298	
IPCC 3rd AR (2001)	1	23	296	
IPCC 2nd AR (1995)	1	21	310	
IPCC 1st AR (1990)	1	11	270	

[8] The access to the different tabs of the ECAM tool, as well as the practical features of each one, are covered in detail in the document "User Manual".

[9] Climate Carbon Feedback: Theoretical concept based on the assumption that the four major carbon sinks (atmosphere, biosphere, oceans, and sediments) will reduce their capacity to uptake CO_2 due to the ongoing climate change with direct effect on GWP of GHG emissions.

General and Country specific factors

In addition to the GWP selection, the Configuration section of the ECAM tool also suggests and allows the user to set **General and Country Specific Factors**.

Currency (*$*)

The currency of the country selected by the user.

Emission factor for grid electricity (*conv_kwh_co2*)

The ratio of CO_2 emission per energy consumed ($kgCO_2$/kWh).

This factor is used at all stages of the UWC to calculate indirect emissions due to grid electricity consumption. It is transferred to the Input section of each stage by an estimate input (see **Equation 6**, **Equation 7**, **Equation 8**, **Equation 17**, **Equation 24**, and **Equation 41**).

The ECAM methodology for defining this factor is based on the UNFCCC List of harmonized GHG accounting standards/approaches and guidelines developed (UNFCCC, 2022). This methodology is used to calculate baseline emissions from the electricity sector when making comparisons of old generation projects to the construction of new power generation projects in a country. It is a methodology adapted to set the grid emission factor values in ECAM.

The above-mentioned methodology is the base to a compilate table (pages 30 to 34) of the European Investment Bank (EIB) (2020), which presents the emission factors calculated for intermittent and firm electricity generation. The calculation of the factor for intermittent generation considers that most of the country emissions come from present conventional energy plants with a minor share of prospective energy plants. For the firm generation, it considers that most of the emissions come from the prospective energy plants.

In the context of using the ECAM tool, the emission factors in the EIB table represent an optimistic (firm energy - with less emissions) and a pessimistic (intermittent energy - with more emissions) scenarios. For conservatism, ECAM adopts the values of the pessimistic scenario, that is, in the **Intermittent Energy** column.

The EIB publishes new calculations annually, which can be accessed by the user and edited directly in the ECAM. Some countries carry out their own official studies at national level on this factor. For these cases, it is recommended that the value be edited manually to better reflect the local reality.

Total Nitrogen (TN) factors

Total Nitrogen factors include:

- Annual protein consumption per capita (***prot_con***),
- industrial and commercial co-discharged protein into the sewer (***F_IND_COM***),
- non-consumed protein added to the wastewater (***F_NON_CON***),
- additional Nitrogen from household products added to the wastewater (***N_HH***).

All these factors are used by ECAM to suggest estimates of the load of TN in domestic wastewater for the **Wastewater Collection**, **Treatment**, and **Onsite sanitation** stages based on the IPCC methodology (IPCC, 2019).

Equation 1 is the base equation for estimating TN loads in wastewater based on each of these factors. This equation is later incorporated into a series of ECAM variables to estimate TN at each of the UWC stages.

$TN\ load\ [kg] = Pop \cdot prot\_con \cdot Years \cdot F\_NPR \cdot N\_HH \cdot F\_NON\_CON \cdot F\_IND\_COM$	**Equation 1**
With:	
Pop [person]	Serviced population
prot_con [kgprotein/person/year]	Protein consumption per capita per year
Years [years]	Period adopted for the assessment
F_NPR [kg N/kg protein]	Fraction of nitrogen in proteins = 0.16
N_HH [kgN/kgN]	Additional nitrogen from household products added to the wastewater
F_NON_CON [kgN/kgN]	Factor for nitrogen in non-consumed protein disposed in sewer system
F_IND_COM [kgN/kgN]	Factor for industrial and commercial co-discharged protein into the sewer system
Source	**IPCC (2019b p. 6.40)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

These estimates are later used to calculate nitrous oxide emissions. Therefore, this means that the user can also choose not to use this estimation, providing their own values of nitrogen in the wastewater if continuous monitoring is carried out by the utility. The choice of activity data source is called "*Tier*", which is especially important in ECAM for discharge emissions. This is covered in topic **Tier (Level of Information)**.

"**Annual protein consumption per capita (prot_con)**" is the protein consumption per capita per year.

If national statistics on protein consumption are not available, the IPCC (2019b) recommends that they should be calculated from FAO data on protein supply (FAO 2022). From the protein supply data, the user must apply a factor that represents the fraction of protein consumed (FPC) (**Equation 2**).

Hence, due to the variability between different areas within a country, it is recommended to use national statistics whenever possible to obtain the most accurate results.

$prot\_con[kgprotein/person/year] = Protein_{supply} * FPC$	**Equation 2**
With:	
$Protein_{supply}$ [kg protein/person/yr]	Annual per capita protein supply
FPC	Fraction of protein consumed. Default regional values are in Table 4.
Source	**IPCC (2019b, p.6.41)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Table 4 - Default FPC factors for domestic wastewater

Region	Fraction of protein consumed (FPC)
Europe	0.85
North America and Oceania	0.80
Industrialised Asia	0.86
Sub-Saharan Africa	0.98
North Africa, West and Central Asia	0.90
South and Southeast Asia	0.96
Latin America	0.92
Source	**IPCC (2019b, p. 6.41)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

"**Industrial and commercial co-discharged protein into the sewer (F_IND_COM)**" is a factor to allow for co-discharge of industrial nitrogen into sewers. Default value is 1.25 by IPCC (2019b). For countries with significant fish processing plants, this factor may be higher. Expert judgement is recommended.

Table 5 - Default value for Industrial and commercial co-discharged protein in the sewer

Parameter	Definition	Default value	Range
$F_{IND\text{-}CON}$	Factor to allow for co-discharge of industrial nitrogen into sewers. For countries with significant fish processing plants, this factor may be higher. Expert judgment is recommended.	1.25	1.0 - 1.5

"**Non consumed protein added to the wastewater (F_NON_CON)**" is a factor to adjust for non-consumed protein disposed in sewer system. Food that is not consumed may be disposed to the sewer, for example, as a result of the use of in-sink food waste disposals in some countries.

The default value for F_NON_CON in ECAM is 1.1 kgN/kgN. However, according to the IPCC (2019b) this value can vary between **1.0 and 1.5**, and the adoption of **1.25** is recommended for countries where there is in-sink disposal of food waste (**Table 6**).

Table 6 - Defining the factor to adjust for non-consumed protein, based on consumed protein

Parameter	Definition	Default value [kgN/kgN]	Range
$F_{NON\text{-}CON}$	Factor to adjust for non-consumed protein, based on consumed protein	1.1 for countries with no in-sink disposals 1.25 for countries with in-sink disposals	1.0 - 1.5

"**Additional nitrogen from household products added to the wastewater (N_HH)**" is the factor used to consider household chemicals (detergents, shampoos, softeners, dishwashing agents, cosmetics, etc.) added to the wastewater. Based on IPCC (2019b), the default value in ECAM is 1.1 [kgN/kgN], but IPCC also provides additional regional factors (compare Table 7) (Henze et al. 2008; Tjandraatmadja et al. 2008). The user is also encouraged to use national statistics that better represent the local reality.

Table 7 - Regional factors for additional nitrogen from household produts

Region	Additional nitrogen from household products [kgN/kgN]
Europe	1.08
North America and Oceania	1.17 (USA) 1.07 (Australia)

Industrialised Asia	No data
Sub-Saharan Africa	No data
North Africa, West and central Asia	No data
South and Southeast Asia	1.13 (India)
Latin America	No data

BOD_5 generation in wastewater (*bod_pday*)

BOD_5 indicates the amount of oxygen within a water sample, which microorganisms consume during the period of 5 days at a temperature of 20 °C, to degrade the water contents aerobically. BOD_5 is thus an indirect measure of the sum of all biodegradable organic substances in the water.

The general factor "BOD_5 generation (bod_pday)" represents the average biochemical oxygen demand (BOD_5) that each resident connected to a sewer system eliminates in the wastewater produced every day. It is used **to estimate the influent BOD load** in wastewater collection, treatment, and onsite sanitation.

Equation 3 is the base equation for estimating the BOD load in wastewater based on each of these factors. This equation is later incorporated into a series of ECAM variables to estimate BOD loads at each of the UWC stages.

$BOD\ load\ [kg] = Pop \cdot bod\_pday \cdot 0.001 \cdot Days$	**Equation 3**
With:	
Pop [people]	Serviced population
bod_pday [g/person/day]	BOD_5 generation (wastewater)
Days [days]	Period adopted for the assessment
0.001	Conversion factor g/kg
Source	**IPCC (2019b p. 6.21)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

The values for bod_pday in ECAM are also country-related and based on IPCC (2019b, p. 6.22).[10] This default value shall be adjusted if local studies provide more accurate estimates.

[10] https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Section 2.1: Inventory Inputs

Inputs are the values on the left side of the ECAM tool Inventory tab (**Figure 8**).

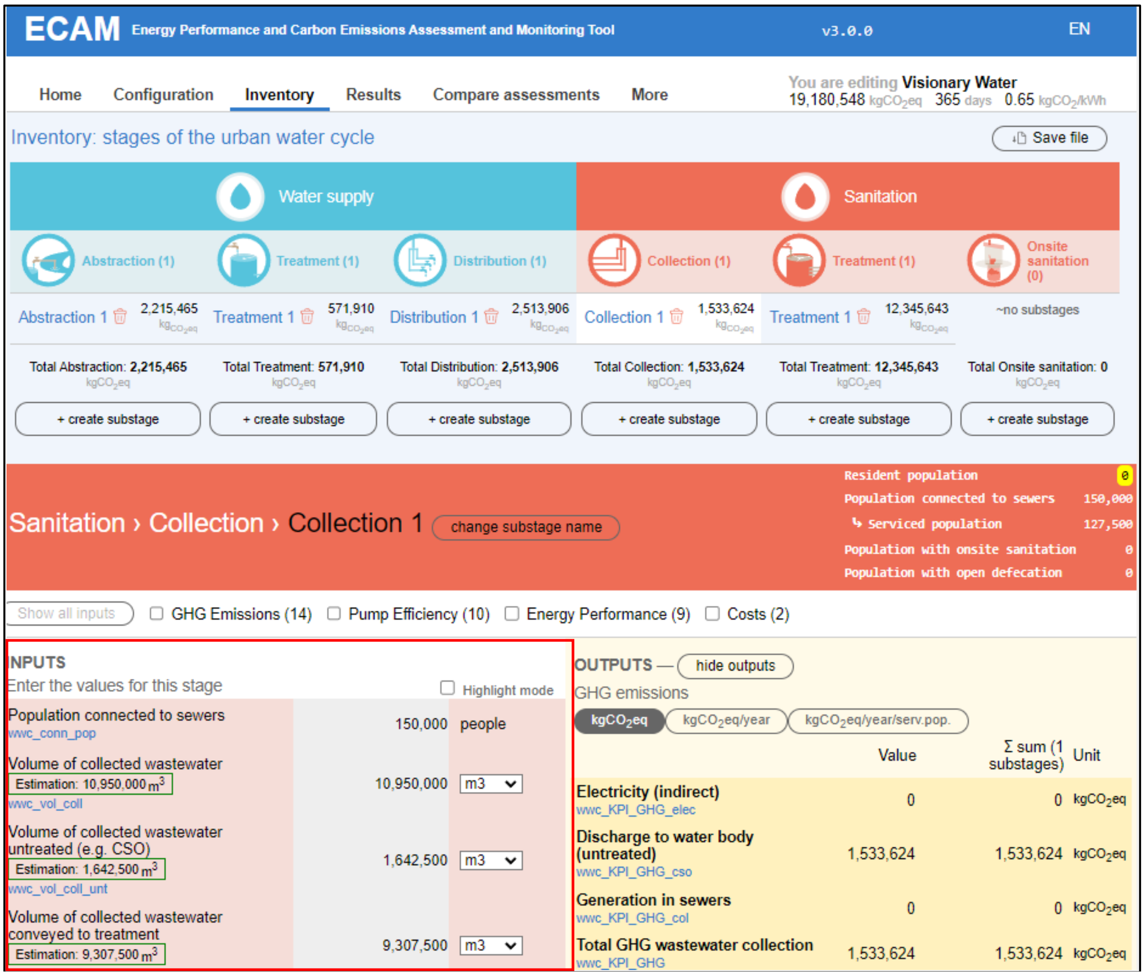


Figure 8 - Inputs section in the Inventory tab

In general, they are composed of:

- **User input**: Input activity data that must be filled in by the user.
- **Estimates**: Input activity data that can be estimated by the tool or filled in by the user.
- **Dropdown menus:** Selectable list, based on a reference table.

In sequence are the calculations for the main input data for each of the systems and stages of the UWC.

Water Supply – General

The inputs of the water supply system refer to the calculations of total costs involved in the drinking water system.

Resident population – water supply

User input of the number of permanent residents within the drinking water utility area of service, regardless of whether they are serviced or not by the utility. It is used to calculate the % of population with water supply.

Resident population	*ws_resi_pop [people]*
Number of permanent residents within the water utility area of service.	

Energy costs – water supply

Input that can be estimated. It is a sum of all the costs of the water supply stages (**Equation 4**).

Energy costs	*ws_nrg_cost*
Costs from electric energy consumption for all water supply utilities, based on the electricity bill during the entire assessment period.	
$ws\_nrg\_cost\ [\$] = wsa\_nrg\_cost + wsd\_nrg\_cost + wst\_nrg\_cost$	**Equation 4**
With:	
ws_nrg_cost [$]	Energy costs from abstraction
wsd_nrg_cost [$]	Energy costs from treatment
wst_nrg_cost [$]	Energy costs from distribution

Total running costs – water supply

Input that can be estimated. It is a sum of all operation and maintenance costs of the water supply stages (**Equation 5**).

Total running costs	*ws_run_cost*
Total operations and maintenance net costs and internal manpower net costs (i.e., not including the capitalised cost of self-constructed assets) related to water supply within the service area, managed by the utility during the entire assessment period.	
$ws\_run_{cost}[\$] = wsa\_run\_cost + wsd\_run\_cost + wst\_run\_cost$	**Equation 5**
With:	
wsa_run_cost [$]	Energy costs from abstraction
wsd_run_cost [$]	Energy costs from treatment
wst_run_cost [$]	Energy costs from distribution

Water Supply – Abstraction

General inputs

Volume of abstracted water – Water Abstraction

User input used to calculate the performance indicator "energy consumption per abstracted water".

Volume of abstracted water	*wsa_vol_conv [m³]*
Sum of the volume of water abstracted (by gravity or pumped) in the water abstraction unit that are the responsibility of the utility during the assessment period.	

Energy consumed from the grid – Water Abstraction

User input used to calculate the following outputs:

- Total energy consumed from the grid in the water system,
- energy consumption per abstracted water,
- indirect CO_2 emissions,
- estimated electricity savings.

Energy consumed from the grid	*wsa_nrg_cons [kWh]*
Electric energy consumption from the grid for the water abstraction unit, reported by the utility, during the entire assessment period.	

Emission factor for grid electricity – Water Abstraction

Input that can be estimated. The value of this variable is the same as the variable "conv_kwh_co2" defined in the ECAM configuration tab. See the "
General and Country specific factors" topic of this document for more information.

Emission factor for grid electricity	*wsa_conv_kwh*
Emission factor for grid electricity (indirect emissions).	
$wsa\_conv\_kwh\ [kgCO2eq/kWh] = conv\_kwh\_co2$	**Equation 6**
With:	
conv_kwh_co2 [$kgCO_2/kWh$]	Emission factor for grid electricity

Do you have fuel engines?

If the utility has its own fuel engines to meet internal demand, this option can be selected, and new inputs must be filled in or estimated.

Fuel type - Water Abstraction

This can be selected through a dropdown menu, in which the user must choose the type of fuel used. This variable is used to calculate the direct emissions associated with onsite engines. The data table for this dropdown menu is available in **Table 8** in the annex.

Fuel type (engines)	*wsa_fuel_typ*
Choose the fuel type (engines)	

Volume of fuel consumed – Water Abstraction

User input associated with the fuel type, it is used to calculate the direct emissions related to onsite engines.

Volume of fuel consumed	*wsa_vol_fuel [m^3]*
Volume of fuel consumed	

Do you want to evaluate pumping efficiency?

If the utility wants to evaluate energy efficiency of pumps and motors, this option can be selected, and new inputs must be filled in or estimated.

Energy consumed from the grid (pumping) – Water Abstraction

User input used to calculate the following outputs:

- Energy consumed per amount of pumped water,
- standardized energy consumption,
- energy consumption with expected new pump efficiency.

Energy consumed from the grid (pumping)	*wsa_nrg_pump [kWh]*
Energy consumed from the grid (pumping)	

Volume pumped – Water Abstraction

User input used to calculate the following outputs:

- Energy consumed per amount of pumped water,
- standardized energy consumption.

Volume pumped	*wsa_vol_pump [m^3]*
Volume of water pumped in each water abstraction unit that are the responsibility of the utility, during the assessment period.	

Pump head – Water Abstraction

User input used to calculate performance indicators regarding energy efficiency. It measures the maximum height that a pump can move fluid against gravity.

Pump head	*wsa_pmp_head [m]*
Head at which the water is pumped in each water abstraction unit that are the responsibility of the utility, during the assessment period.	

Type of pump – Water Abstraction

This can be selected through a dropdown menu, in which the user must choose if the pump is external or submersible. The chosen type is used as reference for benchmarking about expected energy consumption.

Size of pump – Water Abstraction

This can be selected through a dropdown menu, in which the user must choose the size of the assessed pump. This will be used for benchmarking about expected energy consumption.

Size of pump (kW)	*wsa_pmp_size [kW]*
Pump size in kW	

The options for this menu are available in **Table 9** in the annex.

Static head – Water Abstraction

User input used to calculate performance indicators regarding energy efficiency. It is the height that water must travel as it moves through a pipe.

Static head	*wsa_sta_head [m]*
Static head measures the total vertical distance that a pump raises water.	

Mains length – Water Abstraction

User input used to calculate performance indicators regarding energy efficiency.

Mains length	*wsa_main_len [m]*
Total transmission and distribution mains length (there are not service connections at the abstraction and conveyance stage).	

Do you want to evaluate electromechanical efficiency of pump?

Measured pump flow – Water Abstraction

User input used to calculate water power when evaluating electromechanical efficiency of pump.

Measured pump flow	*wsa_pmp_flow [m³/s]*
Volume of liquid that passes through a pump in a given time period.	

Measured pump voltage – Water Abstraction

User input used to calculate the electromechanical efficiency of a pump.

Measured pump voltage	*wsa_pmp_volt [V]*
Measured pump voltage	

Measured pump current – Water Abstraction

User input used to calculate the electromechanical efficiency of a pump.

Measured pump current	*wsa_pmp_amps [A]*
Measured pump current	

Power factor – Water Abstraction

User input used to calculate the electromechanical efficiency of a pump.

Power factor	*wsa_pmp_pf [ratio]*
Power factor is the ratio of working power, measured in kilowatts (kW), to apparent power, measured in kilovolt amperes (kVA). It is a measurement that can quickly determine the amount of load on a motor.	

Expected electromechanical efficiency of new pump – Water Abstraction

User input used to calculate:

- Standardized energy consumption of new pumps,
- energy consumption with expected new pump efficiency.

Expected electromechanical efficiency of new pump	*wsa_pmp_exff [%]*
Expected electromechanical efficiency of new pump.	

Do you know the utility costs by stage?

Energy costs – Water Abstraction

The user optionally fills in the total energy costs of the stage, so that the total costs of the system can be calculated.

Energy costs	*wsa_nrg_cost [$]*
Costs from electric energy consumption for the entire water supply utility, based on the electricity bill during the entire assessment period.	

Total running costs – Water Abstraction

The user optionally fills in the total costs of the stage, so that the total costs of the system can be calculated.

Total running costs	*wsa_run_cost [$]*
Total operations, maintenance net costs and internal manpower net costs (i.e., not including the capitalised cost of self-constructed assets) related to water supply within the service area managed by the utility, during the entire assessment period.	

Water supply – Treatment

Volume of treated water – Water Treatment

User input used to calculate the performance indicators for energy efficiency.

Volume of treated water	*wst_vol_trea [m³]*
Sum of the volume of water treated by WTPs that are the responsibility of the water utility, during the assessment period.	

Treatment type (Potabilization chain) – Water Treatment

This can be selected through a dropdown menu. The users must choose the potabilization chain for their WTP. The options for this menu are displayed in **Table 10** in the annex.

Energy consumed from the grid – Water Treatment

User input used to calculate a few outputs:

- Total energy consumed from the grid in the Water system,
- energy consumption per amount of treated water,
- indirect CO_2emissions,
- estimated electricity savings.

Energy consumed from the grid	*wst_nrg_cons [kWh]*
Energy consumed during the assessment period by each urban water treatment plant managed by the utility.	

Emission factor for grid electricity – Water Treatment

Input that can be estimated. The value of this variable is the same as the variable "conv_kwh_co2" defined in the ECAM Configuration tab. See the "

General and Country specific factors" topic of this document for more information.

Emission factor for the grid electricity	*wst_conv_kwh*	
Emission factor for grid electricity (indirect emissions).		
$wst\_conv\_kwh\ [kgCO2eq/kWh]\ = conv\_kwh\_co2$		**Equation 7**
With:		
conv_kwh_co2 [kgCO2/kWh]	Emission factor for grid electricity	

Do you have fuel engines?

If the utility has its own fuel engines to meet internal demand, this option can be selected, and new inputs must be filled in or estimated.

Fuel type – Water Treatment

Dropdown menu in which the user must choose the type of fuel used. This variable is used to calculate the direct emissions associated with onsite engines. The data table for this dropdown menu is available at **Table 8** in the Annex section.

Fuel type (engines)	*wst_fuel_typ*
Fuel type (engines).	

Volume of fuel consumed – Water Treatment

User input associated with the fuel type, it is used to calculate the direct emissions related to onsite engines.

Volume of fuel consumed	*wst_vol_fuel [m^3]*
Volume of fuel consumed.	

Do you want to evaluate treatment performance?

Percent of quality testes in compliance – Water Treatment

This user input is a service level indicator for the utility control.

Percent of quality testes in compliance	*wst_tst_carr [%]*
Number of treated water tests carried out during the assessment period	

Treatment capacity – Water Treatment

User input used to assess how much of the plants' capacity is being used. It is therefore used for benchmarking as a service level indicator.

Treatment capacity	*wst_tre_cap [m^3]*
The treatment capacity of each WTP or onsite system, that are the responsibility of the wastewater utility during the assessment period.	

Do you want to evaluate pumping efficiency?

Energy consumed from the grid (pumping) – Water Treatment

User input used to calculate the indicator "standardized energy consumption".

Energy consumed from the grid (pumping)	*wst_nrg_pump [kWh]*
Energy consumed from the grid (pumping)	

Volume pumped – Water Treatment

User input used to calculate the following outputs:

- Energy consumption with expected new pump efficiency,
- standardized energy consumption.

Volume pumped	*wst_vol_pump [m^3]*
Volume pumped	

Pump head – Water Treatment

User input used to calculate performance indicators regarding energy efficiency. It is the maximum height that a pump can move fluid against gravity.

Pump head	*wst_pmp_head [m]*
Head at which the water is pumped in each water treatment unit that are the responsibility of the utility, during the assessment period.	

Static head – Water Treatment

User input used to calculate performance indicators regarding energy efficiency. It is the height that water must travel as it moves through a pipe.

Static head	*wst_sta_head [m]*
Static head measures the total vertical distance that a pump raises water.	

Collector length – Water Treatment

User input used to calculate the Unit head loss in m/km of collectors. The head loss for fluid flow is directly proportional to the length of pipe.

Collector length	*wst_coll_len [m]*
Collector length	

Do you want to evaluate electromechanical efficiency of pump?

Measured pump flow – Water Treatment

User input used to calculate waterpower when evaluating electromechanical efficiency of a pump.

Measured pump flow	*wst_pmp_flow [m^3/s]*
Measured pump flow	

Measured pump voltage – Water Treatment

User input used to calculate the electromechanical efficiency of a pump.

Measured pump voltage	*wst_pmp_volt [V]*
Measured pump voltage	

Measured pump current – Water Treatment

User input used to calculate the electromechanical efficiency of a pump.

Measured pump current	*wst_pmp_amps [A]*
Measured pump current	

Power factor – Water Treatment

User input used to calculate the electromechanical efficiency of a pump.

Power factor	*wst_pmp_pf [ratio]*
Power factor is the ratio of working power, measured in kilowatts (kW), to apparent power, measured in kilovolt amperes (kVA). It is a measurement that can quickly determine the amount of load on a motor.	

Expected electromechanical efficiency of new pump – Water Treatment

User input used to calculate the standardized energy consumption of a new pump.

Expected electromechanical efficiency of new pump	*wst_pmp_exff [%]*
Expected electromechanical efficiency of new pump.	

Do you know the utility costs by stage?

Energy costs – Water Treatment

The user optionally fills in the total energy costs of the stage, so that the total costs of the system can be calculated .

Energy costs	*wst_nrg_cost [$]*
Costs from electric energy consumption for the entire water supply utility, based on the electricity bill during the entire assessment period.	

Total running costs – Water Treatment

The user optionally fills in the total costs of the stage, so that the total costs of the system are later calculated.

Total running costs	*wst_run_cost [$]*
Total operations and maintenance net costs and internal manpower net costs (i.e. not including the capitalised cost of self-constructed assets) related to water supply within the service area managed by the utility during the entire assessment period.	

Water supply - Distribution

Serviced population – Water Distribution

User input used to calculate the following service level performance indicators:

- Authorized consumption per person per day,
- Serviced population with water supply (%).

Serviced population	*wsd_serv_pop [people]*
Serviced population is referred to the number of inhabitants, within the area of service managed by the utility, which are connected to the distribution system and are receiving the service.	

Volume of water injected to distribution – Water Distribution

User input used to calculate a lot of service level and energy efficiency indicators regarding the water balance of a utility.

Volume of water injected to distribution	*wsd_vol_dist [m³]*
The water volume entering the distribution system from the water treatment or directly from abstraction during the assessment period.	

Energy consumed from the grid – Water Distribution

User input used to calculate the following outputs:

- Total energy consumed from the grid in the water system,
- energy consumption per volume injected to distribution,
- indirect CO_2 emissions,
- estimated electricity savings.

Energy consumed from the grid	*wsd_nrg_cons [kWh]*
Electric energy consumption from the grid for water distribution during the entire assessment period	

Emission factor for grid electricity – Water Distribution

This input can be estimated. The value of this variable is the same as the variable "conv_kwh_co2" defined in the ECAM **Configuration** tab. See the "

General and Country specific factors" topic of this document for more information.

Emission factor for grid electricity	*wsd_conv_kwh*
Emission factor for grid electricity (indirect emissions)	
$wsd\_conv\_kwh\ [kgCO2eq/kWh] = conv\_kwh\_co2$	**Equation 8**
With:	
conv_kwh_co2 [kgCO2/kWh]	Emission factor for grid electricity

Do you have fuel engines?

If the utility has its own fuel engines to meet internal demand, this option can be selected, and new inputs must be filled in or estimated.

Fuel type (engines) – Water Distribution

This is a dropdown menu, in which the user must choose the type of fuel used. This variable is used to calculate the direct emissions associated with onsite engines. The data table for this dropdown menu is available at **Table 8**, in the annex.

Fuel type (engines)	*wsd_fuel_typ [X]*
Fuel type (engines)	

Volume of fuel consumed (engines) – Water Distribution

User input associated with the fuel type which is used to calculate the direct emissions related to onsite engines.

Volume of fuel consumed (engines)	*wsd_vol_fuel [m^3]*
Volume of fuel consumed (engines)	

Do you have distribution by 'water trucks'?

Fuel type (trucks) – Water Distribution

This is a dropdown menu, in which the user must choose the type of fuel used. This variable is used to calculate the emissions associated with truck transport of potable water. The data table for this dropdown menu is available at **Table 8**, in the annex.

Fuel type (trucks)	*wsd_trck_typ [X]*
Fuel type (trucks)	

Volume of fuel consumed (trucks) – Water Distribution

User input associated with the fuel type which is used to calculate the direct emissions associated with truck transport of potable water.

Volume of fuel consumed (trucks)	*wsd_vol_trck [m^3]*
Volume of fuel consumed (trucks)	

Do you want to evaluate water efficiency?

Volume of authorized consumption – Water Distribution

User input used to calculate service level and energy efficiency indicator such as:

- Authorized consumption per person per day,
- energy consumption per authorized consumption,
- water losses (%),
- minimum required energy for the system to operate by users,
- no revenue water per mains length.

Volume of authorized consumption	*wsd_auth_con [m^3]*
Sum of the volume of metered and/or non-metered water that, during the assessment period, is taken by registered customers, by the water supplier itself, or by others who are implicitly or explicitly authorised to do so by the water supplier, for residential, commercial, industrial or public purposes. It includes water exported.	

Volume of billed authorized consumption – Water Distribution

User input used to calculate non-revenue water.

Volume of billed authorized consumption	*wsd_bill_con [m^3]*
Authorized consumption which are billed and generate revenue (also known as revenue water). It is equal to billed metered consumption plus billed unmetered consumption.	

Do you want to evaluate distribution service performance?

Delivery points with adequate pressure – Water Distribution

User input used to calculate the percentage of supply pressure adequacy.

Delivery points with adequate pressure	*wsd_deli_pts [number]*
Number of delivery points that receive and are likely to receive pressure equal to or above the guaranteed or declared target level at the peak demand hour (but not when demand is abnormal).	

Number of service connections – Water Distribution

User input used to calculate the percentage of supply pressure adequacy.

Number of service connections	*wsd_ser_cons [number]*
Total number of service connections, at the reference date.	

Time system is pressurized – Water Distribution

User input used to calculate and assess the continuity of supply as a service level indicator.

Time system is pressurised	*wsd_time_pre [hours/day]*
Amount of time of the year the system is pressurised.	

Do you want to investigate topographic energy?

Minimum pressure to be supplied at the distribution nodes – Water Distribution

User input used to calculate the theoretical minimum required energy for the system to operate by users.

The description of ECAM suggests a value between 20 and 30 meters, but this value is generally associated with the legislation in the country where the utility operates. Therefore, local regulations must be consulted.

Minimum pressure to be supplied at the distribution nodes	*wsd_min_pres [m]*
According the standards, a minimum pressure must be provided to the consumers (20 - 30 m) , for each water distribution unit.	

Highest node elevation – Water Distribution

User input used to calculate the topographic energy supplied to the system.

Highest node elevation	*wsd_hi_no_el [m asl]*
It is the elevation of the highest node of the network, for each water distribution unit.	

Lowest node elevation of the stage – Water Distribution

User input used to calculate the gravity energy provided from supply to distribution, which is therefore used to calculate the theoretical minimal required energy for the system to operate.

Lowest node elevation of the stage	*wsd_lo_no_el [m asl]*
Is the elevation of the lowest node of the stage, for each water distribution unit.	

Average nodes elevation – Water Distribution

User input used to calculate the gravity energy provided from supply to distribution, which is therefore used to calculate the theoretical minimal required energy for the system to operate.

Average nodes elevation	*wsd_av_no_el [m asl]*
The average elevation of the network. If necessary, it could be calculated as sum of lowest and the highest node elevation of the network divided by two, for each water distribution unit.	

Water table elevation node – Water Distribution

User input used to calculate the gravity energy provided from supply to distribution, which is therefore used to calculate the theoretical minimal required energy for the system to operate.

Water table elevation node	*wsd_wt_el_no [m]*
It is the elevation of the water table to calculate the natural energy provided to the system, for each water distribution unit.	

Do you want to evaluate pumping efficiency?

Energy consumed from the grid (pumping) – Water Distribution

User input used to calculate the following outputs:

- Standardized energy consumption,
- energy consumption with expected new pump efficiency.

Energy consumed from the grid (pumping)	*wsd_nrg_pump [kWh]*
Energy consumed from the grid (pumping)	

Distributed water pumped – Water Distribution

User input used to calculate the standardized energy consumption.

Distributed water pumped	*wsd_vol_pump [m³]*
Volume of water in the drinking water distribution system which requires pumping, for each distribution unit.	

Pump head – Water Distribution

User input used to calculate performance indicators regarding energy efficiency. It is the maximum height that a pump can move fluid against gravity.

Pump head	*wsd_pmp_head [m]*
Head at which the water is pumped in each water distribution unit that are the responsibility of the utility, during the assessment period.	

Size of pump (kW) – Water Distribution

Dropdown menu in which the user must choose the size of the assessed pump. This will be used for benchmarking about expected energy consumption.

Size of pump (kW)	*wsd_pmp_size [kW]*
Pump size kW	

The options for this menu are available at **Table 9**, in the annex.

Static head – Water Distribution

User input used to calculate performance indicators regarding energy efficiency. It is the height that water must travel as it moves through a pipe.

Static head	*wsd_sta_head [m]*
Static head measures the total vertical distance that a pump raises water.	

Mains length – Water Distribution

User input used to calculate performance indicators regarding energy efficiency.

Mains length	*wsd_main_len [m]*
Total transmission and distribution mains length (service connections not included), for each water distribution unit at the reference date.	

Do you want to evaluate electromechanical efficiency of pump?

Measured pump flow – Water Distribution

User input used to calculate waterpower when evaluating electromechanical efficiency of a pump.

Measured pump flow	*wsd_pmp_flow [m³/s]*
Measured pump flow	

Measured pump voltage – Water Distribution

User input used to calculate the electromechanical efficiency of a pump.

Measured pump voltage	*wsd_pmp_volt [V]*
Measured pump voltage	

Measured pump current – Water Distribution

User input used to calculate the electromechanical efficiency of a pump.

Measured pump current	*wsd_pmp_amps [A]*
Measured pump current	

Power factor – Water Distribution

User input used to calculate the electromechanical efficiency of a pump.

Power factor	*wsd_pmp_pf [ratio]*
Power factor	

Expected electromechanical efficiency of new pump – Water Distribution

Expected electromechanical efficiency of new pump is a user input. It is used to calculate:

- Standardized energy consumption of new pump,
- energy consumption with expected new pump efficiency.

Expected electromechanical efficiency of new pump	*wsd_pmp_exff [%]*
Expected electromechanical efficiency of new pump	

Do you know the utility costs by stage?

Energy costs – Water Distribution

The user optionally fills in the total energy costs of the stage, so that the total costs of the system can be calculated.

Energy costs	*wsd_nrg_cost [$]*
Costs from electric energy consumption for the entire water supply utility, based on the electricity bill during the entire assessment period.	

Total running costs – Water Distribution

The user optionally fills in the total costs of the stage, so that the total costs of the system can be calculated.

Total running costs	*wsd_run_cost [$]*
Total operations and maintenance net costs and internal manpower net costs (i.e. not including the capitalised cost of self-constructed assets) related to water supply within the service area, managed by the utility, during the entire assessment period.	

Sanitation – General

Resident population – Sanitation

User input used to calculate the service level performance indicator "Serviced population" with wastewater treatment (%), as well as to estimate the volume of generated wastewater.

Resident population	*ww_resi_pop [people]*
Number of permanent residents within the area of service for wastewater services managed by the utility (whether they are connected or not), at the reference date.	

Volume of generated wastewater – Sanitation

Input that can be estimated. It is calculated considering the resident population and the per capita wastewater generation.

Volume of generated wastewater	*ww_vol_gene*
Volume of generated wastewater	
$ww\_vol\_gene\ [m^3] = PCW \cdot ww\_resi\_pop \cdot Days$	**Equation 9**
With:	
ww_resi_pop [people]	Resident population
PCW [m^3/person.day]	Per capita wastewater generation = 0.2
Days [days]	Assessment period
Sources	PCW assumption based on expert judgement considering the following sources: **Chen et al. (2021)** https://essd.copernicus.org/preprints/essd-2020-156/essd-2020-156-typeset_manuscript-version4.pdf **Mesdaghinia et al. (2015)** https://www.researchgate.net/publication/276187716_The_estimation_of_per_capita_loadings_of_domestic_wastewater_in_Tehran **Von Sperling (2015)** https://doi.org/10.2166/9781780402093

Energy costs – Sanitation

Input that can be estimated. It is a sum of all the costs of the sanitation stages.

Energy costs	*ww_nrg_cost*
Costs from electric energy consumption for all wastewater utilities, based on the electricity bill during the entire assessment period.	
$ww\_nrg\_cost\ [\$] = wwc\_nrg\_cost + wwt\_nrg\_cost + wwo\_nrg\_cost$	**Equation 10**
With:	
wwc_nrg_cost [$]	Energy costs
wwo_nrg_cost [$]	Energy costs
wwt_nrg_cost [$]	Energy costs

Total running costs – Sanitation

Input that can be estimated. It is a sum of all operation and maintenance costs of the sanitation stages.

Total running costs	*ww_run_cost*
Total operations and maintenance net costs and internal manpower net costs (i.e. not including the capitalised cost of self-constructed assets) related to wastewater management within the service area managed by the utility during the entire assessment period.	
$ww\_run\_cost\ [\$] = wwc\_nrg\_cost + wwt\_nrg\_cost + wwo\_nrg\_cost$	**Equation 11**
With:	
wwc_run_cost [$]	Total running costs
wwt_run_cost [$]	Total running costs
wwo_run_cost [$]	Total running costs

Sanitation – Collection

Population connected to sewers – Sanitation Collection

User input. It is used to estimate the following variables:

- Volume of collected wastewater,
- total nitrogen load collected,
- BOD_5 load collected.

Population connected to sewers	*wwc_conn_pop [people]*
Number of permanent residents within the service area managed by the utility which are connected to the sewer system, at the reference date.	

Volume of collected wastewater – Sanitation Collection

Input that can be estimated. It is calculated considering the population connected to the sewers and the per capita wastewater generation.

Volume of collected wastewater	*wwc_vol_coll*
Volume of collected wastewater that is responsibility of the utility, during the assessment period.	
$wwc\_vol\_coll\ [m^3] = PCW \cdot wwc\_conn\_pop\ \cdot Days$	**Equation 12**
With:	
wwc_conn_pop [people]	Population connected to sewers
PCW [m^3/person.day]	Per capita wastewater generation = 0.2
Days [days]	Assessment period
Sources	PCW assumption based on expert judgement considering the following sources: **Chen et al. (2021)** https://essd.copernicus.org/preprints/essd-2020-156/essd-2020-156-typeset_manuscript-version4.pdf **Mesdaghinia et al. (2015)** https://www.researchgate.net/publication/276187716_The_estimation_of_per_capita_loadings_of_domestic_wastewater_in_Tehran **Von Sperling (2015)** https://doi.org/10.2166/9781780402093

Volume of collected wastewater untreated (e.g.CSO) – Sanitation Collection

Volume of collected wastewater untreated is an estimate input. It is the total volume of wastewater collected, minus the volume sent for treatment.

Volume of collected wastewater untreated (e.g. CSO)	*wwc_vol_coll_unt*
Volume of collected wastewater untreated (e.g. CSO)	
$wwc\_vol\_coll\_unt\ [m^3] = wwc\_vol\_coll\ - wwc\_vol\_coll\_tre$	**Equation 13**
With:	
wwc_vol_coll [m^3]	Volume of collected wastewater
wwc_vol_coll_tre [m^3]	Volume of collected wastewater conveyed to treatment

Volume of collected wastewater conveyed to treatment – Sanitation Collection

Input that can be estimated. It is the total volume of wastewater collected, minus the volume of collected wastewater untreated.

Volume of collected wastewater conveyed to treatment and Volume of collected wastewater untreated (e.g.CSO)" are both estimates calculated based on each other. This means that the user must manually fill in at least one of them to obtain the estimate of the other.

Volume of collected wastewater conveyed to treatment	*wwc_vol_coll_tre*
Volume of collected wastewater untreated (e.g. CSO)	
$wwc\_vol\_coll\_tre\ [m^3] = wwc\_vol\_coll - wwc\_vol\_coll\_unt$	**Equation 14**
With:	
wwc_vol_coll	Volume of collected wastewater [m³]
wwc_vol_coll_unt	Volume of collected wastewater untreated (e.g. CSO) [m³]

BOD_5 load collected – Sanitation Collection

Input that can be estimated considering the BOD_5 per capita generation value assumed in the Configuration tab (see "**General and Country specific"** factors).

BOD_5 load collected	*wwc_bod*
BOD_5 load collected	
$wwc\_bod[kg] = wwc\_conn\_pop \cdot bod\_pday \cdot 0.001 \cdot Days$	**Equation 15**
With:	
wwc_conn_pop [people]	Number of permanent residents within the service area managed by the utility, which are connected to the sewer system at the reference date.
bod_pday [g/person/day]	This represents the average Biochemical oxygen demand (BOD_5), that each resident connected to the sewer system eliminates in the daily produced wastewater .
Days [Days]	Period adopted for the assessment of the data and of the PI
0.001	Conversion factor g/kg
Source	**IPCC (2019b, p.6.21)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Total Nitrogen load collected – Sanitation Collection

Input that can be estimated considering the Total Nitrogen values assumed in the Configuration tab (see "General and Country specific factors"). **Equation 16** is based on **Equation 1**.

Total Nitrogen load collected	*wwc_tn*
Total Nitrogen load collected	
$wwc\_tn[kg] = wwc\_conn\_pop \cdot prot\_con \cdot Years \cdot ct\_F\_NPR \cdot N\_HH \cdot F\_NON\_CON \cdot F\_IND\_COM$	**Equation 16**
With:	
wwc_conn_pop [person]	Number of permanent residents within the service area managed by the utility which are connected to the sewer system, at the reference date
prot_con [kgprotein/person/year]	Protein consumption per capita per year. The default value is provided after selection of country. If you have a specific factor that applies to your region you can provide
Years [years]	Period adopted for the assessment of the data and of the PI
ct_F_NPR [kg N/kg protein]	Constant fraction of nitrogen in proteins = 0.16

N_HH [kgN/kgN]	Additional nitrogen from household products added to the wastewater (N_HH)
F_NON_CON [kgN/kgN]	Factor for nitrogen in non consumed protein disposed in sewer system
F_IND_COM [kgN/kgN]	Factor for industrial and commercial co-discharged protein into the sewer system
Source	**IPCC (2019b, p. 6.40)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

For details on each of the elements that make up this equation, access the topic **General and Country specific** factors.

CH_4 emission factor (untreated collected wastewater) – Sanitation Collection

Dropdown menu in which the user must choose the type of discharge. This variable is used to calculate the emissions related to discharge to water body (untreated).

CH_4 emission factor (untreated collected wastewater)	*wwc_ch4_efac_cso [kgCH4/kgBOD]*
CH_4 emission factor (untreated collected wastewater)	

The data table associated with this dropdown menu can be consulted in **Table 11** in the annex.

Remember that to select emission factors associated with wastewater discharge it is necessary to understand the selection of the appropriate "Tier". For this, access topic **Tier (Level of Information)**.

CH_4 emission factor (collected wastewater) – Sanitation Collection

"CH_4 emission factor (collected wastewater)" is a dropdown menu, in which the user must choose the type of sewer. This variable is used to calculate the emissions related to the generation of GHGs in sewers.

CH_4 emission factor (collected wastewater)	*wwc_ch4_efac_col [kgCH4/kgBOD]*
CH_4 emission factor (collected wastewater)	

The data table associated with this dropdown menu can be consulted in ***Table 12*** in the annex.

N_2O emission factor (untreated collected wastewater) – Sanitation Collection

N_2O emission factor (untreated collected wastewater) is a dropdown menu, in which the user must choose the type of discharge. This variable is used to calculate the emissions related to discharge to water body (untreated).

N_2O emission factor (untreated collected wastewater)	*wwc_n2o_efac_cso [kgN2O-N/kgN]*
N_2O emission factor (untreated collected wastewater)	

The data table associated with this dropdown menu can be consulted in ***Table 16*** in the annex.

Remember that to select emission factors associated with wastewater discharge it is necessary to understand the selection of the appropriate "Tier". For this, access topic **Tier (Level of Information)**.

N_2O emission factor (collected wastewater) (default: 0) – Sanitation Collection

The default value 0 is based on the IPCC (2019b), but the user is free to adopt values based on local data or national statistics. Expert judgment is recommended for this purpose.

N_2O emission factor (collected wastewater) (default: 0)	*wwc_n2o_efac_col [kgN2O-N/kgN]*

N_2O emission factor (collected wastewater) (default: 0)

Further discussion on this topic can be found in **N2O emissions from sewers**.

Energy consumed from the grid – Sanitation Collection

User input used to calculate the following outputs:

- Total energy consumed from the grid in the sanitation system,
- energy consumption per wastewater conveyed to treatment,
- indirect CO_2 emissions,
- estimated electricity savings.

Energy consumed from the grid	*wwc_nrg_cons [kWh]*
Energy consumed during the assessment period by each pumping station for conveying wastewater to treatment managed by the utility.	

Emission factor for grid electricity – Sanitation Collection

Input that can be estimated. The value of this variable is the same as the variable "conv_kwh_co2" defined in the ECAM **Configuration** tab. See the "
General and Country specific factors" topic of this document for more information.

Emission factor for grid electricity	*wwc_conv_kwh*
Emission factor for grid electricity (indirect emissions)	
$wwc\_conv\_kwh\ [kgCO2eq/kWh] = conv\_kwh\_co2$	**Equation 17**
With: conv_kwh_co2 [kgCO2/kWh] Emission factor for grid electricity	

Do you have fuel engines?

If the utility has its own fuel engines to meet internal demand, this option can be selected, and new inputs must be filled in or estimated.

Fuel type (engines) – Sanitation Collection

Dropdown menu in which the user must choose the type of fuel used. This variable is used to calculate the direct emissions associated with onsite engines. The data table for this dropdown menu is available at **Table 8**, in the annex.

Fuel type (engines)	*wwc_fuel_typ [X]*
Fuel type (engines)	

Volume of fuel consumed – Sanitation Collection

User input associated with the fuel type, it is used to calculate the direct emissions related to onsite engines.

Volume of fuel consumed	*wwc_vol_fuel [m^3]*
Volume of fuel consumed	

Do you want to evaluate pumping efficiency?

Energy consumed from the grid (pumping) – Sanitation Collection

User input used to calculate the "standardized energy consumption" indicator.

Energy consumed from the grid (pumping)	*wwc_nrg_pump [kWh]*
Energy consumed from the grid (pumping)	

Volume of pumped wastewater – Sanitation Collection

User input used to calculate:

- "Standardized energy consumption",
- "energy consumption with expected new pump efficiency".

Volume of pumped wastewater	*wwc_vol_pump [m^3]*
Volume of pumped wastewater	

Pump head – Sanitation Collection

User input used to calculate performance indicators regarding energy efficiency. It is the maximum height that a pump can move fluid against gravity.

Pump head	*wwc_pmp_head [m]*
Head at which the water is pumped in each water distribution unit that are the responsibility of the utility, during the assessment period	

Static head – Sanitation Collection

User input used to calculate performance indicators regarding energy efficiency. It is the height that water must travel as it moves through a pipe.

Static head	*wwc_sta_head [m]*
Static head measures the total vertical distance that a pump raises water	

Collector length – Sanitation Collection

User input used to calculate performance indicators regarding energy efficiency.

Collector length	*wwc_coll_len [m]*
Collector length	

Do you want to evaluate electromechanical efficiency of pump?

Measured pump flow – Sanitation Collection

User input used to calculate water power when evaluating electromechanical efficiency of pump.

Measured pump flow	*wwc_pmp_flow [m^3/s]*
Measured pump flow	

Measured pump voltage – Sanitation Collection

User input used to calculate the electromechanical efficiency of a pump.

Measured pump voltage	*wwc_pmp_volt [V]*
Measured pump voltage	

Measured pump current – Sanitation Collection

User input used to calculate the electromechanical efficiency of a pump.

Measured pump current	*wwc_pmp_amps [A]*
Measured pump current	

Power factor – Sanitation Collection

Power factor user input used to calculate the electromechanical efficiency of a pump.

Power factor	*wwc_pmp_pf [ratio]*
Power factor is the ratio of working power, measured in kilowatts (kW), to apparent power, measured in kilovolt amperes (kVA). It is a measurement that can quickly determine the amount of load on a motor.	

Expected electromechanical efficiency of new pump – Sanitation Collection

User input used to calculate the indicator "standardized energy consumptio" of new pumps.

Expected electromechanical efficiency of new pump	*wwc_pmp_exff [%]*
Expected electromechanical efficiency of new pump.	

Do you know the utility costs by stage?

Energy costs – Sanitation Collection

The user optionally fills in the total energy costs of the stage, so that the total costs of the system can be calculated.

Energy costs	*wwc_nrg_cost [$]*
Costs from electric energy consumption for the entire wastewater utility, based on the electricity bill during the entire assessment period.	

Total running costs – Sanitation Collection

The user optionally fills in the total costs of the stage, so that the total costs of the system can be calculated.

Total running costs	*wwc_run_cost [$]*
Total operations, maintenance net costs and internal manpower net costs (i.e. not including the capitalised cost of self-constructed assets) related to wastewater management within the service area, that is managed by the utility during the entire assessment period.	

Sanitation – Treatment

Serviced population – Sanitation Treatment

User input used to calculate the following estimates:

- Volume of treated wastewater,
- total nitrogen load in the influent,
- influent BOD_5 load,
- sludge removed from wastewater treatment.

Serviced population	*wwt_serv_pop [people]*
"Serviced population" is referred to the number of inhabitants (or inhabitant equivalents), within the area of service managed by the utility, who are connected to a sewer system and whose wastewater is receiving treatment in a WWTP.	

Volume of treated wastewater – Sanitation Treatment

Input that can be estimated. It is calculated considering the population connected to the treatment system (serviced) and the per capita wastewater generation.

Volume of treated wastewater	*wwt_vol_trea*
Volume of treated wastewater over the assessment period	
$wwt\_vol\_trea[m^3] = PCW \cdot wwt\_serv\_pop \cdot Days$	**Equation 18**
With:	
wwt_serv_pop [people]	Serviced population
PCW [m^3/person.day]	Per capita wastewater generation = 0.2
Days [days]	Assessment period
Sources	PCW assumption based on expert judgement considering the following sources: **Chen et al. (2021)** https://essd.copernicus.org/preprints/essd-2020-156/essd-2020-156-typeset_manuscript-version4.pdf **Mesdaghinia et al. (2015)** https://www.researchgate.net/publication/276187716_The_estimation_of_per_capita_loadings_of_domestic_wastewater_in_Tehran **Von Sperling (2015)** https://doi.org/10.2166/9781780402093

Volume of discharged effluent to water body – Sanitation Treatment

Volume of discharged effluent to water body is an estimate input. It is the total volume of treated wastewater, minus the volume of reused effluent.

Volume of discharged effluent to water body	*wwt_vol_disc*
Volume of wastewater discharged by each wastewater treatment plant that are the responsibility of the utility, during the assessment period. This includes all the wastewater collected, whether it is conveyed to treatment or discharged untreated.	
$wwt\_vol\_disc[m^3] = wwt\_vol\_trea - wwt\_vol\_nonp$	**Equation 19**
With:	
wwt_vol_trea	Volume of treated wastewater [m^3]
wwt_vol_nonp	Volume of reused effluent [m^3]

Influent BOD_5 load – Sanitation Treatment

Input that can be estimated. It is calculated considering the BOD_5 per capita generation value assumed in the Configuration tab (see "

General and Country specific factors"). **Equation 20** is based on **Equation 3**.

Influent BOD_5 load	*wwt_bod_infl*
BOD_5 load entering the WWTP during the assessment period. It can be estimated by multiplying the average BOD_5 concentration in the influent by the volume entering the plant. If this is done daily and summed over the duration of the assessment period, the value will be more accurate.	
$wwt\_bod\_infl[kg] = wwt\_serv\_pop \cdot bod\_pday \cdot 0.001 \cdot Days$	**Equation 20**
With:	
wwt_serv_pop [people]	Serviced population
bod_pday [g/person/day]	BOD_5 generation (wastewater)
Days [days]	Period adopted for the assessment
0.001	Conversion factor g/kg
Source	**IPCC (2019b p. 6.21)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Effluent BOD_5 load – Sanitation Treatment

Effluent BOD_5 load is an estimate input based on a dropdown menu in which the user must choose the type treatment adopted in the WWTP. It is used to calculate the following emissions:

- Discharged water
- GHG emissions avoided due to water eliminating discharge receiving water

The calculation considers the influent BOD and the organics resulting fractions after removal (**Equation Equation** 21).

Effluent BOD_5 load	*wwt_bod_effl*
BOD_5 load at the effluent of the WWTP during the assessment period. It can be estimated by multiplying the average BOD_5 concentration in the effluent by the effluent volume of the plant. If this is done daily and summed over the duration of the assessment period, the value will be more accurate.	
$wwt\_bod\_effl\ [kg] = wwt\_bod\_infl \cdot bod\_effl$	**Equation 21**
With:	
wwt_bod_infl [kg]	Influent BOD_5 load
bod_effl [%]	Percentage of resulting BOD fraction after removal by treatment. Based on Table 18.
Source	**IPCC (2019b, p.6.21)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

The data table associated with this dropdown menu can be consulted in **Table 18** in the annex.

Total Nitrogen load in the influent – Sanitation Treatment

Input that can be estimated. It is calculated considering the Total Nitrogen factors values assumed in the Configuration tab (see "General and Country specific factors"). **Equation 22** is based on **Equation 1**.

Total Nitrogen load in the influent	*wwt_tn_infl*
Total Nitrogen load in the influent during the assessment period	
$wwt\_tn\_infl\ [kg] = wwt\_serv\_pop \cdot prot\_con \cdot Years \cdot ct\_F\_NPR \cdot N\_HH \cdot F\_NON\_CON \cdot F\_IND\_COM$	**Equation 22**
With:	
wwt_serv_pop [people]	Serviced population is referred to the number of inhabitants (or inhabitant equivalents), within the area of service managed by the utility, which are connected to a sewer system and which wastewater are receiving treatment in a WWTP.
prot_con [kgprotein/person/year]	Protein consumption per capita per year. The default value is provided after selection of country. If you have a specific factor that applies to your region you can provide
Years [years]	Period of time adopted for the assessment of the data and of the PI
ct_F_NPR [kg N/kg protein]	Constant fraction of nitrogen in protein = 0.16
N_HH [kgN/kgN]	Additional nitrogen from household products added to the wastewater
F_NON_CON [kgN/kgN]	Factor for nitrogen in non consumed protein disposed in sewer system
F_IND_COM [kgN/kgN]	Factor for industrial and commercial co-discharged protein into the sewer system
Source	**IPCC (2019b, p. 6.40)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Details on each of the elements that make up this equation can be found on the topic **General and Country specific** factors.

Total Nitrogen load in the effluent – Sanitation Treatment

Input that can be estimated based on a dropdown menu in which the user must choose the type treatment adopted in the WWTP. It is used to calculate the following emissions:

- Discharged water,
- GHG emissions avoided due to water eliminating discharge receiving water.

The calculation considers the total nitrogen load in the influent and the nitrogen resulting fractions after removal (**Equation 23)**.

Total Nitrogen load in the effluent	*wwt_tn_effl*
Total Nitrogen load in the effluent of the WWTP during the assessment period.	
$wwt\_tn\_effl\ [kg] = wwt\_tn\_infl \cdot tn\_effl$	**Equation 23**
With:	
wwt_tn_infl [kg]	Total Nitrogen load in the influent
tn_effl [%]	Percentage of resulting TN fraction after removal by treatment. Based on Table 18.
Source	**IPCC (2019b, p. 6.21)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

The data table associated with this dropdown menu can be consulted in **Table 18** in the annex.

CH_4 emission factor (treatment) – Sanitation Treatment

Dropdown menu in which the user must choose the type of treatment. This variable is used to calculate the emissions related to treatment process.

CH_4 emission factor (treatment)	*wwt_ch4_efac_tre [kgCH4/kgBOD]*
Methane emission factor of selected biological wastewater treatment processes	

The data table associated with this dropdown menu can be consulted in **Table 13** in the annex.

N_2O emission factor (treatment) – Sanitation Treatment

Dropdown menu in which the user must choose the type of treatment. This variable is used to calculate the emissions related to the treatment process.

N_2O emission factor (treatment)	*wwt_n2o_efac_tre [kgN2O-N/kgN]*
N_2O emission factor for treatment	

The data table associated with this dropdown menu can be consulted in **Table 15**.

CH_4 emission factor (discharge) – Sanitation Treatment

Dropdown menu in which the user must choose the type of discharge. This variable is used to calculate the emissions related to discharged water.

CH_4 emission factor (discharge)	*wwt_ch4_efac_dis [kgCH4/kgBOD]*
Methane emission factor for discharged water	

The data table associated with this dropdown menu can be consulted in **Table 11 i**n the annex.

Remember that to select emission factors associated with wastewater discharge it is necessary to understand the selection of the appropriate tier For this, access topic **Tier (Level of Information)**.

N_2O emission factor (discharge) – Sanitation Treatment

Dropdown menu in which the user must choose the type of discharge. This variable is used to calculate the emissions related to discharged water.

N_2O emission factor (discharge)	*wwt_nso_efac_dis [kgN2O-N/kgN]*
N_2O emission factor for discharge	

The data table associated with this dropdown menu can be consulted in **Table 16**.

Energy consumed from the grid – Sanitation Treatment

Energy consumed from the grid is a user input. It is used to calculate a few outputs:

- Total energy consumed from the grid in the sanitation system,
- energy consumption per treated wastewater,
- indirect CO_2 emissions,
- estimated electricity savings.

Energy consumed from the grid	*wwt_nrg_cons [kWh]*
Total energy consumed during the assessment period by all wastewater treatment plants managed by the utility	

Emission factor for grid electricity – Sanitation Treatment

Input that can be estimated. The value of this variable is the same as the variable "conv_kwh_co2" defined in the ECAM **Configuration** tab. See the " **General and Country specific** factors" topic of this document for more information.

Emission factor for grid electricity	*wwt_conv_kwh*
Emission factor for grid electricity (indirect emissions)	
$wwt\_conv\_kwh\ [kgCO2eq/kWh] = conv\_kwh\_co2$	**Equation 24**
With:	
conv_kwh_co2 [kgCO2/kWh]	Ratio of CO2 emission per energy consumed

Sludge removed from wastewater treatment (dry weight) – Sanitation Treatment

Dropdown menu in which the user must choose production of sludge based on the treatment technology. It is used to calculate the service level indicator "sludge production".

Sludge removed from wastewater treatment (dry weight)	*wwt_mass_slu [kg]*
Amount of raw sludge removed from wastewater treatment as dry mass during the assessment period	

The data table associated with this dropdown menu can be consulted in Table 20.

BOD_5 removed as sludge – Sanitation Treatment

Input that can be estimated via a dropdown menu. It is calculated considering the dry mass of removed sludge from the WWTP and a sludge factor from IPCC (2019b) (**Equation 25**). The sludge factor depends on the treatment type (**Table 17**).

BOD_5 removed as sludge	*wwt_bod_slud*
Amount of raw sludge removed from wastewater treatment as dry mass during the assessment period	
$wwt\_bod\_slud\ [ton] = wwt\_mass\_slu \cdot Krem \cdot 1000$	**Equation 25**
With:	
wwt_mass_slu [ton]	Sludge removed from wastewater treatment (dry mass)
Krem [kgBOD/kgdrysludge]	Sludge factor based on Table 17
1000	Convertion factor for tonnes to kilograms
Source	**IPCC (2019, p. 6.27)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Do you have fuel engines?

If the utility has its own fuel engines to meet internal demand, this option can be selected, and new inputs must be filled in or estimated.

Fuel type (engines) – Sanitation Treatment

Fuel type is a dropdown menu, in which the user must choose the type of fuel used. This variable is used to calculate the direct emissions associated with onsite engines. The data table for this dropdown menu is available at **Table 8**, in the annex.

Fuel type (engines)	*wwt_fuel_typ [X]*
Fuel type (engines)	

Volume of fuel consumed – Sanitation Treatment

User input associated with the fuel type, it is used to calculate the direct emissions related to onsite engines.

Volume of fuel consumed	*wwt_vol_fuel [m³]*
Volume of fuel consumed	

Are you producing biogas from anaerobic digestion?

Biogas produced (volume) – Sanitation Treatment

Input that can be estimated. It is calculated using the bridle model for process sludge digestion (Snip, 2010). This model calculates biogas depending on the amount of sludge that is digested (**Equation Equation 26**).

Biogas produced (volume)	*wwt_biog_pro*
Biogas produced during the assessment period by the wastewater treatment plant managed by the utility	
$wwt\_biog\_pro\ [Nm^3] = wwt\_mass\_slu \cdot 0.80 \cdot 0.60 \cdot 0.80$	**Equation 26**
With:	
wwt_mass_slu [kg]	Amount of raw sludge removed from wastewater treatment as dry mass during the assessment period
0.80 [kgVS / kgsludge]	Amount of VS in sludge
0.60[kgVSdestroyed/kgVS]	Amount of VS that are destroyed
0.80 [m^3/kgVS destroyed]	Biogas specific production
Sources	Equation based on **Snip (2010, p.19f.)** https://edepot.wur.nl/138115 Factors estimated based on **Andreoli et al. (2007)** and **Metcalf, Eddy (2003).** Obs: Nm^3: in normal conditions of temperature (0ºC) and pressure (1atm), in which one mole of methane gas (16 grams) occupies 0.0224 m^3.

Biogas flared (% volume) – Sanitation Treatment

Input that can be estimated. It is calculated by subtracting the other portions of biogas calculated by the user.

Biogas flared (% volume)	*wwt_biog_fla*
Biogas flared (% volume)	
$wwt\_biog\_fla\ [\%] = 100 - wwt\_biog\_val - wwt\_biog\_lkd - wwt\_biog\_sold$	**Equation 27**
With:	
wwt_biog_val [%]	Biogas valorised in the treatment plant to heat the digesters or the building and/or to run a Co-generator to generate heat and electricity.
wwt_biog_lkd [%]	Biogas leaked to the atmosphere (% volume)
wwt_biog_sold [%]	Biogas sold (% volume)

Biogas valorised as heat and/or electricity (% volume) – Sanitation Treatment

Input that can be estimated. It is calculated by subtracting the other portions of biogas calculated by the user.

Biogas valorised as heat and/or electricity (% volume)	*wwt_biog_val*
Biogas valorised in the treatment plant to heat the digesters or the building and/or to run a Co-generator to generate heat and electricity.	
$wwt\_biog\_val\ [\%] = 100 - wwt\_biog\_fla - wwt\_biog\_lkd - wwt\_biog\_sold$	**Equation 28**
With:	
wwt_biog_fla [%]	Are you producing biogas from anaerobic digestion?
wwt_biog_lkd [%]	Biogas leaked to the atmosphere (% volume)
wwt_biog_sold [%]	Biogas sold (% volume)

Biogas leaked to the atmosphere (% volume) – Sanitation Treatment

Input that can be estimated. It is calculated by subtracting the other portions of biogas calculated by the user.

Biogas leaked to the atmosphere (% volume)	*wwt_biog_lkd*
Biogas leaked to the atmosphere (% volume)	
$wwt\_biog\_val\ [\%] = 100 - wwt\_biog\_val - wwt\_biog\_fla - wwt\_biog\_sold$	**Equation 29**
With:	
wwt_biog_val [%]	Biogas valorised in the treatment plant to heat the digesters or the building and/or to run a Co-generator to generate heat and electricity.
wwt_biog_fla [%]	Biogas flared (% volume)
wwt_biog_sold [%]	Biogas sold (% volume)

Biogas sold (% volume) – Sanitation Treatment

Input that can be estimated. It is calculated by subtracting the other portions of biogas calculated by the user.

Biogas sold (% volume)	*wwt_biog_sold*
Biogas sold (% volume)	
$wwt\_biog\_sol\ [\%] = 100 - wwt\_biog\_val - wwt\_biog\_fla - wwt\_biog\_lkd$	**Equation 30**
With:	
wwt_biog_val [%]	Biogas valorised in the treatment plant to heat the digesters or the building and/or to run a Co-generator to generate heat and electricity
wwt_biog_fla [%]	Biogas flared (% volume)
wwt_biog_lkd [%]	Biogas leaked to the atmosphere (% volume)

Percentage of methane in the biogas (% volume) – Sanitation Treatment

User input used to calculate the GHG emissions related to biogas.

Percentage of methane in the biogas (% volume)	*wwt_ch4_biog [%]*
Percent of the methane content in the produced biogas	

Fuel type (digester) – Sanitation Treatment

Dropdown menu in which the user must choose the type of fuel used. This variable is used to calculate the direct emissions associated with onsite engines. The data table for this dropdown menu is available at **Table 8**, in the annex.

Fuel type (digester)	*wwt_dige_typ [X]*
Fuel type (digester)	

Fuel consumed for the digester – Sanitation Treatment

User input associated with the fuel type, it is used to calculate the direct emissions related to onsite engines.

Fuel consumed for the digester	*wwt_fuel_dig [m³]*
Fuel consumed for the digester	

Energy efficiency for biogas valorization with respect to the theoretical maximum – Sanitation Treatment

User input used to calculate the energy produced from biogas valorisation. In ECAM, default value is 43% for efficiency with respect to the theoretical maximum energy, based on Corominas et al. (2012, p. 2857)

Energy efficiency for biogas valorization with respect to the theoretical maximum	*wwt_nrg_biog_eff [%]*
Energy efficiency for biogas valorization with respect to the theoretical maximum	

Electrical energy produced from biogas valorization – Sanitation Treatment

Input that can be estimated. It is calculated considering the total energy content of biogas valorised.

Electrical energy produced from biogas valorization	*wwt_nrg_biog*
Energy produced from biogas valorization during the assessment period by each wastewater treatment plant managed by the utility	
$wwt\_nrg\_biog\ [kWh] = \frac{wwt\_nrg\_biog\_eff}{100} \cdot wwt\_nrg\_biog\_val$	**Equation 31**
With:	
wwt_nrg_biog_eff [%]	Energy efficiency for biogas valorization with respect to the theoretical maximum
wwt_nrg_biog_val [kWh]	Sum of energy content of biogas used in a cogenerator or a boiler during the assessment period by all wastewater treatment plants managed by the utility
Source	Based on: **Corominas et al. (2012)**

Do you want to evaluate treatment performance?

Treatment capacity – Sanitation Treatment

User input used to calculate the service level indicator “capacity utilization”.

Treatment capacity	*wwt_trea_cap [m³]*
Treatment capacity of each WWTP that are the responsibility of the wastewater utility, during the assessment period	

Number of water quality tests complying – Sanitation Treatment

User input used to calculate the service level indicator “percentage of quality compliance”.

Number of water quality tests complying	*wwt_tst_cmpl [number]*
Number of tests in each wastewater treatment plant that comply with discharge consents during the assessment period	

Number of water quality tests conducted – Sanitation Treatment

User input used to calculate the service level indicator "percentage of quality compliance".

Number of water quality tests conducted	*wwt_tst_cond [number]*
Number of tests carried out in each treated wastewater treatment plant during the assessment period	

Do you want to evaluate pumping efficiency?

Energy consumed from the grid (pumping) – Sanitation Treatment

User input used to calculate the "standardized energy consumption" indicator.

Energy consumed from the grid (pumping)	*wwt_nrg_pump [kWh]*
Energy consumed from the grid (pumping)	

Volume of pumped wastewater – Sanitation Treatment

Volume of pumped wastewater is a user input used to calculate:

- Standardized energy consumption,
- energy consumption with expected new pump efficiency.

Volume of pumped wastewater	*wwt_vol_pump [m^3]*
Volume of pumped wastewater	

Pump head – Sanitation Treatment

User input used to calculate performance indicators regarding energy efficiency. It is the maximum height that a pump can move fluid against gravity.

Pump head	*wwt_pmp_head [m]*
Head at which the water is pumped in each water treatment unit that are the responsibility of the utility, during the assessment period	

Static head – Sanitation Treatment

User input used to calculate performance indicators regarding energy efficiency. It is the height that water must travel as it moves through a pipe.

Static head	*wwt_sta_head [m]*
Static head measures the total vertical distance that a pump raises water	

Collector length – Sanitation Treatment

User input used to calculate performance indicators regarding energy efficiency

Collector length	*wwt_coll_len [m]*
Collector length	

Do you want to evaluate electromechanical efficiency of pump?

Measured pump flow – Sanitation Treatment

User input used to calculate water power when evaluating electromechanical efficiency of pump.

Measured pump flow	*wwt_pmp_flow [m^3/s]*
Measured pump flow	

Measured pump voltage – Sanitation Treatment

User input used to calculate the electromechanical efficiency of a pump.

Measured pump voltage	*wwt_pmp_volt [V]*
Measured pump voltage	

Measured pump current – Sanitation Treatment

User input used to calculate the electromechanical efficiency of a pump.

Measured pump current	*wwt_pmp_amps [A]*
Measured pump current	

Power factor – Sanitation Treatment

User input used to calculate the electromechanical efficiency of a pump.

Power factor	*wwt_pmp_pf [ratio]*
Power factor is the ratio of working power, measured in kilowatts (kW), to apparent power, measured in kilovolt amperes (kVA). It is a measurement that can quickly determine the amount of load on a motor.	

Expected electromechanical efficiency of new pump – Sanitation Treatment

User input used to calculate the indicator "standardized energy consumption" of a new pump.

Expected electromechanical efficiency of new pump	*wwt_pmp_exff [%]*
Expected electromechanical efficiency of new pump	

Do you have truck transport for reused water?

Fuel type (trucks) – Sanitation Treatment

Dropdown menu in which the user must choose the type of fuel used. This variable is used to calculate the emissions associated with Truck transport of reused water. The data table for this dropdown menu is available at **Table 8**, in the annex.

Fuel type (trucks)	*wwt_reus_trck_typ [X]*
Fuel type (trucks)	

Volume of fuel consumed (trucks) – Sanitation Treatment

User input used to calculate the emissions associated with Truck transport of reused water.

Volume of fuel consumed (trucks)	*wwt_reus_vol_trck [m^3]*
Volume of fuel consumed (trucks)	

Do you want to evaluate GHG emissions avoided from reusing water and nutrients?

Volume of reused effluent – Sanitation Treatment

User inpu used to calculate GHG emissions avoided due to water reuse, eliminating discharge to receiving waters.

Volume of reused effluent	*wwt_vol_nonp [m^3]*
Volume of reused effluent	

Total Nitrogen recovered – Sanitation Treatment

User input used to calculate GHG emissions avoided due to nutrient reused displacing synthetic fertilizer.

Total Nitrogen recovered	*wwt_wr_N_rec [kg]*
Total Nitrogen recovered from ww treatment and/or water reuse, and displacing fertilizer	

Total Phosphorus recovered – Sanitation Treatment

User input used to calculate GHG emissions avoided due to nutrient reused displacing synthetic fertilizer.

Total Phosphorus recovered	*wwt_wr_P_rec [kg]*
Total Phosphorus recovered from ww treatment and/or water reuse, and displacing fertilizer	

Evaluate sludge management (SM)?
[SM] Evaluate sludge storage in WWTP?

Sludge stored (dry weight) – Sanitation Treatment

User input used to calculate GHG emissions related to sludge management.

Sludge stored (dry weight)	*wwt_mass_slu_sto [kg]*
Amount of sludge that is stored prior to disposal (dry weight)	

Storage time – Sanitation Treatment

User input used to calculate GHG emissions related to sludge management.

Storage time	*wwt_time_slu_sto [days]*
Time interval the sludge is stored for before being sent to disposal	

Total Volatile Solids (TVS) content of sludge stored (% of dry weight) – Sanitation Treatment

Dropdown menu in which the user should choose if the stored sludge is digested or non-digested. It is used to calculate GHG emissions related to sludge management. The data table for this dropdown menu is available at
Table 21**,** in the annex.

Total Volatile Solids (TVS) content of sludge stored (% of dry weight)	*wwt_slu_sto_TVS [%]*
Total Volatile Solids (TVS) content of sludge stored (% of dry weight)	

CH_4 potential factor – Sanitation Treatment

Dropdown menu in which the user should choose if the stored sludge is digested or non-digested. It is used to calculate GHG emissions related to sludge management. The data table for this dropdown menu is available at
Table 21, in the annex.

CH_4 potential factor	*wwt_slu_sto_f_CH4 [%]*
CH_4 potential factor is the potential of the sludge to generate methane (ratio for CH_4 potential). It is later used to calculate the max CH_4 that could be released in $kgCH_4$.	

Emission factor due to storage (estimate with storage time) – Sanitation Treatment

Input that can be estimated. When stored, sludge can produce "residual methane", even if it has already been digested. This production, indicated by the variable wwt_slu_sto_EF in %, can also be indicated as gCH_4 released / gCH_4 potential, and depends on the storage time (**Equation 32**).

Emission factor due to storage (estimate with storage time)	*wwt_slu_sto_EF*
Emission factor due to sludge storage. It can be estimated with the storage time.	

$$\begin{aligned} &\boldsymbol{if}\ wwt\_time\_slu\_sto < \mathbf{5} && wwt\_slu\_sto\_EF\ [\%] = 0 \\ &\boldsymbol{if}\ \mathbf{5} < wwt\_time\_slu\_sto < \mathbf{20} && wwt\_slu\_sto\_EF\ [\%] = 3 \\ &\boldsymbol{if}\ wwt\_time\_slu\_sto > \mathbf{20} && wwt\_slu\_sto\_EF\ [\%] = 5 \end{aligned}$$

Equation 32

With:

wwt_time_slu_sto [days]	Storage time
Sources	Assumed based on the authors' experiences: **Daelman et al. (2012); Hansen et al. (2006)**

[SM] Is sludge sent to composting?

Sludge composted (dry weight) – Sanitation Treatment

User input used to calculate GHG emissions related to sludge management.

Sludge composted (dry weight)	*wwt_mass_slu_comp [kg]*
Amount of sludge that is sent to composting (dry weight)	

Are composting emissions treated and/or piles are covered? – Sanitation Treatment

Dropdown menu in which the user should choose if the composting piles are covered (**YES**) or not (**NO**). This selection is important because if the piles are covered, the methane emission will not be considered since it is not released to the atmosphere, according to CCME (2009a).

Are composting emissions treated and/or piles are covered?	*wwt_slu_comp_emis_treated_or_piles_covered [X]*
Are composting emissions treated and/or piles are covered?	

Solids content of compost – Sanitation Treatment

User input used to calculate GHG emissions related to sludge management.

Solids content of compost	*wwt_slu_comp_solids_content [%]*
Solids content of compost	

Total Volatile Solids (TVS) content of sludge composted (% of dry weight) – Sanitation Treatment
Dropdown menu in which the user should choose if the stored sludge is digested or non-digested. It is used to calculate GHG emissions related to sludge management. The data table for this dropdown menu is available at
Table 21, in the annex.

Total Volatile Solids (TVS) content of sludge composted (% of dry weight)	*wwt_slu_comp_TVS [%]*
Total Volatile Solids (TVS) content of sludge composted (% of dry weight)	

N content of sludge composted (% of dry weight) – Sanitation Treatment
Dropdown menu in which the user should choose if the composted sludge is digested or non-digested. It is used to calculate GHG emissions related to sludge management. The data table for this dropdown menu is available at
Table 21, in the annex.

N content of sludge composted (% of dry weight)	*wwt_slu_comp_N_cont [%]*
N content of sludge composted (% of dry weight)	

N_2O emission factor for low C:N ratio – Sanitation Treatment
User input used to calculate GHG emissions related to sludge management.

The default value in ECAM is 0.015 kgN2O-N/kgN (Brown et al., 2008).

N_2O emission factor for low C:N ratio	*wwt_slu_comp_low_CN_EF [kgN_2O-N/kgN]*
N_2O emission factor for low C:N ratio (1.5% from Brown et al, 2008)	

CH_4 emission factor for uncovered pile (fraction of initial C in solids) – Sanitation Treatment
User input used to calculate GHG emissions related to sludge management.

The default value in ECAM is 0.025 kgN2O-N/kgN (Brown et al., 2008).

CH_4 emission factor for uncovered pile (fraction of initial C in solids)	*wwt_slu_comp_uncovered_pile_EF [kgCH_4-C/kgC]*
CH_4 emission factor for uncovered pile (fraction of initial C in solids) (2.5% from Brown et al, 2008)	

CO_2 eq sequestration rate – Sanitation Treatment
User input used to calculate GHG emissions avoided due to carbon sequestration in sludge.

The default value in ECAM is 0.25 kgC0_2eq/kg sludge (CCME, 2009a, p. 149).

CO_2 eq sequestration rate	*wwt_slu_comp_seqst_rate [kgC0_2eq/kgSludge]*
Estimated CO_2 equivalents sequestered per kg of sludge	

[SM] Is sludge sent to incinerate?

Sludge incinerated – Sanitation Treatment
User input used to calculate GHG emissions related to sludge management.

Sludge incinerated	*wwt_mass_slu_inc [kg]*
Amount of sludge that is sent to incineration (dry weight)	

Average highest temperature of combustion achieved in a Fluidized Bed incinerator – Sanitation Treatment

User input used to calculate the % of total N that is emitted as N_2O and then the N_2O GHG emissions related to sludge management.

A default value of 1023 K is adopted by ECAM based on CCME (2009a, p. 161f.). If the user chooses a value lower than 1023 K, the default values will still be used for calculation since it creates a reasonable maximum for N_2O emissions. Higher temperatures will reduce the amount of N_2O emissions gradually.

Average highest temperature of combustion achieved in a Fluidized Bed incinerator	*wwt_temp_inc [K]*
Incineration temperature	

N content of sludge incinerated (% of dry weight) – Sanitation Treatment

Dropdown menu in which the user should choose if the incinerated sludge is digested or non-digested. It is used to calculate GHG emissions related to sludge management. The data table for this dropdown menu is available at
Table 21, in the annex.

N content of sludge incinerated (% of dry weight)	*wwt_slu_inc_N_cont [%]*
N content of sludge incinerated (% of dry weight)	

Is 'SNCR air emissions technology with urea' used? – Sanitation Treatment

Dropdown menu in which the user should choose if the incineration uses selective non-catalytic reduction (SNCR). SNCR is an air pollution technology where there is the injection of ammonia or urea into the backend of the combustion chamber to reduce NOx to N_2.

NOx emissions include nitric oxide (NO) and nitrogen dioxide (N_2O) which can be fatal for humans. Converting them to N_2 with SNCR will make the environment safer, but it will produce additional N_2O emissions. If SNCR air emissions technology within the area are used, the N_2O emissions in ECAM are increased by 20% (CCME, 2009a, p. 162).

Is 'SNCR air emissions technology with urea' used?	*wwt_slu_inc_SNCR [X]*
Is 'SNCR air emissions technology with urea' used?	

[SM] Is sludge sent to land application?

Sludge sent to land application (dry weight) – Sanitation Treatment

User input used to calculate GHG emissions related to sludge management and GHG emissions avoided due to carbon sequestration in land application.

Sludge sent to land application (dry weight)	*wwt_mass_slu_app [kg]*
Amount of sludge that is sent to land application (dry weight)	

Solids content of sludge sent to land application – Sanitation Treatment

User input used to calculate GHG emissions related to sludge management.

Solids content of sludge sent to land application	*wwt_slu_la_solids_content [%]*
Solids content of sludge sent to land application	

Total Volatile Solids (TVS) content of sludge sent to land application – Sanitation Treatment

"Total Volatile Solids (TVS) content of sludge sent to land application" is a dropdown menu, in which the user should choose if the sludge is digested or non-digested. It is used to calculate GHG emissions related to sludge management. The data table for this dropdown menu is available at **Table** 21, in the annex.

Total Volatile Solids (TVS) content of sludge sent to land application	*wwt_slu_la_TVS [%]*
Total Volatile Solids (TVS) content of sludge sent to land application	

N content of sludge sent to land application (% of dry weight) – Sanitation Treatment

"N content of sludge sent to land application (% of dry weight)" is a dropdown menu, in which the user should choose if the sludge is digested or non-digested. It is used to calculate GHG emissions related to sludge management. The data table for this dropdown menu is available at **Table** 21, in the annex.

N content of sludge sent to land application (% of dry weight)	*wwt_slu_la_N_cont [%]*
N content of sludge sent to land application (% of dry weight)	

Amount of Nitrogen converted to N_2O – Sanitation Treatment

Dropdown menu in which the user should choose the type of soil, which will define a N_2O emission factor. It is used to calculate GHG emissions related to sludge management. The data table for this dropdown menu is available at **Table 24**, in the annex.

Amount of Nitrogen converted to N_2O	*wwt_slu_la_EF [kgN$_2$O-N/kgN]*
Amount of Nitrogen converted to N_2O	

CO_2eq sequestration rate – Sanitation Treatment

User input used to calculate GHG emissions avoided due to carbon sequestration in sludge.

The default value in ECAM is 0.25 kgC0$_2$eq/kg sludge (CCME, 2009a, p. 149).

CO_2eq sequestration rate	*wwt_slu_la_seqst_rate [kgCO$_2$eq/kgSludge]*
Estimated CO_2 equivalents sequestered per kg of sludge	

[SM] Is sludge sent to landfilling?

Sludge sent to landfilling (dry weight) – Sanitation Treatment

User input used to calculate GHG emissions related to sludge management and GHG emissions avoided due to carbon sequestration in landfilling.

Sludge sent to landfilling (dry weight)	*wwt_mass_slu_land [kg]*
Amount of sludge that is sent to landfilling (dry weight)	

Total Volatile Solids (TVS) content of sludge sent to landfilling – Sanitation Treatment

Dropdown menu in which the user should choose if the sludge is digested or non-digested. It is used to calculate GHG emissions related to sludge management. The data table for this dropdown menu is available at

Table 21, in the annex.

Total Volatile Solids (TVS) content of sludge sent to landfilling	*wwt_slu_lf_TVS [%]*
Total Volatile Solids (TVS) content of sludge sent to landfilling	

Uncertainty factor (UNFCCC/CCNUC, 2008) – Sanitation Treatment

User input used to calculate GHG emissions related to sludge management.

To determine the methane emissions in landfilling, a model correction factor must be used that considers the uncertainties related to the equation.

The value suggested by ECAM is 0.9 (CCME, 2009a, p. 154; UNFCCC/CCNUC, 2008).

Uncertainty factor (UNFCCC/CCNUC, 2008)	*wwt_slu_lf_uncertainty [adimensional]*
Model uncertainty factor (default value:0.9, UNFCCC/CCNUC, 2008)	

CH_4 in landfill gas – Sanitation Treatment

User input that indicates the volume fraction of methane in the landfill gas. It is used to calculate GHG emissions related to sludge management.

The value suggested by ECAM is 50% (CCME, 2009a, p. 154; UNFCCC/CCNUC, 2008).

CH_4 in landfill gas	*wwt_slu_lf_CH4_in_gas [%]*
CH_4 in landfill gas (50% from Clean Development Mechanism, 2008)	

Decomposable organic fraction of raw wastewater solids – Sanitation Treatment

User input that indicate the fraction of degradable organic carbon. It is used to calculate GHG emissions related to sludge management and avoided emissions due to carbon sequestration.

The value suggested by ECAM is 80% (CCME, 2009a, p. 154; Brown et al., 2008; Metcalf; Eddy, 2003).

Decomposable organic fraction of raw wastewater solids	*wwt_slu_lf_DOCf [%]*
Decomposable organic fraction of raw wastewater solids (80% from Brown et al., 2008 and Metcalf; Eddy, 2003)	

Percentage decomposed in first 3 years – Sanitation Treatment

User input used to calculate GHG emissions related to sludge management.

The value suggested by ECAM is 69.9%, which is calculated from UNFCC/CCNUCC (2008) equations for warm, wet conditions environments.

Percentage decomposed in first 3 years	*wwt_slu_lf_decomp_3yr [%]*
Percentage decomposed in first 3 years of the decomposable organic fraction of raw wastewater solids	

Methane correction for anaerobic managed landfills (default=1) – Sanitation Treatment

Dropdown menu in which the user must choose if the landfill has gas recovery. It is used to calculate GHG emissions related to sludge management (UNFCC/CCNUCC, 2008).

The data table for this dropdown menu is available at **Table 23**, in the annex (UNFCC/CCNUCC, 2008).

Methane correction for anaerobic managed landfills (default=1)	*wwt_slu_lf_MCF [ratio]*
Methane correction for anaerobic managed landfills (default=1, UNFCCC/CCNUCC, 2008)	

N content of sludge sent to landfilling (% of dry weight) – Sanitation Treatment

Dropdown menu in which the user should choose if the sludge is digested or non-digested. It is used to calculate GHG emissions related to sludge management.

The data table for this dropdown menu is available at
Table 21, in the annex.

N content of sludge sent to landfilling (% of dry weight)	*wwt_slu_lf_N_cont [%]*
N content of sludge sent to landfilling (% of dry weight)	

N_2O emission factor for low C:N ratio – Sanitation Treatment

User input used to calculate GHG emissions related to sludge management.

The value suggested by ECAM is 0.015 kgN_2O-N/kgN (Brown et al., 2008).

N_2O emission factor for low C:N ratio	*wwt_slu_lf_low_CN_EF [kgN_2O-N/kgN]*
N_2O emission factor for low C:N ratio (1.5% from Brown et al, 2008)	

[SM] Is sludge sent to stockpiling?

Sludge stockpiled (dry weight) – Sanitation Treatment

User input used to calculate GHG emissions related to sludge management.

Sludge stockpiled (dry weight)	*wwt_mass_slu_stock [kg]*
Amount of sludge that is stockpiled (dry weight)	

Stockpile lifespan – Sanitation Treatment

User input used to calculate GHG emissions related to sludge management.

Stockpile lifespan	*wwt_slu_sp_lifespan [years]*
Expected timespan that the biosolid stockpile (BSP) will be emitting GHGs	

[SM] Do you truck transport sludge to disposal site?

Fuel type (trucks) – Sanitation Treatment

Dropdown menu in which the user must choose the type of fuel used. This variable is used to calculate the emissions associated with sludge management (truck transport). The data table for this dropdown menu is available at **Table 8**, in the annex.

Fuel type (trucks)	*wwt_trck_typ [X]*
Fuel type (trucks)	

Volume of fuel consumed (trucks) – Sanitation Treatment

User input used to calculate GHG emissions associated with sludge management (truck transport).

Volume of fuel consumed (trucks)	*wwt_vol_tslu [m^3]*
Volume of fuel consumed (trucks)	

Do you know the utility costs by stage?

Energy costs – Sanitation Treatment

The user optionally fills in the total energy costs of the stage, so that the total costs of the system can be calculated.

Energy costs	*wwt_nrg_costs [$]*
Costs from electric energy consumption for the entire wastewater utility, based on the electricity bill during the entire assessment period	

Total running costs – Sanitation Treatment

The user optionally fills in the total costs of the stage, so that the total costs of the system can be calculated.

Total running costs	*wwt_run_cost [$]*
Total operations and maintenance net costs and internal manpower net costs (i.e. not including the capitalised cost of self-constructed assets) related to wastewater management within the service area managed by the utility during the entire assessment period	

Sanitation - Onsite sanitation

Total running costs – Onsite sanitation

The user optionally fills in the total costs of the stage, so that the total costs of the system can be calculated.

Total running costs	*wwt_run_cost [$]*
Total operations and maintenance net costs and internal manpower net costs (i.e. not including the capitalised cost of self-constructed assets) related to wastewater management within the service area managed by the utility during the entire assessment period	

Population with onsite sanitation – Onsite sanitation

User input used to calculate the serviced population with onsite sanitation, as well as to estimate the load of BOD entering the containments.

Population with onsite sanitation	*wwo_onsi_pop [people]*
Population with onsite sanitation refers to the number of inhabitants within the assessment area for faecal sludge management that has access to some sort of sanitation facility	

BOD_5 entering the containments – Onsite sanitation

Input that can be estimated. It is calculated considering the BOD_5 per capita generation value assumed in the **Configuration** tab (see "

General and Country specific factors"). **Equation 33** is based on **Equation 3**.

BOD_5 entering the containments	*wwo_bod_cont*
BOD_5 entering the containments during the assessment period. It can be estimated by multiplying the average BOD_5 concentration by the volume entering the plant.	
$wwo\_bod\_cont[kg] = wwo\_onsi\_pop \cdot bod\_pday \cdot 0.001 \cdot Days$	**Equation 33**
With:	
wwo_onsi_pop [people]	Population with onsite sanitation
bod_pday [g/person/day]	BOD_5 generation (wastewater)
Days [days]	Period adopted for the assessment
0.001	Conversion factor g/kg
Source	**IPCC (2019b, p. 6.21)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Is the containment experiencing flooding or groundwater infiltration? – Onsite sanitation

This variable will adjust the variable "CH_4 emission factor (containment) - wwo_ch4_efac_con" considering whether there is flooding or not. For example, if the user selects the variable "Yes", it will not be possible to select the option "Pit latrine with flush water".

Is the containment experiencing flooding or groundwater infiltration?	*wwo_flooding [X]*
Is the containment experiencing flooding or groundwater infiltration?	

CH_4 emission factor (containment) – Onsite sanitation

Dropdown menu in which the user must choose the type of containment. This variable is used to calculate the emissions related to containment.

CH$_4$ emission factor (containment)	*wwo_ch4_efac_con [kgCH$_4$/kgBOD]*
CH$_4$ emission factor (containment)	

The data table associated with this dropdown menu can be consulted in **Table 25 - Type of containment** in the annex.

Containments emptied – Onsite sanitation

User input used to estimate the volume of faecal sludge emptied.

Containments emptied	*wwo_cont_emp [%]*
Fraction of produced faecal sludge that is emptied from containments during the assessment period. If only partial emptying is done it should be reflected in the fraction	

Faecal sludge density – Onsite sanitation

Dropdown menu, in which the user must choose the type of containment. This variable is used to estimate the volume of faecal sludge that is emptied.

Faecal sludge density	*wwo_fdensity [kg/m^3]*
Faecal sludge density	

The data table associated with this dropdown menu can be consulted in **Table 25 - Type of containment** in the annex.

Faecal sludge emptied – Onsite sanitation

Input that can be estimated. It is calculated considering the faecal sludge generation per capita, population, sludge density and fraction of faecal sludge emptied from containments (**Equation 34**).

Faecal sludge emptied *wwo_fslu_emp*

Volume of faecal sludge emptied from the containment during the assessment period

$$wwo\_fslu\_emp \quad [m^3] = \frac{(kg\_person\_day * wwo\_onsi\_pop \; * Days * \frac{wwo\_cont\_emp}{100})}{\mathrm{wwo\_fdensity} \; * \mathrm{wwo\_cont\_emp}}$$ **Equation 34**

With:

kg_person_day	Per capita production of faecal sludge = 0.3 (TA, 2011)
wwo_onsi_pop [people]	Number of inhabitants within the assessment area for faecal sludge management that has access to some sort of sanitation facility
Days [Days]	Period of time adopted for the assessment of the data
wwo_fdensity [kg/m^3]	Faecal sludge density
wwo_cont_emp [%]	Fraction of produced faecal sludge that is emptied from containments during the assessment period. If only partial emptying is done it should be reflected in the fraction

The amount of fecal sludge produced per capita can vary significantly based on dietary habits, frequency of fecal excretion, temporal and spatial habits, among others (Wasaza, Borda, 2017). In ECAM, the suggested value is 0.3 kg_person_day (TA, 2011).

BOD$_5$ concentration of faecal sludge – Onsite sanitation

Dropdown menu in which the user must choose the type of containment.

The data table associated with this dropdown menu can be consulted in **Table 25 - Type of containment** in the annex.

BOD_5 concentration of faecal sludge	*wwo_bod_conc_fs [kg/m³]*
Average BOD concentration of faecal sludge during the assessment period after emptying from containment. It can be estimated from the population with onsite sanitation	

BOD_5 removed as faecal sludge – Onsite sanitation

Input that can be estimated. It is calculated considering the faecal sludge emptied and its concentration of BOD_5 (**Equation 35**).

BOD_5 removed as faecal sludge	*wwo_bod_rmvd*
Total BOD_5 that is removed from the containment technology. It can be estimated from the volume or the mass of FS emptied and standard BOD_5 content	
$wwo\_bod\_rmvd\ [kg] = wwo\_fslu\_emp \cdot wwo\_bod\_conc\_fs$	**Equation 35**
With:	
wwo_fslu_emp [m³]	Volume of faecal sludge emptied from the containment during the assessment period
wwo_bod_conc_fs [kg/m³]	Average BOD concentration of faecal sludge during the assessment period after emptying from containment. It can be estimated from the population with onsite sanitation.
Source	Based on: **IPCC (2019b, p. 6.27)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Influent BOD_5 load (treatment) – Onsite sanitation

Input that can be estimated. It is assumed that this value is equal to the BOD_5 removed as faecal sludge.

Influent BOD_5 load (treatment)	*wwo_bod_infl*
BOD_5 load entering the treatment. It can be estimated from the BOD_5 removed as faecal sludge	
$wwo\_bod\_infl\ [kg] = wwo\_bod\_rmvd$	**Equation 36**
With:	
wwo_bod_rmvd [kg]	BOD_5 removed as faecal sludge

Total Nitrogen load in the influent – Onsite sanitation

User input used to calculate emissions related to the treatment process.

Total Nitrogen load in the influent	*wwo_tn_infl [kg]*
Total Nitrogen load in the influent during the assessment period	

CH_4 emission factor (treatment) – Onsite sanitation

Dropdown menu, in which the user must choose the type of treatment. This variable is used to calculate the emissions related to treatment process.

CH_4 emission factor (treatment)	*wwo_ch4_efac_tre [kgCH₄/kgBOD]*
CH_4 emission factor (treatment)	

The data table associated with this dropdown menu can be consulted in **Table 14** in the annex.

N_2O emission factor (treatment) – Onsite sanitation

Dropdown menu in which the user must choose the type of treatment. This variable is used to calculate the emissions related to the treatment process.

N_2O emission factor (treatment)	*wwo_n2o_efac_tre [kgN$_2$O-N/kgN]*
N_2O emission factor (treatment)	

The data table associated with this dropdown menu can be consulted in **Table 15**.

Effluent BOD_5 load (treatment) – Onsite sanitation

Input that can be estimated based on a dropdown menu in which the user must choose the type treatment adopted in the onsite sanitation. It is used to calculate emissions related to discharged water.

The calculation considers the influent BOD and the organics resulting fractions after removal.

Effluent BOD_5 load (treatment)	*wwo_bod_effl*
BOD_5 load at the effluent of the onsite sanitation during the assessment period. It can be estimated by multiplying the average BOD_5 concentration in the effluent by the effluent volume of the plant. If this is done daily and summed over the duration of the assessment period, the value will be more accurate	
$wwo\_bod\_effl\ [kg] = wwo\_bod\_infl \cdot bod\_effl$	**Equation 37**
With:	
wwo_bod_infl [kg]	Influent BOD_5 load (treatment)
bod_effl [%]	Percentage of resulting BOD fraction after removal by treatment. Based on Table 18.
Source	**IPCC (2019b, p. 6.21)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

The data table associated with this dropdown menu can be consulted in **Table 18** in the annex.

Total Nitrogen load in the effluent – Onsite sanitation

Input that can be estimated based on a dropdown menu in which the user must choose the type treatment adopted. It is used to calculate emissions related to discharged water.

The calculation considers the total nitrogen load in the influent and the nitrogen resulting fractions after removal (**Table 19**).

Total Nitrogen load in the effluent	*wwo_tn_effl*
Total Nitrogen load in the effluent during the assessment period	
$wwo\_tn\_effl\ [kg] = wwt\_tn\_infl \cdot tn\_effl$	**Equation 38**
With:	
wwt_tn_infl [kg]	Total Nitrogen load in the influent
tn_effl [%]	Percentage of resulting TN fraction after removal by treatment. Based on Table 19.
Source	**IPCC (2019b, p. 6.21)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

The data table associated with this dropdown menu can be consulted in **Table 18** in the annex.

BOD_5 removed with excess sludge – Onsite sanitation

Input that can be estimated based on a dropdown menu. It is calculated considering the dry mass of removed sludge from the onsite treatment and a sludge factor from IPCC (2019b) (**Equation 25**). The sludge factor depends on the treatment type (**Table 14**).

BOD_5 removed with excess sludge	*wwo_bod_slud*
BOD_5 removed with excess sludge from the treatment process	
$wwo\_bod\_slud\ [kg] = wwo\_bod\_infl\ \cdot bod\_rmvd\_as\_sludge\_estm$	**Equation 39**
With:	
wwo_bod_infl [kg]	Influent BOD (treatment)
bod_rmvd_as_sludge_estm [%]	Sludge factor based on Table 14
1000	Convertion factor for tonnes to kilograms
Source	Adapted from: **IPCC (2019b, p. 6.27)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

CH_4 emission factor (discharge) – Onsite sanitation

Dropdown menu in which the user must choose the type of discharge. This variable is used to calculate the emissions related to discharged water.

CH_4 emission factor (discharge)	*wwo_ch4_efac_dis [kgCH₄/kgBOD]*
CH_4 emission factor (discharge)	

The data table associated with this dropdown menu can be consulted in **Table 11** in the annex.

Remember that to select emission factors associated with wastewater discharge it is necessary to understand the selection of the appropriate tier. For this, access topic **Tier (Level of Information)**.

N_2O emission factor (discharge) – Onsite sanitation

Dropdown menu in which the user must choose the type of discharge. This variable is used to calculate the emissions related to discharged water.

N_2O emission factor (discharge)	*wwo_n2o_efac_dis [kgN_2O-N/kgN]*
N_2O emission factor (discharge)	

The data table associated with this dropdown menu can be consulted in Table 16.

Population with open defecation – Onsite sanitation

User input used to estimate the total nitrogen load from open defecation.

Population with open defecation	*wwo_open_pop [people]*
Population with open defecation	

Total Nitrogen load from open defecation – Onsite sanitation

Input that can be estimated. It is calculated considering the Total Nitrogen factors values assumed in the **Configuration** tab (see **General and Country specific factors**). **Equation 40** is based on **Equation 1.**

Total Nitrogen load from open defecation	wwo_opd_tn
Total Nitrogen load from open defecation. It can be estimated from the population	
$wwo\_opd\_tn\,[kg] = wwo\_open\_pop \cdot prot\_con \cdot Years \cdot ct\_F\_NPR \cdot N\_HH \cdot F\_NON\_CON \cdot F\_IND\_COM$	**Equation 40**
With:	
wwo_open_pop [people]	Population with open defecation
prot_con [kgprotein/person/year]	Protein consumption per capita per year. The default value is provided after selection of country. If you have a specific factor that applies to your region you can provide
Years	Period of time adopted for the assessment of the data and of the PI [years]
ct_F_NPR [kg N/kg protein]	Constant fraction of nitrogen in proteins = 0.16
N_HH [kgN/kgN]	Additional nitrogen from household products added to the wastewater
F_NON_CON [kgN/kgN]	Non consumed protein added to the wastewater
F_IND_COM [kgN/kgN]	Industrial and commercial co-discharged protein into the sewer
Source	**IPCC (2019b, p. 6.40)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Details on each of the elements that make up this equation can be found on the topic **General and Country specific** factors.

N_2O emission factor (open defecation) – Onsite sanitation

N_2O emission factor (open defecation) is a dropdown menu in which the user must choose the type of discharge. This variable is used to calculate the emissions related to discharged water.

N_2O emission factor (open defecation)	wwo_n2o_efac_opd [kgN_2O-N/kgN]
N_2O emission factor (open defecation)	

The data table associated with this dropdown menu can be consulted in **Table 16.**

Energy consumed from the grid – Onsite sanitation

Energy consumed from the grid is a user input. It is used to calculate a few outputs:

- Total energy consumed from the grid in the Sanitation system,
- indirect CO_2 emissions,
- estimated electricity savings.

Energy consumed from the grid	wwo_nrg_cons [kWh]
Energy consumed from the grid during the assessment period	

Emission factor for grid electricity – Onsite sanitation

Input that can be estimated. The value of this variable is the same as the variable "conv_kwh_co2" defined in the ECAM **Configuration** tab. See the

General and Country specific factors topic of this document for more information.

Emission factor for grid electricity	wwo_conv_kwh

Emission factor for grid electricity (indirect emissions)	
$wwo\_conv\_kwh\ [kgCO2eq/kWh] = conv\_kwh\_co2$	**Equation 41**
With:	
conv_kwh_co2 [kgCO2/kWh]	Ratio of CO2 emission per energy consumed

Do you have fuel engines?

Fuel type (engines) – Onsite sanitation

Dropdown menu in which the user must choose the type of fuel used. This variable is used to calculate the direct emissions associated with onsite engines. The data table for this dropdown menu is available at **Table 8,** in the annex.

Fuel type (engines)	*wwo_fuel_typ [X]*
Fuel type (engines)	

Volume of fuel consumed – Onsite sanitation

User input associated with the fuel type which is used to calculate the direct emissions related to onsite engines.

Volume of fuel consumed	*wwo_vol_fuel [m^3]*
Volume of fuel consumed during the assessment period, for example, for transport or generators	

Do you want to evaluate pumping efficiency?

Energy consumed from the grid (pumping) – Onsite sanitation

User input used to calculate the “standardized energy consumption” indicator.

Energy consumed from the grid (pumping)	*wwo_nrg_pump [kWh]*
Energy consumed from the grid (pumping)	

Volume of pumped wastewater – Onsite sanitation

User input used to calculate the standardized energy consumption.

Volume of pumped wastewater	*wwo_vol_pump [m^3]*
Volume of pumped wastewater	

Pump head – Onsite sanitation

User input used to calculate performance indicators regarding energy efficiency. It is the maximum height that a pump can move fluid against gravity.

Pump head	*wwo_pmp_head [m]*
Head at which the water is pumped in each water treatment unit that are the responsibility of the utility, during the assessment period	

Static head – Onsite sanitation

User input used to calculate performance indicators regarding energy efficiency. It is the height that water must travel as it moves through a pipe.

Static head	*wwo_sta_head [m]*
Static head measures the total vertical distance that a pump raises water	

Collector length – Onsite sanitation

User input used to calculate performance indicators regarding energy efficiency.

Collector length	*wwo_coll_len [m]*
Collector length	

Do you want to evaluate electromechanical efficiency of pump?

Measured pump flow – Onsite sanitation

User input used to calculate water power when evaluating electromechanical efficiency of a pump.

Measured pump flow	*wwo_pmp_flow [m^3/s]*
Measured pump flow	

Measured pump voltage – Onsite sanitation

User input used to calculate the electromechanical efficiency of a pump.

Measured pump voltage	*wwo_pmp_volt [V]*
Measured pump voltage	

Measured pump current – Onsite sanitation

User input used to calculate the electromechanical efficiency of a pump

Measured pump current	*wwo_pmp_amps [A]*
Measured pump current	

Power factor – Onsite sanitation

User input used to calculate the electromechanical efficiency of a pump.

Power factor	*wwo_pmp_pf [ratio]*
Power factor is the ratio of working power, measured in kilowatts (kW), to apparent power, measured in kilovolt amperes (kVA). It is a measurement that can quickly determine the amount of load on a motor.	

Expected electromechanical efficiency of new pump – Onsite sanitation

User input used to calculate the indicator “standardized energy consumption” of a new pump.

Expected electromechanical efficiency of new pump	*wwo_pmp_exff [%]*
Expected electromechanical efficiency of new pump	

Evaluate transport of faecal sludge?

Fuel type (trucks) – Onsite sanitation

Dropdown menu in which the user must choose the type of fuel used. This variable is used to calculate the emissions associated with sludge management (truck transport). The data table for this dropdown menu is available at **Table 8**, in the annex.

Fuel type (trucks)	*wwo_pmp_pf [X]*
Fuel type (trucks)	

Volume of fuel consumed (trucks) – Onsite sanitation

User input used to calculate GHG emissions associated with sludge management (truck transport).

Volume of fuel consumed (trucks)	*wwo_vol_trck [m^3]*
Volume of fuel consumed (trucks) during the assessment period	

Are you producing biogas from anaerobic digestion?

Biogas produced (volume) – Onsite sanitation

User input used to calculate emissions related to biogas.

Biogas produced (volume)	*wwo_biog_pro [Nm^3]*
Biogas produced during the assessment period by each faecal sludge treatment plant managed by the utility	

Biogas flared (% volume) – Onsite sanitation

Input that can be estimated. It is calculated by subtracting the other portions of biogas calculated by the user.

Biogas flared (% volume)	*wwo_biog_fla*
Biogas flared refers to the biogas that is combusted by flare gas systems without electricity or heat valorisation	
$wwo\_biog\_fla\ [\%] = 100 - wwo\_biog\_val - wwo\_biog\_lkd - wwo\_biog\_sold$	**Equation 42**
With:	
wwo_biog_val [%]	Biogas valorised in the treatment plant, for example to heat the digesters or the building and/or to run a co-generator to generate heat and electricity
wwo_biog_lkd [%]	Biogas leaked to the atmosphere (% volume)
wwo_biog_sold [%]	Biogas sold (% volume)

Biogas valorised (% volume) – Onsite sanitation

Input that can be estimated. It is calculated by subtracting the other portions of biogas calculated by the user.

Biogas valorised (% volume)	*wwo_biog_val*
Biogas valorised in the treatment plant, for example to heat the digesters or the building and/or to run a Co-generator to generate heat and electricity	
$wwo\_biog\_val\ [\%] = 100 - wwo\_biog\_fla - wwo\_biog\_lkd - wwo\_biog\_sold$	**Equation 43**
With:	
wwo_biog_fla [%]	Biogas flared refers to the biogas that is combusted by flare gas systems without electricity or heat valorisation
wwo_biog_lkd [%]	Biogas leaked to the atmosphere (% volume)
wwo_biog_sold [%]	Biogas sold (% volume)

Biogas leaked to the atmosphere (% volume) – Onsite sanitation

Input that can be estimated. It is calculated by subtracting the other portions of biogas calculated by the user.

Biogas leaked to the atmosphere (% volume)	*wwo_biog_lkd*
Biogas leaked to the atmosphere (% volume)	
$wwo\_biog\_lkd\ [\%] = 100 - wwo\_biog\_val - wwo\_biog\_fla - wwo\_biog\_sold$	**Equation 44**
With:	
wwo_biog_val [%]	Biogas valorised in the treatment plant, for example to heat the digesters or the building and/or to run a Co-generator to generate heat and electricity
wwo_biog_fla [%]	Biogas flared refers to the biogas that is combusted by flare gas systems without electricity or heat valorisation
wwo_biog_sold [%]	Biogas sold (% volume)

Biogas sold (% volume) – Onsite sanitation

Input that can be estimated. It is calculated by subtracting the other portions of biogas calculated by the user.

Biogas sold (% volume)	*wwo_biog_sold*
Biogas sold (% volume)	
$wwo\_biog\_sol\ [\%] = 100 - wwo\_biog\_val - wwo\_biog\_fla - wwo\_biog\_lkd$	**Equation 45**
With:	
wwo_biog_val [%]	Biogas valorised in the treatment plant, for example to heat the digesters or the building and/or to run a Co-generator to generate heat and electricity
wwo_biog_fla [%]	Biogas flared refers to the biogas that is combusted by flare gas systems without electricity or heat valorisation
wwo_biog_lkd [%]	Biogas leaked to the atmosphere (% volume)

Percentage of methane in the biogas (volume) – Onsite sanitation

User input used to calculate the GHG emissions related to biogas.

Percentage of methane in the biogas (volume)	*wwo_ch4_biog [%]*
Percentage of methane in the biogas (volume)	

Fuel type (digester) – Onsite sanitation

Dropdown menu in which the user must choose the type of fuel used. This variable is used to calculate the direct emissions associated with onsite engines. The data table for this dropdown menu is available at **Table 8**, in the annex.

Fuel type (digester)	*wwo_dige_typ [%]*
Fuel type (digester)	

Fuel consumed for the digester – Onsite sanitation

User input associated with the fuel type, it is used to calculate the direct emissions related to onsite engines.

Fuel consumed for the digester	*wwo_fuel_dig [m³]*
Fuel consumed for the digester	

Electrical energy produced from biogas valorization – Onsite sanitation

User input used to calculate GHG emissions avoided due to biogas valorisation.

Electrical energy produced from biogas valorization	*wwo_nrg_biog [kWh]*
Electrical energy produced from biogas valorization	

Do you want to assess landfilling of faecal sludge?

Dry weight sent to landfill – Onsite sanitation

User input used to calculate GHG emissions related to sludge management, and GHG emissions avoided due to carbon sequestration in landfilling

Dry weight sent to landfill	*wwo_mass_landfil [kg]*
Dry weight sent to landfill during the assessment period	

Total Volatile Solids (TVS) content of sludge sent to landfilling (% of dry weight) – Onsite sanitation

Dropdown menu in which the user should choose the type of faecal sludge. It is used to calculate GHG emissions related to sludge management. The data table for this dropdown menu is available at **Table 22**, in the annex.

Total Volatile Solids (TVS) content of sludge sent to landfilling (% of dry weight)	*wwo_lf_TVS [%]*
Total Volatile Solids (TVS) content of sludge sent to landfilling (% of dry weight)	

Uncertainty factor (UNFCCC/CCNUC, 2008) – Onsite sanitation

User input used to calculate GHG emissions related to sludge management. To determine the methane emissions in landfilling, a model correction factor must be used that considers the uncertainties related to the equation.

The value suggested by ECAM is 0.9 (CCME, 2009a, p. 154, **Equation 35;** UNFCCC/CCNUC, 2008).

Uncertainty factor (UNFCCC/CCNUC, 2008)	*wwo_lf_uncertainty [adimensional]*
Model uncertainty factor (default value:0.9, UNFCCC/CCNUC, 2008)	

CH_4 in landfill gas – Onsite sanitation

User input that indicates the volume fraction of methane in the landfill gas. It is used to calculate GHG emissions related to sludge management.

The value suggested by ECAM is 50% (CCME, 2009a, p. 154, ; UNFCCC/CCNUC, 2008).

CH_4 in landfill gas	*wwo_lf_CH4_in_gas [%]*
CH_4 in landfill gas (50% from Clean Development Mechanism, 2008)	

Decomposable organic fraction of raw wastewater solids – Onsite sanitation

User input that indicates the fraction of degradable organic carbon that can decompose. It is used to calculate GHG emissions related to sludge management and avoided emissions due to carbon sequestration.

The value suggested by ECAM is 80% (CCME, 2009a, p. 154, **Equation 35**; Brown et al., 2008; Metcalf, Eddy, 2003).

Decomposable organic fraction of raw wastewater solids	*wwo_lf_DOCf [%]*
Decomposable organic fraction of raw wastewater solids (80% from Brown et al., 2008 and Metcalf; Eddy, 2003)	

Percentage decomposed in first 3 years – Onsite sanitation

User input used to calculate GHG emissions related to sludge management.

The value suggested by ECAM is 69.9%, which is calculated from UNFCC/CCNUCC (2008) equations for warm, wet conditions environments.

Percentage decomposed in first 3 years	*wwo_lf_decomp_3yr [%]*
Percentage decomposed in first 3 years of the decomposable organic fraction of raw wastewater solids	

Methane correction for anaerobic managed landfills (default=1) – Onsite sanitation

Dropdown menu in which the user must choose if the landfill has gas recovery. It is used to calculate GHG emissions related to sludge management (UNFCC/CCNUCC, 2008).

The data table for this dropdown menu is available at **Table 23** in the Annex section. (UNFCC/CCNUCC, 2008).

Methane correction for anaerobic managed landfills (default=1)	*wwo_lf_MCF [ratio]*
Methane correction for anaerobic managed landfills (default=1, UNFCCC/CCNUCC, 2008)	

N content of sludge sent to landfilling (% of dry weight) – Onsite sanitation

Dropdown menu in which the user should choose if the sludge is digested or non-digested. It is used to calculate GHG emissions related to sludge management.

The data table for this dropdown menu is available at
Table 21, in the annex.

N content of sludge sent to landfilling (% of dry weight)	*wwo_lf_N_cont [%]*
N content of sludge sent to landfilling (% of dry weight)	

N_2O emission factor for low C:N ratio – Onsite sanitation

User input used to calculate GHG emissions related to sludge management.

The value suggested by ECAM is 0.015 kgN2O-N/kgN (Brown et al., 2008).

N_2O emission factor for low C:N ratio	*wwo_lf_low_CN_EF [kgN_2O-N/kgN]*
N_2O emission factor for low C:N ratio (1.5% from Brown et al, 2008)	

Do you want to assess land application of faecal sludge?

Dry weight sent to land application – Onsite sanitation

User input used to calculate GHG emissions related to sludge management and GHG emissions avoided due to carbon sequestration in land application.

Dry weight sent to land application	*wwo_mass_landapp [kg]*
Amount of (faecal) sludge that is sent to land application (dry weight)	

Solids content of sludge sent to land application – Onsite sanitation

User input used to calculate GHG emissions related to sludge management.

Solids content of sludge sent to land application	*wwo_la_solids_content [%]*
Solids content of sludge sent to land application	

Total Volatile Solids (TVS) content of sludge sent to land application – Onsite sanitation

Dropdown menu, in which the user should choose if the sludge is digested or non-digested. It is used to calculate GHG emissions related to sludge management. The data table for this dropdown menu is available at
Table 21, in the annex.

Total Volatile Solids (TVS) content of sludge sent to land application	*wwo_la_TVS [%]*
Total Volatile Solids (TVS) content of sludge sent to land application	

N content of sludge sent to land application (% of dry weight) – Onsite sanitation

Dropdown menu, in which the user should choose if the sludge is digested or non-digested. It is used to calculate GHG emissions related to sludge management. The data table for this dropdown menu is available at
Table 21, in the annex.

N content of sludge sent to land application (% of dry weight)	*wwo_la_N_cont [%]*
N content of sludge sent to land application (% of dry weight)	

Amount of Nitrogen converted to N2O-N – Onsite sanitation

Dropdown menu in which the user should choose the type of soil, which will define a N_2O emission factor. It is used to calculate GHG emissions related to sludge management. The data table for this dropdown menu is available at **Table 24**, in the annex.

Amount of Nitrogen converted to N_2O-N	*wwo_la_N_to_N2O [kgN_2O-N/kgN]*
Amount of Nitrogen converted to N2O-N	

CO_2eq sequestration rate – Onsite sanitation

User input used to calculate GHG emissions avoided due to carbon sequestration in sludge.

The default value in ECAM is 0.25 kg$C0_2$eq/kgSludge (CCME, 2009a, p. 149).

CO_2eq sequestration rate	*wwo_la_seqst_rate [kgCO_2eq/kgSludge]*
Estimated CO_2 equivalents sequestered per kg of sludge	

Do you want to assess dumping of faecal sludge?

Volume dumped – Onsite sanitation

User input used to calculate GHG emissions related to sludge management.

Volume dumped	*wwo_vol_dumping [m^3]*
Volume of faecal sludge dumped during the assessment period	

Total Nitrogen load in dumped faecal sludge – Onsite sanitation

User input used to calculate GHG emissions related to sludge management.

Total Nitrogen load in dumped faecal sludge	*wwo_N_dumping [kg]*
Total nitrogen load in dumped faecal sludge	

CH_4 emission factor (dumping) – Onsite sanitation

Dropdown menu in which the user must choose the type of discharge. This variable is used to calculate the emissions related to sludge management.

CH_4 emission factor (dumping)	*wwo_ch4_efac_dumping [$kgCH_4/kgBOD$]*
Methane emission factor for faecal sludge dumping	

The data table associated with this dropdown menu can be consulted in **Table 11** in the annex.

Remember that to select emission factors associated with wastewater discharge it is necessary to understand the selection of the appropriate tier. For this, access topic **Tier (Level of Information)**.

N_2O emission factor (dumping) – Onsite sanitation

Dropdown menu in which the user must choose the type of discharge. This variable is used to calculate the emissions related to sludge management.

N_2O emission factor (dumping)	*wwo_n2o_efac_dumping [$kgN_2O\text{-}N/kgN$]*
N_2O emission factor for faecal sludge dumping	

The data table associated with this dropdown menu can be consulted in **Table 16**.

Do you want to assess land application of urine?

Total Nitrogen in urine applied to land – Onsite sanitation

User input used to calculate GHG emissions related to sludge management.

Total Nitrogen in urine applied to land	*wwo_N_urine [kg]*
Total Nitrogen in urine applied to land	

N_2O emission factor (urine applied to land) – Onsite sanitation

User input used to calculate GHG emissions related to sludge management.

Default value suggested by ECAM is 0.01 kgN2O-N/kgN based on IPCC (2006c)[11].

[11] Default value 0.01 from IPCC (2006c, p. 11.11): Table 11.1: 'Default emission factors to estimate direct N_2O emissions from managed soils'. Link: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf.

N_2O emission factor (urine applied to land)	*wwo_N_urine_EF [kgN$_2$O-N/kgN]*
EF for N additions from mineral fertilisers, organic amendments and crop residues, and N mineralised from mineral soil as a result of loss of soil carbon	

Do you want to assess GHG avoided from reusing nutrients?

Total Nitrogen reused that displaces synthetic fertilizer – Onsite sanitation

User input used to calculate GHG emissions avoided due to nutrient reused displacing synthetic fertilizer.

Total Nitrogen reused that displaces synthetic fertilizer	*wwo_reused_N [kg]*
Amount of total Nitrogen reused that displaces synthetic fertilizer	

Total Phosphorus reused that displaces synthetic fertilizer – Onsite sanitation

User input used to calculate GHG emissions avoided due to nutrient reused displacing synthetic fertilizer.

Total Phosphorus reused that displaces synthetic fertilizer	*wwo_reused_P [kg]*
Amount of total Phosphorus reused that displaces synthetic fertilizer	

Do you know the utility costs by stage?

Energy costs – Onsite sanitation

The user optionally fills in the total energy costs of the stage, so that the total costs of the system can be calculated.

Energy costs	*wwo_nrg_cost [$]*
Costs from electric energy consumption for the entire wastewater utility, based on the electricity bill during the entire assessment period	

Total running costs – Onsite sanitation

The user optionally fills in the total costs of the stage, so that the total costs of the system can be calculated.

Total running costs	*wwo_run_cost [$]*
Total operations and maintenance net costs and internal manpower net costs (i.e. not including the capitalised cost of self-constructed assets) related to wastewater management within the service area managed by the utility during the entire assessment period	

Section 2.2: Inventory Outputs

Outputs are the values on the right side of the ECAM tool Inventory tab (Figure 9).

They are composed of: GHG emissions, energy performance and service level indicators.

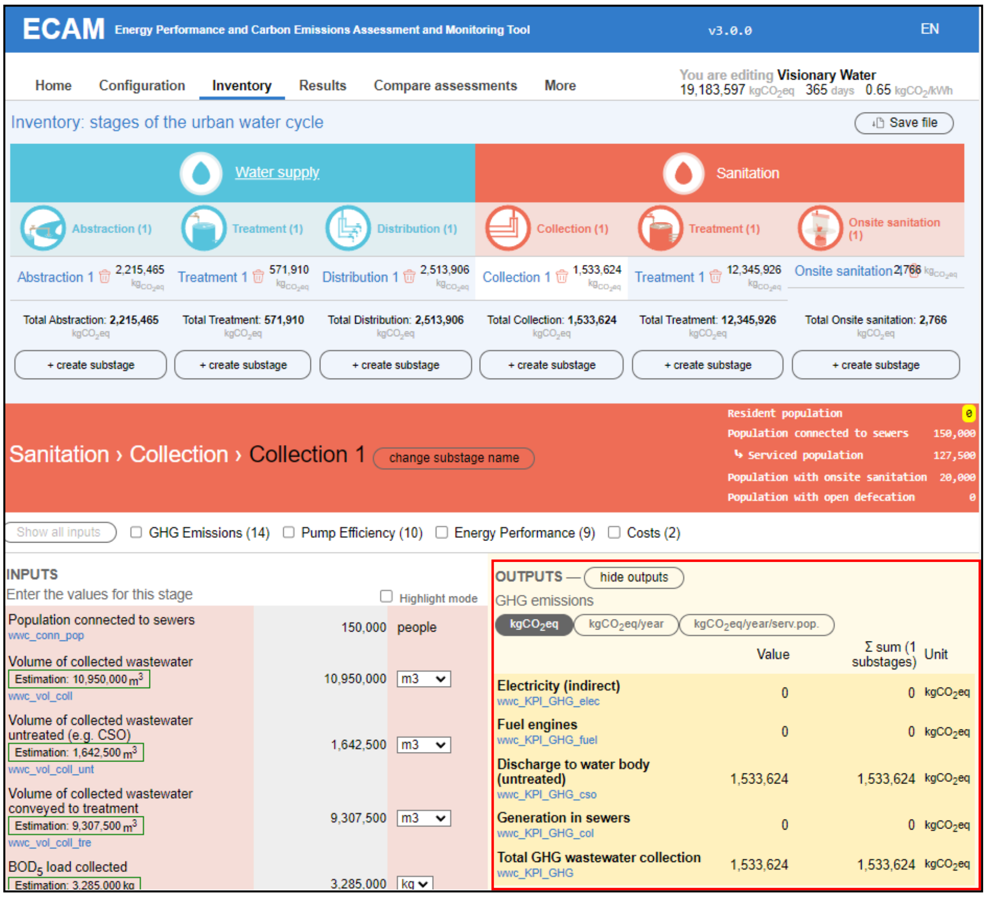


Figure 9 - Outputs section in the inventory tab

In this section, the output equations will be presented, as well as their corresponding formulas. The following additional information may be useful:

- To learn more about how emissions are generated by each stage, access topic **Which activities in the urban water cycle release GHG emissions? Which influencing factors exist at each activity?**.

- In this section, the description of the input variables that make up the equation of an output are brief. To find out more about a specific input or estimate, search for the topic associated with it or use the "Find" tool of your text or pdf editor, typing the name of the variable's code (example: wwc_ch4_efac_cso).

GHG emissions

Water Supply – General

Abstraction – Water Supply

This output takes the value of total emissions from stage **Water Abstraction** and reorganizes it as information from the water supply system. This information will be used to calculate the total system emissions.

Abstraction	*ws_KPI_GHG_abs*
Abstraction	
$ws\_KPI\_GHG\_abs\ [kgCO2eq] = wsa\_KPI\_GHG$	**Equation 46**
With:	
wsa_KPI_GHG [kgCO2eq] Total GHG water abstraction	

Treatment – Water Supply

This output takes the value of total emissions from stage **Water Treatment** and reorganizes it as information from the water supply system. This information will be used to calculate the total system emissions.

Treatment	*ws_KPI_GHG_tre*
Treatment	
$ws\_KPI\_GHG\_tre\ [kgCO2eq] = wst\_KPI\_GHG$	**Equation 47**
With:	
wst_KPI_GHG [kgCO2eq] Total GHG water treatment	

Distribution – Water Supply

This output takes the value of total emissions from stage **Water Distribution** and reorganizes it as information from the water supply system. This information will be used to calculate the total system emissions.

Distribution	*ws_KPI_GHG_dis [kgCO2eq]*
Distribution	
$ws\_KPI\_GHG\_dis = wsd\_KPI\_GHG$	**Equation 48**
With:	
wsd_KPI_GHG [kgCO2eq] Total GHG water distribution	

Total GHG water supply – Water Supply

The total emission of the water supply system is calculated based on the emissions of each stage.

Total GHG water supply	
Total GHG emissions from non-electricity and electricity consumption	
$ws\_KPI\_GHG\ \ [kgCO2eq] = ws\_KPI\_GHG\_abs + ws\_KPI\_GHG\_tre + ws\_KPI\_GHG\_dis$	**Equation 49**
With:	
ws_KPI_GHG_abs [kgCO2eq] Total GHG water abstraction	
ws_KPI_GHG_tre [kgCO2eq] Total GHG water treatment	

ws_KPI_GHG_abs [kgCO2eq]	Total GHG water distribution

Water Supply – Abstraction

Electricity (indirect) – Water Abstraction

Based on the input data entered in the tool, ECAM will calculate the GHG emissions from electricity.

These emissions are calculated by multiplying the energy consumption of the grid by the emission factor for grid electricity defined as a general factor (see topic

General and Country specific factors for more information about the grid factor methodology and sources).

Electricity (indirect)	*wsa_KPI_GHG_elec*
Electricity (indirect emissions)	
$wsa\_KPI\_GHG\_elec\ [kgCO2eq] = wsa\_nrg\_cons \cdot wsa\_conv\_kwh$	**Equation 50**
With:	
wsa_nrg_cons [kWh]	Electric energy consumption from the grid, for the water abstraction unit, by the utility, during the entire assessment period
wsa_conv_kwh [kgCO2eq/kWh]	Emission factor for grid electricity (indirect emissions)
Sources	Based on **EIB (2020)** and **UNFCCC (2022)**

Fuel engines – Water Abstraction

ECAM will calculate the GHG emissions from onsite engines based on the input data entered in the tool.

The calculation for this output is done in two steps, firstly, the emissions for each type of GHG are calculated. Then, these emissions, which are already converted into equivalent CO_2, are summed to obtain the result.

Fuel engines	*wsa_KPI_GHG_fuel*
Emissions related to combustion of fossil fuel in fuel engines	
$co2 = wsa\_vol\_fuel \cdot FD \cdot \frac{NCV}{1000} \cdot EFCO2$ $ch4 = wsa\_vol\_fuel \cdot FD \cdot \frac{NCV}{1000} \cdot EFCH4.engines \cdot ct\_ch4\_eq$ $n2o = wsa\_vol\_fuel \cdot FD \cdot \frac{NCV}{1000} \cdot EFN2O.engines \cdot ct\_n2o\_eq$	**Equation 51**
$wsa\_KPI\_GHG\_fuel\ [kgCO2eq] = co2 + n2o + ch4$	**Equation 52**
With:	
wsa_vol_fuel [m^3]	Volume of fuel consumed
FD [kg/L]	Fuel density
NCV [TJ/Gg]	Net calorific values
$EFCO_2$ (kg/TJ)	Emission factor for CO_2

$EFCH_4$ (kg/TJ)	Emission factor for CH_4
EFN2O (kg/TJ)	Emission factor for N_2O
ct_ch4_eq [$kgCO_2eq/kgCH_4$]	GWP from CH_4 to CO_2eq (see **Selection of the Global Warming Potential Report**)
ct_n2o_eq [$kgCO_2eq/kgN_2O$]	GWP from N_2O to CO_2eq (see **Selection of the Global Warming Potential Report**)
Sources	**IPCC (2006b p. 2.16)** https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf

Fuel density (FD), net calorific values (NCV) and the emission factor (EF) are related with the type of fuel, which is selected by the user in the stage input section (**Table 8)**.

Total GHG water abstraction – Water Abstraction

The total GHG emissions of this stage are calculated by adding up all the emissions.

Total GHG water abstraction	*wsa_KPI_GHG*
Total GHG emitted by this water abstraction utility	
$wsa\_KPI\_GHG\ [kgCO2eq] = wsa\_KPI\_GHG\_elec + wsa\_KPI\_GHG\_fuel$	**Equation 53**
With:	
wsa_KPI_GHG_elec [kgCO2eq]	Electricity (indirect emissions)
wsa_KPI_GHG_fuel [kgCO2eq]	Fuel engines

Water Supply – Treatment

Electricity (indirect) – Water Abstraction

ECAM will calculate the GHG emissions from electricity based on the input data entered in the tool.

These emissions are calculated by multiplying the energy consumption of the grid by the emission factor for grid electricity defined as a general factor (see topic

General and Country specific factors for more information about the grid factor methodology and sources).

Electricity (indirect)	*wst_KPI_GHG_elec*
GHG indirect emissions from electricity	
$wsa\_KPI\_GHG\_elec\ [kgCO2eq] = wst\_nrg\_cons \cdot wst\_conv\_kwh$	**Equation 54**
With:	
wst_nrg_cons [kWh]	Energy consumed during the assessment period by each urban water treatment plant managed by the utility
wst_conv_kwh [kgCO2eq/kWh]	Emission factor for grid electricity (indirect emissions)
Sources	Based on **EIB (2020)** and **UNFCCC (2022)**

Fuel engines – Water Abstraction

Based on the input data, ECAM will calculate the GHG emissions from onsite engines.

The calculation for this output is done in two steps, first, the emissions for each type of GHG are calculated. Then, these emissions, which are already converted into equivalent CO_2, are summed to obtain the result.

Fuel engines	*wst_KPI_GHG_fuel*
Fuel engines	
$$co2 = wst\_vol\_fuel \cdot FD \cdot \frac{NCV}{1000} \cdot EFCO2$$ $$ch4 = wst\_vol\_fuel \cdot FD \cdot \frac{NCV}{1000} \cdot EFCH4.engines \cdot ct\_ch4\_eq$$ $$n2o = wst\_vol\_fuel \cdot FD \cdot \frac{NCV}{1000} \cdot EFN2O.engines \cdot ct\_n2o\_eq$$	**Equation 55**
$wst\_KPI\_GHG\_fuel\ [kgCO2eq] = co2 + n2o + ch4$	**Equation 56**
With:	
wst_vol_fuel [m^3]	Volume of fuel consumed
FD [kg/L]	Fuel Density
NCV [TJ/Gg]	Net Calorific Values
$EFCO_2$ (kg/TJ)	Emission Factor for CO_2
$EFCH_4$ (kg/TJ)	Emission Factor for CH_4
EFN_2O (kg/TJ)	Emission Factor for N_2O
ct_ch4_eq [$kgCO_2eq/kgCH_4$]	GWP from CH4 to CO_2eq (see Selection of the Global Warming Potential Report)
ct_n2o_eq [$kgCO_2eq/kgN_2O$]	GWP from N_2O to CO_2eq (see Selection of the Global Warming Potential Report
Source	**IPCC (2006b, Volume 2,p. 16)** https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf

Fuel Density (FD), Net Calorific Values (NCV) and the Emission Factor (EF) are related with the type of fuel, which is selected by the user in the input section (**Table 8**).

Total GHG water treatment – Water Abstraction

The total GHG emissions of this stage are calculated by adding up all the emissions.

Total GHG water treatment	*wst_KPI_GHG*
Total GHG emitted by this water treatment utility	
$$co2 = wst\_KPI\_GHG\_elec.co2 + wst\_KPI\_GHG\_fuel.co2$$ $$ch4 = wst\_KPI\_GHG\_elec.ch4 + wst\_KPI\_GHG\_fuel.ch4$$ $$n2o = wst\_KPI\_GHG\_elec.n2o + wst\_KPI\_GHG\_fuel.n2o$$	**Equation 57**
$wst\_KPI\_GHG\ [kgCO2eq] = co2 + ch4 + n2o$	**Equation 58**
With:	
wst_KPI_GHG_elec [kgCO2eq]	GHG indirect emissions from electricity

wst_KPI_GHG_fuel [kgCO2eq]	Fuel engines

Water Supply – Distribution

Electricity (indirect) – Water Distribution

ECAM will calculate the GHG emissions from Electricity based on the input data entered in the tool.

These emissions are calculated by multiplying the energy consumption of the grid by the emission factor for grid electricity defined as a general factor (see topic

General and Country specific factors for more information about the grid factor methodology and sources).

Electricity (indirect)	*wsd_KPI_GHG_elec*
GHG indirect emissions from electricity	
$wsd\_KPI\_GHG\_elec\ [kgCO2eq] = wsd\_nrg\_cons \cdot wsd\_conv\_kwh$	**Equation 59**
With:	
wsd_nrg_cons [kWh]	Electric energy consumption from the grid for water distribution during the entire assessment period
wsd_conv_kwh [$kgCO_2eq/kWh$]	Emission factor for grid electricity (indirect emissions)
Sources	Based on **EIB (2020)** and **UNFCCC (2022)**

Fuel engines– Water Distribution

ECAM will calculate the GHG emissions from onsite engines based on the input data entered in the tool.

The calculation for this output is done in two steps, firstly, the emissions for each type of GHG are calculated. Then, these emissions, which are already converted into equivalent CO_2, are summed to obtain the result.

Fuel engines	*wsd_KPI_GHG_fuel*
Fuel engines	
$co2 = wsd\_vol\_fuel \cdot FD \cdot \frac{NCV}{1000} \cdot EFCO2$ $ch4 = wsd\_vol\_fuel \cdot FD \cdot \frac{NCV}{1000} \cdot EFCH4\,.engines \cdot ct\_ch4\_eq$ $n2o = wsd\_vol\_fuel \cdot FD \cdot \frac{NCV}{1000} \cdot EFN2O.engines \cdot ct\_n2o\_eq$	**Equation 60**
$wsd\_KPI\_GHG\_fuel\ [kgCO2eq] = co2 + n2o + ch4$	**Equation 61**
With:	
wsd_vol_fuel [m^3]	Volume of fuel consumed
FD [kg/L]	Fuel density

NCV [TJ/Gg]	Net calorific values
$EFCO_2$ [kg/TJ]	Emission factor for CO_2
$EFCH_4$ [kg/TJ]	Emission factor for CH_4
EFN_2O [kg/TJ]	Emission factor for N_2O
ct_ch4_eq [$kgCO_2eq/kgCH_4$]	GWP from CH_4 to CO2eq (see Selection of the Global Warming Potential Report)
ct_n2o_eq [$kgCO_2eq/kgN_2O$]	GWP from N_2O to CO2eq (see Selection of the Global Warming Potential Report)
Source	**IPCC (2006b, p. 16)** https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf

Fuel density (FD), net calorific values (NCV) and the emission factor (EF) are related with the type of fuel, which is selected by the user in the stage input section (**Table 8).**

Truck transport of potable water – Water Distribution

Based on the input data entered in the tool, ECAM will calculate the GHG emissions from Truck transport of potable water.

The calculation for this output is done in two steps, firstly, the emissions for each type of GHG are calculated. Then, these emissions, which are already converted into equivalent CO_2, are summed to obtain the result.

Truck transport of potable water	*wsd_KPI_GHG_trck*
Fuel consumed during distribution by 'water trucks'	

$$co2 = wsd\_vol\_trck \cdot FD \cdot \frac{NCV}{1000} \cdot EFCO2$$
$$ch4 = wsd\_vol\_trck \cdot FD \cdot \frac{NCV}{1000} \cdot EFCH4.vehicles \cdot ct\_ch4\_eq$$
$$n2o = wsd\_vol\_trck \cdot FD \cdot \frac{NCV}{1000} \cdot EFN2O.vehicles \cdot ct\_n2o\_eq$$

Equation 62

$$wsd\_KPI\_GHG\_trck\ [kgCO2eq] = co2 + n2o + ch4$$

Equation 63

With:

wsa_vol_fuel [m^3]	Volume of fuel consumed
FD [kg/L]	Fuel density
NCV [TJ/Gg]	Net calorific values
$EFCO_2$ (kg/TJ)	Emission factor for CO_2
$EFCH_4$ (kg/TJ)	Emission factor for CH_4
EFN_2O (kg/TJ)	Emission factor for N_2O
ct_ch4_eq [$kgCO_2eq/kgCH_4$]	GWP from CH_4 to CO_2eq (see Selection of the Global Warming Potential Report)
ct_n2o_eq [$kgCO_2eq/kgN_2O$]	GWP from N_2O to CO_2eq (see Selection of the Global Warming Potential Report)
Source	**IPCC (2006b, p.3.21)** frontend/docs/2006-ipcc/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf#page=21

Total GHG water distribution – Water Distribution

The total GHG emissions of this stage are calculated by adding up all the emissions.

Total GHG water distribution	*wsd_KPI_GHG*
Total GHG emitted by this water distribution utility	
$wsd\_KPI\_GHG\ [kgCO2eq] = wsd\_KPI\_GHG\_elec + wsd\_KPI\_GHG\_fuel + wsd\_KPI\_GHG\_trck$	**Equation 64**
With:	
wsd_KPI_GHG_elec [kgCO2eq]	GHG indirect emissions from electricity
wsd_KPI_GHG_fuel [kgCO2eq]	Fuel engines
wsa_KPI_GHG_trck [kgCO2eq]	Fuel consumed during distribution by 'water trucks'

Sanitation – General

Collection – Sanitation

This output takes the value of total emissions from stage **Sanitation Collection** and reorganizes it as information from the Sanitation system. This information will be used to calculate the total system emissions.

Collection	*ww_KPI_GHG_col*
Collection	
$ww\_KPI\_GHG\_col\ [kgCO2eq] = wwc\_KPI\_GHG$	**Equation 65**
With:	
wwc_KPI_GHG [kgCO2eq]	Total GHG emitted by this wastewater collection utility

Treatment – Sanitation

This output takes the value of total emissions from stage **Sanitation Treatment** and reorganizes it as information from the Sanitation system. This information will be used to calculate the total system emissions.

Treatment	*ww_KPI_GHG_tre*
Treatment	
$ww\_KPI\_GHG\_tre\ [kgCO2eq] = wwt\_KPI\_GHG$	**Equation 66**
With:	
wwt_KPI_GHG [$kgCO_2eq$]	Total GHG emitted by this wastewater treatment utility

Onsite sanitation – Sanitation

This output takes the value of total emissions from stage Onsite Sanitation and reorganizes it as information from the Sanitation system. This information will be used to calculate the total system emissions.

Onsite sanitation	*ww_KPI_GHG_ons*
Onsite sanitation	
$ww\_KPI\_GHG\_ons\ [kgCO2eq] = wwo\_KPI\_GHG$	**Equation 67**
With:	
wwo_KPI_GHG [$kgCO_2eq$]	Total GHG onsite sanitation

Total GHG sanitation – Sanitation

From the emissions of each stage, the total emission of the Sanitation system is calculated.

Total GHG sanitation	*ww_KPI_GHG_ons*
GHG Emissions from non-electricity and electricity consumption	
$ww\_KPI\_GHG\_ons\ [kgCO2eq] = ww\_KPI\_GHG\_col + ww\_KPI\_GHG\_tre + ww\_KPI\_GHG\_ons$	**Equation 68**
With:	
ww_KPI_GHG_col [$kgCO_2eq$]	Collection
ww_KPI_GHG_tre [$kgCO_2eq$]	Treatment
ww_KPI_GHG_ons [$kgCO_2eq$]	Onsite sanitation

Sanitation – Collection

Electricity (indirect) – Sanitation Collection

ECAM will calculate the GHG emissions from Electricity (indirect) with the input data entered in the tool.

These emissions are calculated by multiplying the energy consumption of the grid by the emission factor for grid electricity defined as a general factor (see topic

General and Country specific factors for more information about the grid factor methodology and sources).

Electricity (indirect)	*wwc_KPI_GHG_elec*
GHG indirect emissions from electricity	
$wwc\_KPI\_GHG\_elec\ [kgCO2eq] = wwc\_nrg\_cons \cdot wwc\_conv\_khw$	**Equation 69**
With:	
wwc_nrg_cons [kWh]	Energy consumed during the assessment period by each pumping station for conveying wastewater to treatment managed by the utility
wwc_conv_khw [$kgCO_2eq/kWh$]	Emission factor for grid electricity (indirect emissions)
Sources	Based on **EIB (2020)** and **UNFCCC (2022)**

Fuel engines – Sanitation Collection

ECAM will calculate the GHG emissions from onsite engines using the input data entered in the tool.

The calculation for this output is done in two steps, firstly, the emissions for each type of GHG are calculated. Then, these emissions, which are already converted into equivalent CO_2, are summed to obtain the result.

Fuel engines	*wwc_KPI_GHG_fuel*
Emissions related to combustion of fossil fuel in fuel engines	
$co2 = wwc\_vol\_fuel \cdot FD \cdot \frac{NCV}{1000} \cdot EFCO2$ $ch4 = wwc\_vol\_fuel \cdot FD \cdot \frac{NCV}{1000} \cdot EFCH4.engines \cdot ct\_ch4\_eq$ $n2o = wwc\_vol\_fuel \cdot FD \cdot \frac{NCV}{1000} \cdot EFN2O.engines \cdot ct\_n2o\_eq$	**Equation 70**
$wwc\_KPI\_GHG\_fuel\ [kgCO2eq] = co2 + n2o + ch4$	**Equation 71**
With:	
wwc_vol_fuel [m³]	Volume of fuel consumed
FD [kg/L]	Fuel Density
NCV [TJ/Gg]	Net Calorific Values
$EFCO_2$ (kg/TJ)	Emission Factor for CO_2
$EFCH_4$ (kg/TJ)	Emission Factor for CH_4
EFN_2O (kg/TJ)	Emission Factor for N_2O
ct_ch4_eq [$kgCO_2eq/kgCH_4$]	GWP from CH_4 to CO_2 eq (see Selection of the Global Warming Potential Report)
ct_n2o_eq [$kgCO_2eq/kgN_2O$]	GWP from N_2O to CO_2 eq (see Selection of the Global Warming Potential Report)
Source	**IPCC (2006b, 2.16)** https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf

Fuel Density (FD), Net Calorific Values (NCV) and the Emission Factor (EF) are related with the type of fuel, which is selected by the user in the stage input section (Table 8).

Discharge to water body (untreated) – Sanitation Collection

Based on the input data entered in the tool, ECAM will calculate the GHG emissions from Discharge to water body (untreated).

Discharge to water body (untreated)	*wwc_KPI_GHG_cso*
Discharge to water body (untreated)	
$ch4 = wwc\_bod \cdot \frac{wwc\_vol\_coll\_unt}{wwc\_vol\_coll} \cdot wwc\_ch4\_efac\_cso \cdot ct\_ch4\_eq$ $n2o = wwc\_tn \cdot \frac{wwc\_vol\_coll\_unt}{wwc\_vol\_coll} \cdot wwc\_n2o\_efac\_cso \cdot ct\_N\_to\_N2O\_44\_28 \cdot ct\_n2o\_eq$	**Equation 72**
$wwc\_KPI\_GHG\_cso\ [kgCO2eq] = ch4 + n2o$	**Equation 73**

With:	
wwc_bod [kg]	BOD_5 load collected
wwc_vol_coll_unt [m³]	Volume of collected wastewater untreated (e.g. CSO)
wwc_vol_coll [m³]	Volume of collected wastewater that is responsibility of the utility, during the assessment period
wwc_tn [kg]	Total nitrogen load collected
wwc_ch4_efac_cso [kgCH4/kgBOD]	CH_4 emission factor (untreated collected wastewater)
ct_ch4_eq [kgCO2eq/kgCH4]	GWP from CH_4 to CO_2eq (see **Selection of the Global Warming Potential Report)**.
wwc_n2o_efac_cso [kgN2O-N/kgN]	N_2O emission factor (untreated collected wastewater)
ct_N_to_N2O_44_28 [kgN2O/kgN2O-N]	Conversion factor of N_2O-N to N_2O[12]= 1.57
ct_n2o_eq [kgCO2eq/kgN20]	GWP from N_2O to CO_2 eq (see **Selection of the Global Warming Potential Report)**)
Source	Adapted from: **IPCC (2019b, p. 6.17, 6.37)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Generation in sewers – Sanitation Collection

ECAM will calculate the GHG emissions from Generation in sewers using the input data.

Generation in sewers	*wwc_KPI_GHG_col*
Generation in sewers	

$$ch4 = wwc\_bod \cdot \frac{wwc\_vol\_coll\_tre}{wwc\_vol\_coll} \cdot wwc\_ch4\_efac\_col \cdot ct\_ch4\_eq$$

$$n2o = wwc\_tn \cdot \frac{wwc\_vol\_coll\_tre}{wwc\_vol\_coll} \cdot wwc\_n2o\_efac\_col \cdot ct\_N\_to\_N2O\_44\_28 \cdot ct\_n2o\_eq$$

Equation 74

$$wwc\_KPI\_GHG\_col\ [kgCO2eq] = ch4 + n2o$$

Equation 75

With:	
wwc_bod [kg]	BOD_5 load collected
wwc_vol_coll_tre [m³]	Volume of collected wastewater conveyed to treatment
wwc_vol_coll [m³]	Volume of collected wastewater that is responsibility of the utility, during the assessment period
wwc_ch4_efac_col [kgCH4/kgBOD]	CH_4 emission factor (collected wastewater)
ct_ch4_eq [kgCO2eq/kgCH4]	GWP from CH_4 to CO_2eq (see **Selection of the Global Warming Potential Report**)

[12] To account for nitrous oxide emissions, it is necessary to convert total nitrogen to N_2O based on molar mass.

wwc_tn [kg]	Total nitrogen load collected
wwc_n2o_efac_col [kgN2O-N/kgN]	N_2O emission factor (collected wastewater)
ct_N_to_N2O_44_28 [gN2O/gN2O-N]	Conversion factor of N_2O-N to N_2O[13]= 1.57
ct_n2o_eq [kgCO2eq/kgN2O]	GWP from N_2O to CO_2 eq (see **Selection of the Global Warming Potential Report**)
Source	Adapted from: **IPCC (2019b, p. 6.17, 6.37)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Total GHG wastewater collection – Sanitation Collection

The total GHG emissions of this stage are calculated by adding up all the emissions.

Total GHG wastewater collection	*wwc_KPI_GHG*
Total GHG emitted by this wastewater collection utility	
$$wwc\_KPI\_GHG\ [kgCO2eq] = wwc\_KPI\_GHG\_elec + wwc\_KPI\_GHG\_fuel + wwc\_KPI\_GHG\_cso + wwc\_KPI\_GHG\_col$$	**Equation 76**
With:	
wwc_KPI_GHG_elec [$kgCO_2eq$]	GHG indirect emissions from electricity
wwc_KPI_GHG_fuel [$kgCO_2eq$]	Fuel engines
wwc_KPI_GHG_cso [$kgCO_2eq$]	Discharge to water body (untreated)
wwc_KPI_GHG_col [$kgCO_2eq$]	Generation in sewers

Sanitation – Treatment

Electricity (indirect) – Sanitation Treatment

Based on the input data, ECAM will calculate the GHG emissions from electricity (indirect).

These emissions are calculated by multiplying the energy consumption of the grid by the emission factor for grid electricity defined as a general factor (see topic

General and Country specific factors for more information about the grid factor methodology and sources).

Electricity (indirect)	*wwt_KPI_GHG_elec*
GHG indirect emissions from electricity	
$$wwt\_KPI\_GHG\_elec\ [kgCO2eq] = wwt\_nrg\_cons \cdot wwt\_conv\_kwh$$	**Equation 77**
With:	

[13] To account for nitrous oxide emissions, it is necessary to convert Total Nitrogen to N2O based on molar mass.

wwt_nrg_cons [kWh]	Total energy consumed during the assessment period by all wastewater treatment plants managed by the utility
wwt_conv_kwh [$kgCO_2eq/kWh$]	Emission factor for grid electricity (indirect emissions)
Sources	Based on **EIB (2020)** and **UNFCCC (2022)**

Fuel engines – Sanitation Treatment

ECAM will calculate the GHG emissions from onsite engines with the input data.

The calculation for this output is done in two steps, firstly, the emissions for each type of GHG are calculated. Then, these emissions, which are already converted into CO_2eq, are summed to obtain the result.

Fuel engines	*wwt_KPI_GHG_fuel*
Direct CO2 emitted from onsite engines in wastewater stages based upon sum of CO2, CH4 and N2O emission from stationary combustion	
$co2 = wwt\_vol\_fuel \cdot FD \cdot \frac{NCV}{1000} \cdot EFCO2$ $ch4 = wwt\_vol\_fuel \cdot FD \cdot \frac{NCV}{1000} \cdot EFCH4.engines \cdot ct\_ch4\_eq$ $n2o = wwt\_vol\_fuel \cdot FD \cdot \frac{NCV}{1000} \cdot EFN2O.engines \cdot ct\_n2o\_eq$	**Equation 78**
$wwt\_KPI\_GHG\_fuel\ [kgCO2eq] = co2 + n2o + ch4$	**Equation 79**
With:	
wwt_vol_fuel [m^3]	Volume of fuel consumed
wwt_fuel_typ	Selected Fuel type
FD [kg/L]	Fuel Density
NCV [TJ/Gg]	Net Calorific Values
$EFCO_2$ (kg/TJ)	Emission Factor for CO_2
$EFCH_4$ (kg/TJ)	Emission Factor for CH_4
EFN_2O (kg/TJ)	Emission Factor for N_2O
ct_ch4_eq [$kgCO_2eq/kgCH_4$]	GWP from CH_4 to CO_2eq (see **Selection of the Global Warming Potential Report**)
ct_n2o_eq [$kgCO_2eq/kgN_2O$]	GWP from N_2O to CO2eq (see **Selection of the Global Warming Potential Report**)
Source	**IPCC (2006b, p. 2.16)** https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf

Fuel Density (FD), Net Calorific Values (NCV) and the Emission Factor (EF) are related with the type of fuel, which is selected by the user in the stage input section (Table 8).

Treatment process – Sanitation Treatment

The calculation for this output is done in two steps, first, the emissions for each type of GHG are calculated. Then, these emissions, which are already converted into equivalent CO_2, are summed to obtain the result.

Treatment process	*wwt_KPI_GHG_tre*
GHG from treatment process	
$ch4 = (wwt\_bod\_infl - wwt\_bod\_slud) \cdot wwt\_ch4\_efac\_tre \cdot ct\_ch4\_eq$ $n2o = (wwt\_tn\_infl) \cdot wwt\_n2o\_efac\_tre \cdot ct\_N\_to\_N2O\_44\_28 \cdot ct\_n2o\_eq$	**Equation 80**
$wwt\_KPI\_GHG\_tre\ [kgCO2eq] = ch4 + n2o$	**Equation 81**
With:	
wwt_bod_infl [kg]	BOD_5 load entering the WWTP during the assessment period. It can be estimated by multiplying the average BOD_5 concentration in the influent by the volume entering the plant. If this is done daily and summed over the duration of the assessment period, the value will be more accurate.
wwt_bod_slud [kg]	BOD_5 (organic component) removed from wastewater (in the form of sludge) (Sj in eq.6.1 IPCC 2019b)
wwt_ch4_efac_tre [kgCH4/kgBOD]	Methane emission factor of selected biological wastewater aerobic treatment processes
ct_ch4_eq [kgCO_2eq/kgCH_4]	CH_4 emission factor (untreated collected wastewater)
wwt_tn_infl [kg]	Total nitrogen load in the influent during the assessment period
wwt_n2o_efac_tre [kgN_2O-N/kgN]	N_2O emission factor for treatment
ct_N_to_N2O_44_28 [gN_2O/gN_2O-N]	Conversion factor of N_2O-N to N_2O[14]= 1.57
ct_n2o_eq [kgCO_2eq/kgN_2O]	N_2O emission factor (untreated collected wastewater)
Source	Adapted from: **IPCC (2019b, p. 6.17, 6.37)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Biogas (anaerobic digestion of sludge) – Sanitation Treatment

ECAM will calculate the GHG emissions from biogas (anaerobic digestion of sludge) using the input data.

Biogas (anaerobic digestion of sludge)	*wwt_KPI_GHG_biog*
GHG emissions from biogas	
$wwt\_KPI\_GHG\_biog\ \ [kgCO2eq] = wwt\_KPI\_GHG\_biog\_leaked$	**Equation 82**
With:	
wwt_KPI_GHG_biog_leaked [kgCO_2eq]	Biogas leaked

[14] To account for nitrous oxide emissions, it is necessary to convert total nitrogen to N_2O based on molar mass.

Emissions from leaked Biogas include only methane. They are calculated in three steps:

Biogas leaked	*wwt_KPI_GHG_biog_leaked*	
GHG emissions from biogas		
$wwt\_moles\_biogas\_produced\ [moles] = \frac{P\ \cdot wwt\_biog\_pro}{R \cdot T}$		**Equation 83**
$CH4\ leaked[kg] = wwt\_moles\_biogas\_produced \cdot \frac{(wwt\_biog\_lkd)}{100} \cdot \frac{(wwt\_ch4\_biog)}{100} \cdot\ 0.016$		**Equation 84**
$wwt\_KPI\_GHG\_biog\_leaked\ [kgCO2eq] = CH4\ leaked\ \cdot ct\_ch4\_eq$		**Equation 85**
With:		
wwt_moles_biogas_produced [moles]	Moles of biogas produced. Calculated considering normal conditions of pressure and temperature.	
P [J/m^3]	Normal condition for pressure = 1.013e5	
wwt_biog_pro [m^3]	Biogas produced	
R [J/K·mol]	General gas constant = 8.31446261815324	
T [K]	Normal condition for temperature = 273.15	
wwt_biog_lkd [% of volume]	Biogas leaked to the atmosphere	
wwt_ch4_biog [% of volume]	Percentage of methane in the biogas	
0.016	Conversion factor for moles CH4 to kgCH4	
wwt_moles_biogas_produced [moles]	Moles of biogas produced. Calculated considering conditions of pressure and temperature	
wwt_KPI_GHG_biog_leaked [kgCO_2eq]	Biogas leaked	
ct_ch4_eq [kgCO_2eq/kgCH_4]	GWP from CH_4 to CO_2eq (see **Selection of the Global Warming Potential Report**)	
Source	**Snip (2010)**, based on **CCME (2009a)**	

Fuel (digester) – Sanitation Treatment

The calculation for this output is perfomed in two steps, first, the emissions for each type of GHG are calculated. Then, these emissions, which are already converted into equivalent CO_2, are summed to obtain the result.

Fuel (digester)	*wwt_KPI_GHG_dig_fuel*
Amount of CO2 eq emissions due to fuel employed for digester (CO2+N2O+CH4).	
$co2\ [kgCO2eq] =\ wwt\_fuel\_dig\ \cdot FD\ \cdot \frac{NCV}{1000} \cdot EFCO2$ $ch4\ [kgCO2eq] =\ wwt\_fuel\_dig\ \cdot FD\ \cdot \frac{NCV}{1000} \cdot EFCH4.engines \cdot\ ct\_ch4\_eq$ $n2o\ [kgCO2eq] = wwt\_fuel\_dig\ \cdot FD\ \cdot \frac{NCV}{1000} \cdot EFN2O.engines \cdot\ ct\_n2o\_e$	**Equation 86**
$wwt\_KPI\_GHG\_dig\_fuel\ [kgCO2eq] = co2 + n2o + ch4$	**Equation 87**
With:	

wwt_fuel_dig [m^3]	Volume of fuel consumed
FD [kg/L]	Fuel density
NCV [TJ/Gg]	Net calorific values
$EFCO_2$ (kg/TJ)	Emission factor for CO_2
$EFCH_4$ (kg/TJ)	Emission factor for CH_4
EFN_2O (kg/TJ)	Emission factor for N_2O
ct_ch4_eq [$kgCO_2eq/kgCH_4$]	GWP from CH_4 to CO_2eq (see **Selection of the Global Warming Potential Report)**
ct_n2o_eq [$kgCO_2eq/kgN_2O$]	GWP from N_2O to CO_2eq (see **Selection of the Global Warming Potential Report**)
Source	**IPCC 2006b (p. 2.16)** https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf

Fuel density (FD), net calorific values (NCV) and the emission factor (EF) are related with the type of fuel, which is selected by the user in the stage input section (**Table 8**).

Sludge management – Sanitation Treatment

the sludge management emissions[15] accounted for in ECAM include:

- Emissions from storage,
- emissions from composting,
- emissions from incineration,
- emissions from landfilling,
- emissions from stockpilling,
- emissions from transport.

Sludge management	*wwt_KPI_GHG_slu*
GHG emissions from sludge management operations (storing, composting, incineration, land application, landfilling, stockpiling and truck transport).	
$$wwt\_KPI\_GHG_{slu}[kgCO2eq] = wwt\_KPI\_GHG\_slu\_storage + wwt\_KPI\_GHG\_slu\_composting + wwt\_KPI\_GHG\_slu\_incineration + wwt\_KPI\_GHG\_slu\_land\_application + wwt\_KPI\_GHG\_slu\_landfilling + wwt\_KPI\_GHG\_slu\_stockpilling + wwt\_KPI\_GHG\_slu\_transport$$	**Equation 88**
With:	
wwt_KPI_GHG_slu_storage [$kgCO_2eq$]	Amount of CO_2eq emissions related to sludge storage
wwt_KPI_GHG_slu_composting [kgCO2eq]	Amount of CO_2eq emissions due to sludge composted
wwt_KPI_GHG_slu_incineration [$kgCO_2eq$]	Amount of CO_2eq emissions due to sludge incineration
wwt_KPI_GHG_slu_land_application [$kgCO_2eq$]	Amount of CO_2eq emissions due to land application of sludge

[15] Note that, as for wastewater treatment and biogas production emissions, biogenic CO_2 emissions are not considered by ECAM at this stage. Further discussion is given at **CO2 emissions from biological degradation** and **Biogas flaring emissions**.

wwt_KPI_GHG_slu_landfilling [$kgCO_2eq$]	Fugitive methane emissions from biosolids decomposition in the landfill during the first 3 years after placement, and N_2O emissions from landfilled biosolids.
wwt_KPI_GHG_slu_stockpilling [$kgCO_2eq$]	Amount of CO_2eq emissions due to sludge stockpiling
wwt_KPI_GHG_slu_transport [$kgCO_2eq$]	Indirect CO_2 emitted from sludge transport off-site

The sections below explains the individual calculation of each component of Equation 88.

Sludge storage

Some utilities store sludge in tanks prior to dewatering or other processes. If these tanks are not aerated, they have the potential to produce methane.

Sludge storage *wwt_KPI_GHG_slu_storage*

Amount of CO_2 eq emissions related to sludge storage

$$ch4\_potential\ [kgCH4] = wwt\_mass\_slu\_sto \cdot \frac{wwt\_slu\_sto\_TVS}{100} \cdot ct\_VS\_to\_OC \cdot ct\_C\_to\_CH4\_16\_12 \cdot \frac{wwt\_slu\_sto\_f\_CH4}{100}$$ **Equation 89**

$$wwt\_KPI\_GHG\_slu\_storage\ [kgCO2eq] = ch4\_potential \cdot \frac{wwt\_slu\_sto\_EF}{100} \cdot ct\_ch4\_eq$$ **Equation 90**

With:

wwt_mass_slu_sto [kg]	Amount of sludge that is stored prior to disposal (dry weight)
wwt_slu_sto_TVS [%]	Total volatile solids (TVS) content of sludge stored
ct_VS_to_OC [kgOC/kgVS]	Organic carbon content in volatile solids = 0.56
ct_C_to_CH4_16_12 [$kgCH_4$/kgOC]	Conversion factor of organic C to CH_4 = 1.33
wwt_slu_sto_f_CH4 [%]	CH_4 potential factor
wwt_slu_sto_EF [%]	Emission factor due to storage. Can be estimated with the storage time.
ct_ch4_eq [$kgCO_2eq/kgCH_4$]	GWP from CH_4 to CO_2eq (see Selection of the Global Warming Potential Report)
Source	**IPCC (2019, p.3.1 – 3.25)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_3_Ch03_SWDS.pdf

Sludge composting

The sludge composting process can release fugitive emissions of methane and nitrous oxide. Nitrous oxide can be formed under low C:N ratio conditions, while methane can be formed under oxygen-limiting conditions.

Sludge composting calculations are addressed on IPCC 2006 Guidelines (Volume 5, Chapter 4), but suggested EFs are based on specific DOC, N content and moisture content conditions. In CCME (2009a) this formula is restructured under the BEAM model, where it is possible to calculate according to the sludge characteristics. This second is the approach adopted by ECAM.

Sludge composting *wwt_KPI_GHG_slu_composting*

Amount of CO_2 eq emissions related to sludge storage

$$CH4\ [kgCO2eq] = wwt\_mass\_slu\_comp \cdot \frac{wwt\_slu\_comp\_TVS}{100} \cdot ct\_VS\_to\_OC \cdot wwt\_slu\_comp\_uncovered\_pile\_EF \cdot ct\_C\_to\_CH4\_16\_12 \cdot ct\_ch4\_eq$$ $$N2O\ [kgCO2eq] = wwt\_mass\_slu\_comp \cdot \frac{wwt\_slu\_comp\_N\_cont}{100} \cdot wwt\_slu\_comp\_low\_CN\_EF \cdot ct\_N\_to\_N2O\_44\_28 \cdot ct\_n2o\_eq$$	**Equation 91**
$$wwt\_KPI\_GHG\_slu\_composting[kgCO2eq] = CH4 + N2O$$	**Equation 92**
With:	
wwt_mass_slu_comp [kg]	Amount of sludge that is sent to composting (dry weight)
wwt_slu_comp_TVS [%]	Total volatile solids (TVS) content of sludge composted (% of dry weight)
ct_VS_to_OC [kgOC/kgVS]	Organic carbon content in volatile solids = 0.56
wwt_slu_comp_uncovered _pile_EF [kgCH_4-C/kgC]	CH_4 emission factor for uncovered pile (fraction of initial C in solids)
ct_C_to_CH4_16_12 [kgCH_4/kgOC]	Conversion factor of organic C to CH_4 = 1.33
wwt_slu_comp_N_cont [%]	N content of sludge stored (% of dry weight)
ct_N_to_N2O_44_28 [kgN_2O/kgN2O-N]	Conversion factor of N_2O-N to N_2O[16]= 1.57
wwt_slu_comp_low_CN_EF [%]	Emission factor due to storage. Can be estimated with the storage time.
ct_ch4_eq [kgCO_2eq/kgCH_4]	GWP from CH_4 to CO_2eq (see **Selection of the Global Warming Potential Report**
ct_n2o_eq [kgCO_2eq/kg$N_2$0]	GWP from N_2O to CO_2eq (see **Selection of the Global Warming Potential Report**)
Special conditions	If piles are coverred (wwt_slu_comp_emis_treated_or_piles_covered = yes), CH_4 emissions will be 0 If solids content of the compost > 55 (solids_content_of_compost>55), CH_4 and N_2O emissions will be 0 If the ratio C/N >30, N_2O emissions will be 0
Sources	**IPCC (2006d, p. 4.1 – 4.8)** https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_4_Ch4_Bio_Treat.pdf **CCME (2009a, p. 147 - 149)** https://climatesmartwater.org/wp-content/uploads/sites/2/2018/03/The-Biosolids-Emissions-Assessment-Model-BEAM.pdf

Sludge incineration

Incineration is a source of GHG, like other types of combustion. Relevant gases include methane and nitrous oxide.

Sludge incineration calculations are addressed on IPCC 2019 Refinement Guidelines Volume 5, Chapter 5 (IPCC 2019b). In CCME (2009a) the calculation is restructured under the BEAM model, where it is possible to calculate according to the sludge characteristics. This second is the approach adopted by ECAM.

[16] To account for nitrous oxide emissions, it is necessary to convert total nitrogen to N_2O based on molar mass.

Note that for the calculation of nitrous oxide emissions, factors created from a model by Suzuki et al. (2003), which associates the emission of this gas with the average highest freeboard temperature of the process.

Sludge incineration	*wwt_KPI_GHG_slu_incineration*
Amount of CO_2eq emissions due to sludge incineration	
$CH4\ [kgCO2eq] = 4.85e^{-5} \cdot wwt\_mass\_slu\_inc \cdot ct\_ch4\_eq$ $N2O\ [kgCO2eq] = wwt\_mass\_slu\_inc \cdot \frac{wwt\_slu\_inc\_N\_cont}{100} \cdot \frac{161.3 - 0.14 \cdot wwt\_temp\_inc}{100} \cdot ct\_n2o\_eq$	**Equation 91**
$wwt\_KPI\_GHG\_slu\_composting[kgCO2eq] = CH4\ + N2O$	**Equation 94**
With:	
$4.85e^{-5}$ [kg CH4/dry kg sludge]	Amount of CH_4 in sludge, assuming 20% solids, from Foley & Lant (2007)
wwt_mass_slu_inc [kg]	Amount of sludge that is sent to incineration (dry weight)
ct_ch4_eq [$kgCO_2eq/kgCH_4$]	GWP from CH_4 to CO_2eq (see **Selection of the Global Warming Potential Report**)
wwt_slu_inc_N_cont [%]	N content of sludge incinerated (% of dry weight)
161.3	First constant for calculating de % of N emitted as N_2O (Suzuki et al., 2003)
0.14	Second constant for calculating de % of N emitted as N_2O (Suzuki et al., 2003)
wwt_temp_inc [K]	Incineration temperature
ct_n2o_eq [$kgCO_2eq/kgN_20$]	GWP from N_2O to CO_2eq (see **Selection of the Global Warming Potential Report**)
Special conditions	If selective non-catalytic reduction technology is used to convert NOx emissions to N_2, ECAM will incease N_2O emissiosn by 20% as suggested by CCME (2009a, page 162)
Source	**CCME (2009a, p. 161)** https://climatesmartwater.org/wp-content/uploads/sites/2/2018/03/The-Biosolids-Emissions-Assessment-Model-BEAM.pdf

Sludge land application

The application of sludge in soils causes an increase in the amount of nitrogen available, optimizing rates of nitrification and denitrification, which increases the generation of nitrous oxide.

Sludge land application are addressed on IPCC 2019 Refinement Guidelines Volume 4, Chapter 11 (IPCC 2019a). In CCME (2009a) the calculation is restructured under the BEAM model, where it is possible to calculate according to the sludge characteristics. This second is the approach adopted by ECAM.

Sludge land application	*wwt_KPI_GHG_slu_land_application*
Amount of CO_2eq emissions due to land application of sludge	

$$N2O[kgCO2eq] = wwt\_mass\_slu\_app \cdot \frac{wwt\_slu\_la\_N\_cont}{100} \cdot wwt\_slu\_la\_EF \cdot ct\_N\_to\_N2O\_44\_28 \cdot ct\_n2o\_eq$$		**Equation 92**
$$wwt\_KPI\_GHG\_slu\_land\_application[kgCO2eq] = N2O$$		**Equation 93**
With:		
wwt_mass_slu_app [kg]	Amount of sludge that is sent to land application (dry weight)	
wwt_slu_la_N_cont [%]	N content of sludge sent to land application (% of dry weight)	
wwt_slu_la_EF [kgN_2O-N/kgN]	Amount of nitrogen converted to N_2O	
ct_N_to_N2O_44_28	Conversion factor of N_2O-N to N_2O[17]= 1.57	
ct_n2o_eq [kgCO_2eq/kgN_20]	GWP from N_2O to CO_2eq (see **Selection of the Global Warming Potential Report**)	
Special conditions:	If the content of solids is >80 (wwt_slu_la_solids_content>80), the emissions are reduced by 50% (CCME (2009, page 169).	
Sources	**CCME (2009a, p. 166)** https://climatesmartwater.org/wp-content/uploads/sites/2/2018/03/The-Biosolids-Emissions-Assessment-Model-BEAM.pdf	

Landfilling of sludge

Disposal of sludge in landfills can generate two types of significant emissions: fugitive methane emissions from anaerobic conditions, and nitrous oxide emissions related to the increase in available nitrogen in the soil (thus increasing nitrification and denitrification rates).

Landfilling of sludge is addressed on IPCC 2019 Refinement Guidelines Volume 5, Chapter 3 and 4(IPCC 2019b). In CCME (2009a) the calculation is restructured under the BEAM model, where it is possible to calculate according to the sludge characteristics. This second is the approach adopted by ECAM.

Note that for fugitive methane emissions, ECAM only considers emissions referring to the first 3 years after placement.

Landfilling of sludge	**wwt_KPI_GHG_slu_landfilling**	
Fugitive methane emissions from biosolids decomposition in the landfill during the first 3 years after placement, and N2O emissions from landfilled biosolids		
$$CH4[kgCH4] = wwt\_mass\_slu\_land \cdot \frac{wwt\_slu\_lf\_TVS}{100} \cdot ct\_VS\_to\_OC \cdot wwt\_slu\_lf\_uncertainty \cdot ct\_C\_to\_CH4\_16\_12 \cdot \frac{wwt\_slu\_lf\_CH4\_in\_gas}{100} \cdot \frac{wwt\_slu\_lf\_DOCf}{100} \cdot \frac{wwt\_slu\_lf\_decomp\_3yr}{100} \cdot wwt\_slu\_lf\_MCF \cdot ct\_ch4\_eq$$		**Equation 94**
$$N2O[kgCO2eq] = wwt\_mass\_slu\_land \cdot \frac{wwt\_slu\_lf\_N\_cont}{100} \cdot wwt\_slu\_lf\_low\_CN\_EF \cdot ct\_N\_to\_N2O\_44\_28 \cdot ct\_n2o\_eq$$		**Equation 95**
$$wwt\_KPI\_GHG\_slu\_landfilling[kgCO2eq] = CH4 + N2O$$		**Equation 96**
With:		
wwt_mass_slu_land [kg]	Amount of sludge that is sent to landfilling (dry weight)	
wwt_slu_lf_TVS [%]	Total volatile solids (TVS) content of sludge sent to landfilling	

[17] To account for nitrous oxide emissions, it is necessary to convert total nitrogen to N_2O based on molar mass.

ct_VS_to_OC [kgOC/kgVS]	Organic carbon content in volatile solids = 0.56
wwt_slu_lf_uncertainty	Model uncertainty factor =0.9 (UNFCCC/CCNUC, 2008)
ct_C_to_CH4_16_12 [kgCH_4/kgOC]	Conversion factor of organic C to CH_4 = 1.33
wwt_slu_lf_CH4_in_gas [%]	CH_4 in landfill gas = 50% (UNFCCC/CCNUC, 2008)
wwt_slu_lf_DOCf [%]	Decomposable organic fraction of raw wastewater solids (80% from Brown et al., 2008; Metcalf, Eddy, 2003)
wwt_slu_lf_decomp_3yr [%]	Percentage decomposed in first 3 years of the decomposable organic fraction of raw wastewater solids = 69.9% (UNFCCC/CCNUC, 2008)
wwt_slu_lf_MCF [ratio]	Methane correction for anaerobic managed landfills
ct_ch4_eq [kgCO_2eq/kgCH_4]	GWP from CH_4 to CO_2eq (see **Selection of the Global Warming Potential Report**)
wwt_slu_lf_N_cont [%]	N content of sludge sent to land application (% of dry weight)
wwt_slu_lf_low_CN_EF [kgN_2O-N/kgN]	Amount of nitrogen converted to N_2O
ct_N_to_N2O_44_28	Conversion factor of N_2O-N to N_2O[18]= 1.57
ct_n2o_eq [kgCO_2eq/kg$N_2$0]	GWP from N_2O to CO_2eq (see **Selection of the Global Warming Potential Report**)
Sources	**CCME (2009a, p. 175)** https://climatesmartwater.org/wp-content/uploads/sites/2/2018/03/The-Biosolids-Emissions-Assessment-Model-BEAM.pdf

Sludge stockpiling

Stockpilling is a technique sometimes employed to dry or store sludge in wastewater treatment plants. Depending on the conditions under which the technique is employed, as well as the stockpilling period, GHG emissions can be significant.

There are very few experiments in which GHG emissions from sludge stockpiles have been measured. As a source, ECAM uses the experiences of Majunder et al. (2014), who measured the flux of gases at different ages of sludge piles during different seasons.

The authors propose the use of a gas flow model to calculate these emissions, which considers the sludge mass (wwt_mass_slu_stock) and the stockpile lifespan (wwt_slu_sp_lifespan). This model was imported into ECAM, and is described in detail in Majunder et al. (2014).

Sludge stockpiling	*wwt_KPI_GHG_slu_stockpilling*
Amount of CO_2eq emissions due to sludge stockpiling	
Sources	**Majunder et al. (2014)** https://www.sciencedirect.com/science/article/pii/S0301479714002047?via%3Dihub

Sludge Transport

As with the other mobile fugitive emissions mentioned in this document, sludge transport generates GHG emissions.

[18] To account for nitrous oxide emissions, it is necessary to convert total nitrogen to N_2O based on molar mass.

Truck transport of sludge	wwt_KPI_GHG_slu_transport	
Indirect CO_2 emitted from sludge transport off-site		
$co2 = wwt\_vol\_tslu \cdot FD \cdot \frac{NCV}{1000} \cdot EFCO2$ $ch4 = wwt\_vol\_tslu \cdot FD \cdot \frac{NCV}{1000} \cdot EFCH4.vehicles \cdot ct\_ch4\_eq$ $n2o = wwt\_vol\_tslu \cdot FD \cdot \frac{NCV}{1000} \cdot EFN2O.vehicles \cdot ct\_n2o\_eq$		**Equation 97**
$wwt\_KPI\_GHG\_slu\_transport[kgCO2eq] = co2 + n2o + ch4$		**Equation 98**
With:		
wwt_vol_tslu [m³]	Volume of fuel consumed	
FD [kg/L]	Fuel density	
NCV [TJ/Gg]	Net calorific values	
EFCO2 (kg/TJ)	Emission factor for CO_2	
EFCH4 (kg/TJ)	Emission factor for CH_4	
EFN2O (kg/TJ)	Emission factor for N_2O	
ct_ch4_eq [$kgCO_2eq/kgCH_4$]	GWP from CH_4 to CO_2eq (see **Selection of the Global Warming Potential Report**)	
ct_n2o_eq [$kgCO_2eq/kgN_2O$]	GWP from N_2O to CO_2eq (see **Selection of the Global Warming Potential Report**)	
Source	**IPCC (2006b, p. 3.21)** https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf	

Discharged water – Sanitation Treatment

The calculation for this output is done in two steps, first, the emissions for each type of GHG are calculated. Then, these emissions, which are already converted into equivalent CO_2, are summed to obtain the result.

Discharged water	*wwt_KPI_GHG_disc*	
Discharged water		
$ch4 = wwt\_bod\_effl \cdot wwt\_ch4\_efac\_dis \cdot ct\_ch4\_eq$ $n2o = wwt\_tn\_effl \cdot wwt\_n2o\_efac\_dis \cdot ct\_N\_to\_N2O\_44\_28 \cdot ct\_n2o\_eq$		**Equation 99**
$wwt\_KPI\_GHG\_disc\ [kgCO2eq] = ch4 + n2o$		**Equation 100**
With:		
wwt_bod_effl [kg]	BOD_5 load at the effluent of the WWTP during the assessment period. It can be estimated by multiplying the average BOD_5 concentration in the effluent by the effluent volume of the plant. If this is done daily and summed over the duration of the assessment period, the value will be more accurate.	
wwt_ch4_efac_dis [$kgCH_4/kgBOD_5$]	Methane emission factor for discharged water	

ct_ch4_eq [$kgCO_2eq/kgCH_4$]	GWP from CH_4 to CO_2eq (see **Selection of the Global Warming Potential Report**)
wwt_tn_effl [kg]	Total Nitrogen load in the effluent during the assessment period
wwt_n2o_efac_dis [kgN_2O-N/kgN]	N_2O emission factor (discharge)
ct_N_to_N2O_44_28 [gN_2O/gN_2O-N]	Conversion factor of N_2O-N to N_2O[19]= 1.57
ct_n2o_eq [$kgCO_2eq/kgN_2O$]	GWP from N_2O to CO_2eq (see **Selection of the Global Warming Potential Report**)
Source	Adapted from: **IPCC (2019b, p. 6.17, 6.37)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Truck transport of reused water – Sanitation Treatment

ECAM will calculate the GHG emissions from truck transport of reused water with input data.

The calculation for this output is done in two steps, firstly, the emissions for each type of GHG are calculated. Then, these emissions, which are already converted into equivalent CO_2, are summed to obtain the result.

Truck transport of reused water	*wwt_KPI_GHG_reus_trck*
GHG emissions from truck transport of reused water	

$$co2 = wwt\_reus\_vol\_trck \cdot FD \cdot \frac{NCV}{1000} \cdot EFCO2$$

$$ch4 = wwt\_reus\_vol\_trck \cdot FD \cdot \frac{NCV}{1000} \cdot EFCH4engines \cdot ct\_ch4\_eq$$

$$n2o = wwt\_reus\_vol\_trck \cdot FD \cdot \frac{NCV}{1000} \cdot EFN2Oengines \cdot ct\_n2o\_eq$$

Equation 101

$$wwt\_KPI\_GHG\_reus\_trck\ [kgCO2eq] = co2 + n2o + ch4$$

Equation 102

With:

wwt_reus_vol_trck [m^3]	Volume of fuel consumed (trucks)
ct_ch4_eq [$kgCO_2eq/kgCH_4$]	GWP from CH_4 to CO_2eq (see **Selection of the Global Warming Potential Report**)
ct_n2o_eq [$kgCO2eq/kgN_2O$]	GWP from N_2O to CO_2eq (see **Selection of the Global Warming Potential Report**)
FD [kg/L]	Fuel density
NCV [TJ/Gg]	Net calorific values
$EFCO_2$ (kg/TJ)	Emission factor for CO_2
$EFCH_4$ (kg/TJ)	Emission factor for CH_4
EFN_2O (kg/TJ)	Emission factor for N_2O
Sources	**IPCC (2006b, p. 3.21)** https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf

[19] To account for nitrous oxide emissions, it is necessary to convert total nitrogen to N_2O based on molar mass.

Total GHG wastewater treatment – Sanitation Treatment

The total GHG emissions of this stage are calculated by adding up all the emissions.

Total GHG wastewater treatment	*wwt_KPI_GHG*
Total GHG emitted by this wastewater treatment utility	
$$wwt\_KPI\_GHG\ [kgCO2eq] = wwt\_KPI\_GHG\_elec + wwt\_KPI\_GHG\_fuel + wwt\_KPI\_GHG\_tre + wwt\_KPI\_GHG\_biog + wwt\_KPI\_GHG\_dig\_fuel + wwt\_KPI\_GHG\_slu + wwt\_KPI\_GHG\_reus\_trck + wwt\_KPI\_GHG\_disc$$	**Equation 103**
With:	
wwt_KPI_GHG_elec [$kgCO_2eq$]	GHG indirect emissions from electricity
wwt_KPI_GHG_fuel [$kgCO_2eq$]	Direct CO_2 emitted from onsite engines in wastewater stages based upon sum of CO_2, CH_4 and N_2O emission from stationary combustion
wwt_KPI_GHG_tre [$kgCO_2eq$]	GHG from treatment process (CH_4+N_2O)
wwt_KPI_GHG_biog [$kgCO_2eq$]	GHG emissions from biogas
wwt_KPI_GHG_dig_fuel [$kgCO_2eq$]	Amount of CO_2eq emissions due to fuel employed for digester (CO_2+N_2O+CH_4)
wwt_KPI_GHG_slu [$kgCO_2eq$]	GHG emissions from sludge management operations (storing, composting, incineration, land application, landfilling, stockpiling and truck transport)
wwt_KPI_GHG_reus_trck [$kgCO_2eq$]	GHG emissions from truck transport of reused water
wwt_KPI_GHG_disc [$kgCO_2eq$]	Discharged water

Sanitation – Onsite Sanitation

Electricity (indirect) – Onsite Sanitation

ECAM will calculate the GHG emissions from electricity (indirect) using the input data entered in the tool.

These emissions are calculated by multiplying the energy consumption of the grid by the emission factor for grid electricity defined as a general factor (see topic

General and Country specific factors for more information about the grid factor methodology and sources).

Electricity (indirect)	*wwo_KPI_GHG_elec*
Electricity (indirect emissions)	
$$wwo\_KPI\_GHG\_elec\ [kgCO2eq] = wwo\_nrg\_cons \cdot wwo\_conv\_kwh$$	**Equation 104**
With:	
wwo_nrg_cons [kWh]	Energy consumed from the grid during the assessment period

wwo_conv_kwh [$kgCO_2eq/kWh$]	Emission factor for grid electricity (indirect emissions)
Sources	Based on **EIB (2020)** and **UNFCCC (2022)**

Fuel engines – Onsite Sanitation

ECAM will calculate the GHG emissions from onsite engines with the input data entered in the tool.

The calculation for this output is done in two steps, firstly, the emissions for each type of GHG are calculated. Then, these emissions, which are already converted into equivalent CO_2, are summed to obtain the result.

Fuel engines	*wwo_KPI_GHG_fuel*
Emissions related to combustion of fossil fuel in fuel engines	

$$co2 = wwo\_vol\_fuel \cdot FD \cdot \frac{NCV}{1000} \cdot EFCO2$$

$$ch4 = wwo\_vol\_fuel \cdot FD \cdot \frac{NCV}{1000} \cdot EFCH4.engines \cdot ct\_ch4\_eq$$

$$n2o = wwo\_vol\_fuel \cdot FD \cdot \frac{NCV}{1000} \cdot EFN2O.engines \cdot ct\_n2o\_eq$$

Equation 105

$$wwo\_KPI\_GHG\_fuel\ [kgCO2eq] = co2 + n2o + ch4$$

Equation 106

With:

wwo_vol_fuel [m^3]	Volume of fuel consumed
FD [kg/L]	Fuel density
NCV [TJ/Gg]	Net calorific values
$EFCO_2$ (kg/TJ)	Emission factor for CO_2
$EFCH_4$ (kg/TJ)	Emission factor for CH_4
EFN_2O (kg/TJ)	Emission factor for N_2O
ct_ch4_eq [$kgCO_2eq/kgCH_4$]	GWP from CH_4 to CO_2eq (see **Selection of the Global Warming Potential Report**)
ct_n2o_eq [$kgCO_2eq/kgN_2O$]	GWP from N_2O to CO_2eq (see **Selection of the Global Warming Potential Report**)
Source	**IPCC (2006, p. 2.16)** https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf

Containment – Onsite Sanitation

ECAM will calculate the GHG emissions from Containment with input data entered in the tool. These include methane emissions related to the anaerobic conditions.

Containment	*wwo_KPI_GHG_containment*
Containment	

$$wwo\_KPI\_GHG\_containment\ [kgCO2eq] = (wwo\_bod\_cont - wwo\_bod\_rmvd) \cdot wwo\_ch4\_efac\_con \cdot ct\_ch4\_eq$$

Equation 107

With:	
wwo_bod_cont [kg]	BOD_5 entering the containments
wwo_bod_rmvd [kg]	Total BOD_5 that is removed from the containment technology. It can be estimated from the volume or the mass of FS emptied and standard BOD_5 content
wwo_ch4_efac_con [$kgCH_4/kgBOD$]	CH_4 emission factor (containment)
ct_ch4_eq [$kgCO_2eq/kgCH_4$]	GWP from CH_4 to CO_2eq (see **Selection of the Global Warming Potential Report**)
Source	Adapted from: **IPCC (2019b, p. 6.17)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Biogas (anaerobic digestion of sludge) – Onsite Sanitation

ECAM will calculate the GHG emissions from Biogas (anaerobic digestion of sludge) with input data entered in the tool.

Biogas (anaerobic digestion of sludge)	*wwo_KPI_GHG_biog*
Biogas (anaerobic digestion of sludge)	
$wwo\_KPI\_GHG\_biog\ [kgCO2eq] = wwo\_KPI\_GHG\_biog\_leaked$	**Equation 108**
With:	
wwo_KPI_GHG_biog_leaked [$kgCO_2eq$]	Biogas leaked

The sections below explains the individual calculation of each component of Equation 111.

Biogas leaked	*wwo_KPI_GHG_biog_leaked*
GHG emissions from biogas	
$wwo\_moles\_biogas\_produced\ [moles] = \frac{P\ \cdot wwo\_biog\_pro}{R \cdot T}$	**Equation 109**
$CH4\ leaked[kg] = wwo\_moles\_biogas\_produced \cdot \frac{(wwo\_biog\_lkd)}{100} \cdot \frac{(wwo\_ch4\_biog)}{100} \cdot\ 0.016$	**Equation 110**
$wwo\_KPI\_GHG\_biog\_leaked\ [kgCO2eq] = CH4\ leaked\ \cdot ct\_ch4\_eq$	**Equation 111**
With:	
wwo_moles_biogas_produced [moles]	Moles of biogas produced. Calculated considering normal conditions of pressure and temperature.
P [J/m^3]	Normal condition for Pressure = 1.013e5
wwo_biog_pro [m^3]	Biogas produced
R [J/K·mol]	General gas constant = 8.31446261815324
T [K]	Normal condition for temperature = 273.15
wwo_biog_lkd [% of volume]	Biogas leaked to the atmosphere
wwo_ch4_biog [% of volume]	Percentage of methane in the biogas

0.016	Conversion factor for moles CH4 to kgCH4
wwo_moles_biogas_produced [moles]	Moles of biogas produced. Calculated considering conditions of pressure and temperature
wwo_KPI_GHG_biog_leaked [$kgCO_2eq$]	Biogas leaked
ct_ch4_eq [$kgCO_2eq/kgCH_4$]	GWP from CH_4 to CO_2eq (see **Selection of the Global Warming Potential Report**)
Source	**Snip (2010)** based on **CCME (2009a)**

Fuel (digester) – Onsite Sanitation

ECAM will calculate the GHG emissions from fuel (digester) with the input data entered in the tool.

The calculation for this output is done in two steps, first, the emissions for each type of GHG are calculated. Then, these emissions, which are already converted into equivalent CO_2, are summed to obtain the result.

Fuel (digester)	*wwo_KPI_GHG_biog_leaked*
Amount of CO_2eq emissions due to fuel employed for digester (CO_2+N_2O+CH_4)	
$$co2 = wwo\_fuel\_dig \cdot FD \cdot \frac{NCV}{1000} \cdot EFCO2$$ $$ch4 = wwo\_fuel\_dig \cdot FD \cdot \frac{NCV}{1000} \cdot EFCH4.engines \cdot ct\_ch4\_eq$$ $$n2o = wwo\_fuel\_dig \cdot FD \cdot \frac{NCV}{1000} \cdot EFN2O.engines \cdot ct\_n2o\_eq$$	**Equation 112**
$$wwo\_KPI\_GHG\_dig\_fuel[kgCO2eq] = co2 + n2o + ch4$$	**Equation 113**
With:	
wwo_fuel_dig [m^3]	Volume of fuel consumed
FD [kg/L]	Fuel density
NCV [TJ/Gg]	Net calorific values
EFCO2 (kg/TJ)	Emission factor for CO_2
EFCH4 (kg/TJ)	Emission factor for CH_4
EFN2O (kg/TJ)	Emission factor for N_2O
ct_ch4_eq [$kgCO_2eq/kgCH_4$]	GWP from CH_4 to CO_2eq (see **Selection of the Global Warming Potential Report**)
ct_n2o_eq [$kgCO_2eq/kgN_2O$]	GWP from N_2O to CO_2eq (see **Selection of the Global Warming Potential Report**)
Source	**IPCC (2006b, p. 2.16)** https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf

Fuel density (FD), net calorific values (NCV) and the emission factor (EF) are related with the type of fuel, which is selected by the user in the stage input section (**Table 8**).

Treatment process – Onsite Sanitation

The calculation for this output is done in two steps, first, the emissions for each type of GHG are calculated. Then, these emissions, which are already converted into equivalent CO_2, are summed to obtain the result.

Treatment process	*wwo_KPI_GHG_tre*
Treatment process	
$ch4 = (wwo\_bod\_infl - wwo\_bod\_slud) \cdot wwo\_ch4\_efac\_tre \cdot ct\_ch4\_eq$ $n2o = (wwo\_tn\_infl) \cdot wwo\_n2o\_efac\_tre \cdot ct\_N\_to\_N2O\_44\_28 \cdot ct\_n2o\_eq$	**Equation 114**
$wwo\_KPI\_GHG\_tre\ [kgCO2eq] = ch4 + n2o$	**Equation 115**
With:	
wwo_bod_infl [kg]	GHG emissions avoided in wastewater treatment
wwo_bod_slud [kg]	GHG emissions avoided in onsite sanitation
wwo_ch4_efac_tre [$kgCH_4/kgBOD$]	CH_4 emission factor (treatment)
ct_ch4_eq [$kgCO_2eq/kgCH_4$]	GWP from CH_4 to CO_2eq (see Selection of the Global Warming Potential Report)
wwo_tn_infl [kg]	Total nitrogen load in the influent during the assessment period
wwo_n2o_efac_tre [kgN_2O-N/kgN]	N_2O emission factor (treatment)
ct_N_to_N2O_44_28 [gN_2O/gN_2O-N]	Conversion factor of N_2O-N to N_2O[20]= 1.57
ct_n2o_eq [$kgCO_2eq/kgN_2O$]	GWP from N_2O to CO_2eq (see Selection of the Global Warming Potential Report)
Source	Adapted from: **IPCC (2019b p. 6.17, 6.37)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Sludge management – Onsite Sanitation

The sludge management emissions[21] that are accounted for in ECAM include:

- Emissions from storage,
- emissions from composting,
- emissions from incineration,
- emissions from landfilling,
- emissions from stockpilling,
- emissions from transport.

[20] To account for nitrous oxide emissions, it is necessary to convert Total Nitrogen to N2O based on molar mass.

[21] Note that, as for wastewater treatment and biogas production emissions, biogenic CO2 emissions are not considered by ECAM at this stage. Further discussion is given at **CO2 emissions from biological degradation** and **Biogas flaring emissions**.

Sludge management	*wwo_KPI_GHG_sludge*
GHG emissions from faecal sludge management operations	

$$wwo\_KPI\_GHG\_sludge\,[kgCO2eq] = wwo\_KPI\_GHG\_landfil + wwo\_KPI\_GHG\_landapp + wwo\_KPI\_GHG\_dumping + wwo\_KPI\_GHG\_urine + wwo\_KPI\_GHG\_trck$$

Equation 116

With:

wwo_KPI_GHG_landfil [$kgCO_2eq$]	GHG emissions avoided in wastewater treatment
wwo_KPI_GHG_landapp [$kgCO_2eq$]	GHG emissions avoided in onsite sanitation
wwo_KPI_GHG_dumping [$kgCO_2eq$]	Total GHG emissions due to (faecal) sludge dumping
wwo_KPI_GHG_urine [$kgCO_2eq$]	Amount of CO_2eq emissions due to N_2O emission from land application of urine
wwo_KPI_GHG_trck [kgCO2eq]	Truck transport of faecal sludge

The sections below explains the individual calculation of each component of Equation 119.

Landfilling

Disposal of sludge in landfills can generate two types of significant emissions: fugitive methane emissions from anaerobic conditions, and nitrous oxide emissions related to the increase in available nitrogen in the soil (thus increasing nitrification and denitrification rates).

Landfilling of sludge is addressed on IPCC 2019 Refinement Guidelines Volume 5, Chapter 3 and 4 (IPCC 2019b). In CCME (2009b) the calculation is restructured under the BEAM model, where it is possible to calculate according to the sludge characteristics. This second is the approach adopted by ECAM.

Note that for fugitive methane emissions, ECAM only considers emissions referring to the first 3 years after placement.

Landfilling of sludge	*wwo_KPI_GHG_landfil*
Fugitive methane emissions from biosolids decomposition in the landfill during the first 3 years after placement, and N_2O emissions from landfilled biosolids	

$$CH4[kgCH4] = wwo\_mass\_landfil \cdot \frac{wwo\_lf\_TVS}{100} \cdot ct\_VS\_to\_OC \cdot wwt\_lf\_uncertainty \cdot ct\_C\_to\_CH4\_16\_12 \cdot \frac{wwt\_lf\_CH4\_in\_gas}{100} \cdot \frac{wwt\_lf\_DOCf}{100} \cdot \frac{wwt\_lf\_decomp\_3yr}{100} \cdot wwt\_lf\_MCF \cdot ct\_ch4\_eq$$

Equation 117

$$N2O[kgCO2eq] = wwo\_mass\_landfil \cdot \frac{wwt\_lf\_N\_cont}{100} \cdot wwt\_lf\_low\_CN\_EF \cdot ct\_N\_to\_N2O\_44\_28 \cdot ct\_n2o\_eq$$

Equation 118

$$wwo\_KPI\_GHG\_landfil[kgCO2eq] = CH4 + N2O$$

Equation 119

With:

wwo_mass_landfil [kg]	Amount of sludge that is sent to landfilling (dry weight)
wwo_lf_TVS [%]	Total volatile solids (TVS) content of sludge sent to landfilling
ct_VS_to_OC [kgOC/kgVS]	Organic carbon content in volatile solids = 0.56

wwo_lf_uncertainty	Model uncertainty factor =0.9 (UNFCCC/CCNUC, 2008)
ct_C_to_CH4_16_12 [kgCH_4/kgOC]	Conversion factor of organic C to CH_4 = 1.33
wwo_lf_CH4_in_gas [%]	CH_4 in landfill gas = 50% (UNFCCC/CCNUC, 2008)
wwo_lf_DOCf [%]	Decomposable organic fraction of raw wastewater solids (80% from Brown et al., 2008; Metcalf, Eddy, 2003)
wwo_lf_decomp_3yr [%]	Percentage decomposed in first 3 years of the decomposable organic fraction of raw wastewater solids = 69.9% (UNFCCC/CCNUC, 2008)
wwo_lf_MCF [ratio]	Methane correction for anaerobic managed landfills
ct_ch4_eq [kgCO2eq/kgCH4]	GWP from CH_4 to CO_2eq (see **Selection of the Global Warming Potential Report**)
wwo_lf_N_cont [%]	N content of sludge sent to land application (% of dry weight)
wwo_lf_low_CN_EF [kgN_2O-N/kgN]	Amount of nitrogen converted to N_2O
ct_N_to_N2O_44_28	Conversion factor of N_2O-N to N_2O[22]= 1.57
ct_n2o_eq [kgCO2eq/kg$N_2$0]	GWP from N_2O to CO_2eq (see **Selection of the Global Warming Potential Report**)
Sources	**CCME (2009a, b)** https://climatesmartwater.org/wp-content/uploads/sites/2/2018/03/The-Biosolids-Emissions-Assessment-Model-BEAM.pdf http://faculty.washington.edu/slb/docs/CCME_final_report.pdf

Sludge land application

The application of sludge in soils causes an increase in the amount of nitrogen available, optimizing rates of nitrification and denitrification, which increases the generation of nitrous oxide.

Sludge land application are addressed on IPCC 2019 Refinement Guidelines Volume 4, Chapter 11 (IPCC 2019a). In CCME (2009a) the calculation is restructured under the BEAM model, where it is possible to calculate according to the sludge characteristics. This second is the approach adopted by ECAM.

Sludge land application	*wwo_KPI_GHG_landapp*
Amount of CO2,eq emissions due to land application of sludge	

$$N2O[kgCO2eq] = wwo\_mass\_landapp \cdot \frac{wwo\_la\_N\_cont}{100} \cdot wwo\_la\_N\_to\_N2O \cdot ct\_N\_to\_N2O\_44\_28 \cdot ct\_n2o\_eq \quad \textbf{Equation 120}$$

$$wwo\_KPI\_GHG\_landapp[kgCO2eq] = N2O \quad \textbf{Equation 121}$$

With:

wwo_mass_landapp [kg]	Amount of sludge that is sent to land application (dry weight)
wwo_la_N_cont [%]	N content of sludge sent to land application (% of dry weight)
wwo_la_N_to_N2O [kgN_2O-N/kgN]	Amount of nitrogen converted to N_2O-N

[22] To account for nitrous oxide emissions, it is necessary to convert total nitrogen to N_2O based on molar mass.

ct_N_to_N2O_44_28	Conversion factor of N_2O-N to N_2O[23]= 1.57
ct_n2o_eq [$kgCO_2eq/kgN_20$]	GWP from N_2O to CO_2eq (see **Selection of the Global Warming Potential Report**
Special conditions:	If the content of solids is >80 (wwt_slu_la_solids_content>80), the emissions are reduced by 50% (CCME (2009a, page 169).
Sources	**CCME (2009a, p. 166, 188, 2009b)** http://faculty.washington.edu/slb/docs/CCME_final_report.pdf https://climatesmartwater.org/wp-content/uploads/sites/2/2018/03/The-Biosolids-Emissions-Assessment-Model-BEAM.pdf

Dumping

The application of sludge in soils causes an increase in the amount of nitrogen available, optimizing rates of nitrification and denitrification, which increases the generation of nitrous oxide.

Sludge land application are addressed on IPCC (2019a, p. 11.1–11.48). In CCME (2009a) the calculation is restructured under the BEAM model, where it is possible to calculate according to the sludge characteristics. This second is the approach adopted by ECAM.

Dumping	*wwo_KPI_GHG_dumping*
Total GHG emissions due to (faecal) sludge dumping	
$CH4 = wwo\_vol\_dumping \cdot wwo\_bod\_conc\_fs \cdot wwo\_ch4\_efac\_dumping \cdot ct\_ch4\_eq$ $N2O = wwo\_N\_dumping \cdot wwo\_n2o\_efac\_dumping \cdot ct\_N\_to\_N2O\_44\_28 \cdot ct\_n2o\_eq$	**Equation 122**
$wwo\_KPI\_GHG\_dumping\ [kgCO2eq] = CH4 + N2O$	**Equation 123**
With:	
wwo_vol_dumping [m^3]	Volume of faecal sludge dumped during the assessment period
wwo_bod_conc_fs [kg/m^3]	Average BOD concentration of faecal sludge during the assessment period after emptying from containment. It can be estimated from the population with onsite sanitation.
wwo_ch4_efac_dumping [$kgCH_4/kgBOD$]	Methane emission factor for faecal sludge dumping
wwo_N_dumping [kg]	Total nitrogen load in dumped faecal sludge
wwo_n2o_efac_dumping [kgN_2O-N/kgN]	N_2O emission factor for faecal sludge dumping
ct_N_to_N2O_44_28	Conversion factor of N_2O-N to N_2O[24]= 1.57
ct_n2o_eq [$kgCO_2eq/kgN_20$]	GWP from N_2O to CO_2eq (see **Selection of the Global Warming Potential Report**)
ct_ch4_eq [$kgCO_2eq/kgCH_4$]	GWP from CH_4 to CO_2eq (see **Selection of the Global Warming Potential Report**)
Sources	**CCME (2009a)** **IPCC (2019a)**

[23] To account for nitrous oxide emissions, it is necessary to convert Total Nitrogen to N2O based on molar mass.
[24] To account for nitrous oxide emissions, it is necessary to convert Total Nitrogen to N2O based on molar mass.

Urine application

The application of urine in soils causes an increase in the amount of nitrogen available, optimizing rates of nitrification and denitrification, which increases the generation of nitrous oxide.

Urine application is addressed on IPCC (2019a, p. 11.1 – 11.48).

Urine application	*wwo_KPI_GHG_urine*
Amount of CO2eq emissions due to N2O emission from land application of urine	
$N2O[kgCO2eq] = wwo\_N\_urine \cdot wwo\_N\_urine\_EF \cdot ct\_N\_to\_N2O\_44\_28 \cdot ct\_n2o\_eq$	**Equation 124**
$wwo\_KPI\_GHG\_urine[kgCO2eq] = CH4$	**Equation 125**
With:	
wwo_N_urine [kg]	Total nitrogen in urine applied to land
wwo_N_urine_EF [kgN_2O-N/kgN]	EF for N additions from mineral fertilisers, organic amendments and crop residues, and N mineralised from mineral soil as a result of loss of soil carbon
ct_N_to_N2O_44_28	Conversion factor of N_2O-N to N_2O[25]= 1.57
ct_n2o_eq [kgCO_2eq/kg$N_2$0]	GWP from N_2O to CO_2eq (see **Selection of the Global Warming Potential Report**)
Source	**IPCC (2006c, p. 11.11)** https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf

Truck transport of faecal sludge

As with the other mobile fugitive emissions mentioned in this document, sludge transport generates GHG emissions.

Truck transport of faecal sludge	*wwo_KPI_GHG_trck*
Truck transport of faecal sludge	
$$co2 = wwo\_vol\_trck \cdot FD \cdot \frac{NCV}{1000} \cdot EFCO2$$ $$ch4 = wwo\_vol\_trck \cdot FD \cdot \frac{NCV}{1000} \cdot EFCH4.vehicles \cdot ct\_ch4\_eq$$ $$n2o = wwo\_vol\_trck \cdot FD \cdot \frac{NCV}{1000} \cdot EFN2O.vehicles \cdot ct\_n2o\_e$$	**Equation 126**
$wwo\_KPI\_GHG\_trck[kgCO2eq] = co2 + n2o + ch4$	**Equation 127**
With:	
wwo_vol_trck [m^3]	Volume of fuel consumed
FD [kg/L]	Fuel density
NCV [TJ/Gg]	Net calorific values
$EFCO_2$ (kg/TJ)	Emission factor for CO_2
$EFCH_4$ (kg/TJ)	Emission factor for CH_4
EFN_2O (kg/TJ)	Emission factor for N_2O

[25] To account for nitrous oxide emissions, it is necessary to convert Total Nitrogen to N2O based on molar mass.

ct_ch4_eq [$kgCO_2eq/kgCH_4$]	GWP from CH_4 to CO_2eq (see **Selection of the Global Warming Potential Report**)
ct_n2o_eq [$kgCO_2eq/kgN_2O$]	GWP from N_2O to CO_2eq (see **Selection of the Global Warming Potential Report**)
Source	**IPCC (2006, p. 3.21)** https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf

Discharged water – Onsite Sanitation

ECAM will calculate the GHG emissions from Discharged water with input data.

The calculation for this output is done in two steps, firstly, the emissions for each type of GHG are calculated. Then, these emissions, which are already converted into equivalent CO2, are summed to obtain the result.

Discharged water	*wwo_KPI_GHG_dis*
Discharged water	
$ch4 = wwo\_bod\_effl \cdot wwo\_ch4\_efac\_dis \cdot ct\_ch4\_eq$ $n2o = wwo\_tn\_effl \cdot wwo\_n2o\_efac\_dis \cdot ct\_N\_to\_N2O\_44\_28 \cdot ct\_n2o\_eq$	**Equation 128**
$wwo\_KPI\_GHG\_dis\ \ [kgCO2eq] = ch4 + n2o$	**Equation 129**
With:	
wwo_bod_effl [kg]	BOD_5 load at the effluent of the onsite treatment during the assessment period
wwo_ch4_efac_dis [$kgCH_4/kgBOD$]	CH_4 emission factor (discharge)
ct_ch4_eq [$kgCO_2eq/kgCH_4$]	GWP from CH_4 to CO_2eq (see **Selection of the Global Warming Potential Report**)
wwo_tn_effl [kg]	Total nitrogen load in the effluent during the assessment period
wwo_n2o_efac_dis [$kgN_2O\text{-}N/kgN$]	N_2O emission factor (discharge)
ct_N_to_N2O_44_28 [$gN_2O/gN_2O\text{-}N$]	Conversion factor of N_2O-N to N_2O[26]= 1.57
ct_n2o_eq [$kgCO_2eq/kgN_2O$]	GWP from N_2O to CO_2eq (see **Selection of the Global Warming Potential Report**)
Source	Adapted from: **IPCC (2019, p. 6.17, 6.37)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Open defecation – Onsite Sanitation

ECAM will calculate the GHG emissions from Open defecation based on the input data. The emissions are most sourced from nitrous oxide, since anaerobic conditions are unlikely, which is needed to generate methane (IPCC, 2019).

Open defecation	*wwo_KPI_GHG_unt_opd*
Open defecation	
$wwo\_KPI\_GHG\_unt\_opd\ [kgCO2eq] = wwo\_opd\_tn \cdot wwo\_n2o\_efac\_opd \cdot ct\_N\_to\_N2O\_44\_28 \cdot ct\_n2o\_eq$	**Equation 130**
With:	
wwo_opd_tn [kg]	Total Nitrogen load from open defecation. It can be estimated from the population

[26] To account for nitrous oxide emissions, it is necessary to convert Total Nitrogen to N2O based on molar mass.

wwo_n2o_efac_opd [kgN_2O-N/kgN]	N_2O emission factor (open defecation)
ct_N_to_N2O_44_28 [gN_2O/gN_2O-N]	Conversion factor of N_2O-N to N_2O[27]= 1.57
ct_n2o_eq [$kgCO_2eq/kgN_2O$]	GWP from N_2O to CO_2eq (see Selection of the Global Warming Potential Report)
Source	Adapted from: **IPCC (2019b p. 6.37)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Total GHG onsite sanitation – Onsite Sanitation

The total GHG emissions of this stage are calculated by adding up all the emissions.

Total GHG onsite sanitation	*wwo_KPI_GHG*
Total GHG onsite sanitation	
$$wwo\_KPI\_GHG\ [kgCO2eq] = wwo\_KPI\_GHG\_elec + wwo\_KPI\_GHG\_fuel + wwo\_KPI\_GHG\_unt\_opd + wwo\_KPI\_GHG\_containment + wwo\_KPI\_GHG\_tre + wwo\_KPI\_GHG\_dis + wwo\_KPI\_GHG\_biog + wwo\_KPI\_GHG\_dig\_fuel + wwo\_KPI\_GHG\_sludge$$	**Equation 131**
With:	
wwo_KPI_GHG_elec [$kgCO_2eq$]	Electricity (indirect emissions)
wwo_KPI_GHG_fuel [$kgCO_2eq$]	Fuel engines
wwo_KPI_GHG_unt_opd [$kgCO_2eq$]	Open defecation
wwo_KPI_GHG_containment [$kgCO_2eq$]	Containment
wwo_KPI_GHG_tre [$kgCO_2eq$]	Treatment process
wwo_KPI_GHG_dis [$kgCO_2eq$]	Discharged water
wwo_KPI_GHG_biog [$kgCO_2eq$]	Biogas (anaerobic digestion of sludge)
wwo_KPI_GHG_dig_fuel [$kgCO_2eq$]	Amount of CO_2eq emissions due to fuel employed for digester
wwo_KPI_GHG_sludge [$kgCO_2eq$]	GHG emissions from faecal sludge management operations

[27] To account for nitrous oxide emissions, it is necessary to convert Total Nitrogen to N2O based on molar mass.

Energy performance and Service Level indicators

This section presents the energy efficiency and service level indicators calculated by the ECAM tool.

The purpose of performance indicators (PI) is to present information on the efficiency and effectiveness of the services provided by the urban water utility. In this way, ECAM organizes this information so that the utility can quickly access it and use it to:

- **Performance assessment**: using indicators to determine the status and evolution of the performance of the services provided
- **Comparative performance assessment**: using the indicators to compare with reference values or with other utilities (process called "benchmarking")
- **Performance improvement**: using indicators to monitor good practices identified and adopted by the utility

The following sub-topics will present the indicators calculated by ECAM, as well as their formulas and equations. This is an additional feature of the ECAM and the relevant sources will be provided when the ECAM suggests benchmark[28] values for the indicator.

For more information on the indicators, IWA's international reference bibliography is suggested, which was used to define the indicators (Alegre et al., 2016; Cabrera et al., 2011).

Water Supply – General

Serviced population – Water Supply

Serviced population	*ws_serv_pop*
Serviced population is referred to the number of inhabitants, within the area of service managed by the utility, which are connected to the distribution system and are receiving the service. It can be used for operational control or projections.	
$ws\_serv\_pop\ [people] = wsd\_serv\_pop$	**Equation 132**

Serviced population with water supply (%)– Water Supply

Serviced population with water supply (%)	*ws_SL_serv_pop*
Serviced population with water supply (%) used to assess service coverage.	
$ws\_SL\_serv\_pop\ [\%] = \frac{100 \cdot ws\_serv\_pop}{ws\_resi\_pop}$	**Equation 133**
With:	
ws_serv_pop [people]	Serviced population
ws_resi_pop [people]	Number of permanent residents within the water utility area of service

[28] The benchmarks will be indicated in the sub-topics below and can be consulted in topic **Annex 2 – Benchmark table**, in the annexes.

Energy consumed from the grid (Abstraction+Treatment+Distribution) – Water Supply

Energy consumed from the grid (Abstraction+Treatment+Distribution)	*ws_run_cons*
Total energy consumed from the grid for the entire water supply utility, based on the electricity bill during the entire assessment period. It can be used for operational control or projections.	
$ws\_nrg\_cons\ [kWh] = wsa\_nrg\_cons + wst\_nrg\_cons + wsd\_nrg\_cons$	**Equation 134**
With:	
wsa_nrg_cons [kWh]	Energy consumed from abstraction
wst_nrg_cons [kWh]	Energy consumed from treatment
wsd_nrg_cons [kWh]	Energy consumed from distribution

Volume of fuel consumed (engines) – Water Supply

Volume of fuel consumed (engines)	*ws_vol_fuel*
Total volume of fuel consumed. It can be used for operational control or projections.	
$ws\_vol\_fuel\ [L] = wsa\_vol\_fuel + wst\_vol\_fuel + wsd\_vol\_fuel$	**Equation 135**
With:	
wsa_vol_fuel [m^3]	Volume of fuel consumed from abstraction
wst_vol_fuel [m^3]	Volume of fuel consumed from treatment
wsd_vol_fuel [m^3]	Volume of fuel consumed from distribution

Water Supply – Abstraction

Energy consumption per abstracted water – Water Abstraction

Energy consumption per abstracted water	*wsa_nrg_per_abs_watr*
It can be used for operating cost projections. Caution should be exercised when using this indicator for comparisons, as it may vary according to the reality of each system. An example is the topographic conditions of the system, which may demand greater or lesser energy intensity. However, the evaluation of the individual history of this indicator for each system can provide information regarding years with better or worse energy performance.	
$wsa\_nrg\_per\_abs\_watr\ [kWh/m^3] = \frac{wsa\_nrg\_cons}{wsa\_vol\_conv}$	**Equation 136**
With:	
wsa_nrg_cons [kWh]	Electric energy consumption from the grid, for the water abstraction unit, by the utility, during the entire assessment period
wsa_vol_conv [m^3]	Sum of the volume of water abstracted (gravity or pumped) in the water abstraction unit that are the responsibility of the utility, during the assessment period

Energy consumed per pumped water – Water Abstraction

Energy consumed per pumped water *wsa_nrg_per_pmp_watr*

It can be used for operating cost projections. Caution should be exercised when using this indicator for comparisons, as it may vary according to the reality of each system. An example is the topographic conditions of the system, which may demand greater or lesser energy intensity. However, the evaluation of the individual history of this indicator for each system can provide information regarding years with better or worse energy performance.

$$wsa\_nrg\_per\_pmp\_watr\ [kWh/m^3] = \frac{wsa\_nrg\_pump}{wsa\_vol\_pump}$$ **Equation 137**

With:

wsa_nrg_pump [kWh] — Energy consumed from the grid (pumping)

wsa_vol_pump [m^3] — Volume of water pumped in each water abstraction unit that are the responsibility of the utility, during the assessment period

Calculated water power – Water Abstraction

Calculated water power *wsa_pmp_pw*

It is used to calculate the electromechanical efficiency of an existing pump.

$$wsa\_pmp\_pw\ [kW] = \frac{wsa\_pmp\_flow \cdot wsa\_pmp\_head \cdot ct\_gravit}{1000}$$ **Equation 138**

With:

wsa_pmp_flow [m^3/s] — Measured pump flow

wsa_pmp_head [m] — Head at which the water is pumped in each water abstraction unit that are the responsibility of the utility, during the assessment period

ct_gravit [$kg/(s^2.m^2)$] — 9.810

Standardized Energy Consumption – Water Abstraction

Standardized Energy Consumption *wsa_KPI_std_nrg_cons*

It is the average amount of energy consumed per m^3 at a pump head of 100 m. Since it is a standardized energy efficiency indicator it can be used for comparisons between utilities and facilities. See **Table 26** for its benchmarking values and sources.

$$wsa\_KPI\_std\_nrg\_cons\ [kWh/m^3/100m] = \frac{wsa\_nrg\_pump}{(wsa\_vol\_pump \cdot wsa\_pmp\_head)/100}$$ **Equation 139**

With:

wsa_nrg_pump [kWh] — Energy consumed from the grid (pumping)

wsa_vol_pump [m^3] — Volume of water pumped in each water abstraction unit that are the responsibility of the utility, during the assessment period

wsa_pmp_head [m] — Head at which the water is pumped in each water abstraction unit that are the responsibility of the utility, during the assessment period

Unit head loss – Water Abstraction

Unit head loss *wsa_KPI_un_head_loss*

Represents fluid energy per unit of pipe measurement. It can be used as an additional component to assess the energy efficiency of an installation. It can be used for operational control or projections. See **Table 26** for its benchmarking values and sources.

$$wsa\_KPI\_un\_head\_loss\ [m/km] = \frac{1e3 \cdot (wsa\_pmp\_head - wsa\_sta\_head)}{wsa\_main\_len}$$ **Equation 140**

With:

wsa_pmp_head [m]	Head at which the water is pumped in each water abstraction unit that are the responsibility of the utility, during the assessment period
wsa_sta_head [m]	Static head
wsa_main_len [m]	Total transmission and distribution mains length (there are not service connections at the abstraction and conveyance stage)

Electromechanical efficiency of existing pump – Water Abstraction

Electromechanical efficiency of existing pump *wsa_KPI_nrg_elec_eff*

Estimate for pump and motor efficiency evaluation.

$$wsa\_KPI\_nrg\_elec\_eff\ [\%] = \frac{100 \cdot wsa\_pmp\_pw}{(wsa\_pmp\_volt \cdot wsa\_pmp\_amps \cdot \sqrt{3} \cdot \frac{wsa\_pmp\_pf}{1000})}$$ **Equation 141**

With:

wsa_pmp_pw [kW]	Calculated water power
wsa_pmp_volt [V]	Measured pump voltage
wsa_pmp_amps [A]	Measured pump current
wsa_pmp_pf [ratio]	Power factor

Estimated GHG reduction per assessment period – Water Abstraction

Estimated GHG reduction per assessment period *wsa_KPI_ghg_estm_red*

Estimated GHG reduction associated with equipment replacement. It can be used for operational projections.

$$wsa\_KPI\_ghg\_estm\_red\ \ [kgCO2eq] = wsa\_KPI\_nrg\_estm\_sav \cdot wsa\_conv\_kwh$$ **Equation 142**

With:

wsa_KPI_nrg_estm_sav [kWh]	Estimated electricity savings
wsa_conv_kwh [kgCO_2eq/kWh]	Emission factor for grid electricity (indirect emissions)

Standardized energy consumption of new pump – Water Abstraction

Standardized energy consumption of new pump *wsa_KPI_std_nrg_newp*

It is the average amount of energy consumed per m^3 at a pump head of 100 m for a new pump. Since it is a standardized energy efficiency indicator, it can be used for comparisons between utilities and facilities. In this case, it can also be used for comparison with the old pump.

$$wsa\_KPI\_std\_nrg\_newp\ [kWh/m^3/100m] = \frac{wsa\_KPI\_nrg\_elec\_eff}{wsa\_pmp\_exff \cdot wsa\_KPI\_std\_nrg\_cons}$$ **Equation 143**

With:

wsa_KPI_nrg_elec_eff [%]	Electromechanical efficiency of existing pump
wsa_pmp_exff [%]	Expected electromechanical efficiency of new pump

wsa_KPI_std_nrg_cons [kWh/m³/100m]	Standardized energy consumption

Energy consumption with expected new pump efficiency – Water Abstraction

Energy consumption with expected new pump efficiency *wsa_KPI_nrg_elec_eff*

Energy consumption with expected new pump efficiency. It can be used for operational projections.

$$wsa\_KPI\_nrg\_elec\_eff\ [kWh] = \frac{wsa\_KPI\_nrg\_elec\_eff}{wsa\_pmp\_exff \cdot wsa\_nrg\_pump}$$ **Equation 144**

With:

wsa_KPI_nrg_elec_eff [%]	Electromechanical efficiency of existing pump
wsa_pmp_exff [%]	Expected electromechanical efficiency of new pump
wsa_nrg_pump [kWh]	Energy consumed from the grid (pumping)

Estimated electricity savings – Water Abstraction

Estimated electricity savings *wsa_KPI_nrg_estm_sav*

Estimated electricity savings related to a new pump. It can be used for operational projections.

$$wsa\_KPI\_nrg\_estm\_sav\ [kWh] = wsa\_nrg\_cons - wsa\_KPI\_nrg\_cons\_new$$ **Equation 145**

With:

wsa_nrg_cons [kWh]	Electric energy consumption from the grid, for the water abstraction unit, by the utility, during the entire assessment period
wsa_KPI_nrg_cons_new [kWh]	Energy consumption with expected new pump efficiency

Water Supply – Treatment

Energy consumption per treated water – Water Treatment

Energy consumption per treated water *wst_KPI_nrg_per_m3*

Unit energy consumption per treated water in water treatment plants. It is used to evaluate the energy efficiency of a water treatment system. See Table 26 for its benchmarking values and sources.

$$wst\_KPI\_nrg\_per\_m3\ [kWh/m^3] = \frac{wst\_nrg\_cons}{wst\_vol\_trea}$$ **Equation 146**

With:

wst_nrg_cons [kWh]	Energy consumed during the assessment period by each urban water treatment plant managed by the utility
wst_vol_trea [m³]	Sum of the volume of water treated by WTPs that are the responsibility of the water utility, during the assessment period

Capacity utilization – Water Treatment

Capacity utilization *wst_KPI_capac_util*

Percentage of treatment capacity utilized. It is a physical operational indicator for the water treatment facility, since use very close to maximum capacity may indicate the need to expand the facility. On the other hand, it can also be used for energy efficiency evaluation, since the energy consumption will be less optimized if the use of the plant is very small in relation to its design. See **Table 26** for its benchmarking values and sources.

$$wst\_KPI\_capac\_util\ [\%] = \frac{100 \cdot wst\_vol\_trea}{wst\_trea\_cap}$$ **Equation 147**

With:

wst_vol_trea [m³]	Sum of the volume of water treated by WTPs that are the responsibility of the water utility, during the assessment period
wst_trea_cap [m³]	The treatment capacity of each WTP or on site system facility that are the responsibility of the wastewater utility, during the assessment period

Percent of quality tests in compliance – Water Treatment

Percent of quality tests in compliance *wst_KPI_tst_carr*

Percent of quality tests in compliance with the applicable standards or legislation during assessment period. It is used for operational control.

$$wst\_KPI\_tst\_carr\ [\%] = wst\_tst\_carr$$ **Equation 148**

With:

wst_tst_carr [%]	Percent of quality tests in compliance

Standardized Energy Consumption – Water Treatment

Standardized Energy Consumption *wst_KPI_std_nrg_cons*

It is the average amount of energy consumed per m³ at a pump head of 100 m. Since it is a standardized energy efficiency indicator it can be used for comparisons between utilities and facilities.

$$wst\_KPI\_std\_nrg\_cons\ [kWh/m^3/100m] = \frac{wst\_nrg\_pump}{(wst\_vol\_pump \cdot wst\_pmp\_head)/100}$$ **Equation 149**

With:

wst_nrg_pump [kWh]	Energy consumed from the grid (pumping)
wst_vol_pump [m³]	Volume pumped
wst_pmp_head [m]	Pump head

Unit head loss – Water Treatment

Unit head loss *wst_KPI_un_head_loss*

Represents fluid energy per unit of pipe measurement. It can be used as an additional component to assess the energy efficiency of an installation. It can be used for operational control or projections.

$$wst\_KPI\_un\_head\_loss\ \ [m/km] = \frac{1e3 \cdot (wst\_pmp\_head - wst\_sta\_head)}{wst\_coll\_len}$$ **Equation 150**

With:

wst_pmp_head [m]	Pump head
wst_sta_head [m]	Static head
wst_coll_len [m]	Collector length

Calculated water power – Water Treatment

Calculated water power *wst_pmp_pw*

It is used to calculate the electromechanical efficiency of an existing pump.

$$wst\_pmp\_pw\ [kW] = \frac{wst\_pmp\_flow \cdot wst\_pmp\_head \cdot ct\_gravit}{1000} \quad \textbf{Equation 151}$$

With:

wst_pmp_flow [m³/s]	Measured pump flow
wst_pmp_head [m]	Pump head
ct_gravit [kg/(s².m²)]	9.810

Electromechanical efficiency of existing pump – Water Treatment

Electromechanical efficiency of existing pump *wst_KPI_nrg_elec_eff*

Estimate for pump and motor efficiency evaluation.

$$wst\_KPI\_nrg\_elec\_eff\ [\%] = \frac{100 \cdot wst\_pmp\_pw}{(wst\_pmp\_volt \cdot wst\_pmp\_amps \cdot \sqrt{3} \cdot \frac{wst\_pmp\_pf}{1000})} \quad \textbf{Equation 152}$$

With:

wst_pmp_pw [kW]	Calculated water power
wst_pmp_volt [V]	Measured pump voltage
wst_pmp_amps [A]	Measured pump current
wst_pmp_pf [ratio]	Power factor
Source	https://www.theaemt.com/technical-info/general-engineering/engineering-formulae

Standardized energy consumption of new pump – Water Treatment

Standardized energy consumption of new pump *wst_KPI_std_nrg_newp*

It is the average amount of energy consumed per m³ at a pump head of 100 m. Since it is a standardized energy efficiency indicator it can be used for comparisons between utilities and facilities.

$$wst\_KPI\_std\_nrg\_newp\ \ [kWh/m^3/100m] = \frac{wst\_KPI\_nrg\_elec\_eff}{wst\_pmp\_exff \cdot wst\_KPI\_std\_nrg\_cons} \quad \textbf{Equation 153}$$

With:

wst_KPI_nrg_elec_eff [%]	Electromechanical efficiency of existing pump
wst_pmp_exff [%]	Expected electromechanical efficiency of new pump
wst_KPI_std_nrg_cons [kWh/m³/100m]	Standardized energy consumption

Energy consumption with expected new pump efficiency – Water Treatment

Energy consumption with expected new pump efficiency *wst_KPI_nrg_cons_new*

Energy consumption with expected new pump efficiency. It can be used for operational projections.

$$wst\_KPI\_nrg\_cons\_new\ [kWh] = \frac{wst\_vol\_pump \cdot wst\_KPI\_std\_nrg\_newp}{100 \cdot wst\_pmp\_head} \quad \textbf{Equation 154}$$

With:

wst_vol_pump [m³]	Volume pumped

wst_KPI_std_nrg_newp [kWh/m^3/100m]	Standardized energy consumption of new pump
wst_pmp_head [m]	Pump head

Estimated electricity savings

Estimated electricity savings *wst_KPI_nrg_estm_sav*

Estimated electricity savings. It can be used for operational projections.

$$wst\_KPI\_nrg\_estm\_sav\ [kWh] = wst\_nrg\_cons - wst\_KPI\_nrg\_cons\_new$$ **Equation 155**

With:

wst_nrg_cons [kWh]	Energy consumed during the assessment period by each urban water treatment plant managed by the utility
wst_KPI_nrg_cons_new [kWh]	Energy consumption with expected new pump efficiency

Estimated GHG reduction per assessment period – Water Treatment

Estimated GHG reduction per assessment period *wst_KPI_ghg_estm_red*

Estimated GHG reduction associated with equipment replacement. It can be used for operational projections.

$$wst\_KPI\_ghg\_estm\_red\ [kgCO2eq] = wst\_KPI\_nrg\_estm\_sav \cdot wst\_conv\_kwh$$ **Equation 156**

With:

wst_KPI_nrg_estm_sav [kWh]	Estimated electricity savings
wst_conv_kwh [kgCO^{2}eq/kWh]	Emission factor for grid electricity (indirect emissions)

Water Supply – Distribution

Energy consumption per volume injected to distribution – Water Distribution

Energy consumption per volume injected to distribution *wsd_KPI_nrg_per_vd*

Unit energy consumption per water injected to distribution. It can be used for operating cost projections. Caution should be exercised when using this indicator for comparisons, as it may vary according to the reality of each system. An example is the topographic conditions of the system, which may demand greater or lesser energy intensity. However, the evaluation of the individual history of this indicator for each system can provide information regarding years with better or worse energy performance.

$$wsd\_KPI\_nrg\_per\_vd\ [kWh/m^3] = \frac{wsd\_nrg\_cons}{wsd\_vol\_dist}$$ **Equation 157**

With:

wsd_nrg_cons [kWh]	Electric energy consumption from the grid for water distribution during the entire assessment period
wsd_vol_dist [m^3]	The water volume entering the distribution system from the water treatment or directly from abstraction during the assessment period

Estimated GHG reduction per assessment period – Water Distribution

Estimated GHG reduction per assessment period *wsd_KPI_ghg_estm_red*

Estimated GHG reduction associated with pump replacement. It can be used for operational projections.

$$wsd\_KPI\_ghg\_estm\_red\ [kgCO2eq] = wsd\_KPI\_nrg\_estm\_sav \cdot wsd\_conv\_kwh$$ **Equation 158**

With:

wsd_KPI_nrg_estm_sav [kWh]	Estimated electricity savings
wsd_conv_kwh [kgCO²eq/kWh]	Emission factor for grid electricity (indirect emissions)

Energy consumption with expected new pump efficiency – Water Distribution

Energy consumption with expected new pump efficiency *wsd_KPI_nrg_cons_new*

Energy consumption with expected new pump efficiency. It can be used for operational projections.

$$wsd\_KPI\_nrg\_cons\_new\ [kWh] = \frac{wsd\_KPI\_nrg\_elec\_eff}{wsd\_pmp\_exff \cdot wsd\_nrg\_pump}$$ **Equation 159**

With:

wsd_KPI_nrg_elec_eff [%]	Electromechanical efficiency of existing pump
wsd_pmp_exff [%]	Expected electromechanical efficiency of new pump
wsd_nrg_pump [kWh]	Energy consumed from the grid (pumping)

Global water distribution energy efficiency – Water Distribution

Global water distribution energy efficiency *wsd_KPI_nrg_efficien*

Integrate all system distribution inefficiencies (pumps, friction, leaks and others). Compliments, giving a more complete information.

$$wsd\_KPI\_nrg\_efficien\ [\%] = \frac{100 \cdot wsd\_nrg\_mini}{wsd\_nrg\_supp}$$ **Equation 160**

With:

wsd_nrg_mini [kWh]	This energy takes into account the node consumption elevation plus the minimum pressure required by the users
wsd_nrg_supp [kWh]	The energy provided to a system can be natural and shaft (pumping energy). With the provided expression the energy is precisely calculated

Electromechanical efficiency of existing pump – Water Distribution

Electromechanical efficiency of existing pump *wsd_KPI_nrg_elec_eff*

Estimate for pump and motor efficiency evaluation.

$$wsd\_KPI\_nrg\_elec\_eff\ [\%] = \frac{100 \cdot wsd\_pmp\_pw}{(wsd\_pmp\_volt \cdot wsd\_pmp\_amps \cdot \sqrt{3} \cdot \frac{wsd\_pmp\_pf}{1000})}$$ **Equation 161**

With:

wsd_pmp_pw [kW]	Calculated water power
wsd_pmp_volt [V]	Measured pump voltage
wsd_pmp_amps [A]	Measured pump current
wsd_pmp_pf [ratio]	Power factor

Estimated electricity savings – Water Distribution

Estimated electricity savings	*wsd_KPI_nrg_estm_sav*
Estimated electricity savings related to a new pump. It can be used for operational projections.	
$wsd\_KPI\_nrg\_estm\_sav\ [kWh] = wsd\_nrg\_cons - wsd\_KPI\_nrg\_cons\_new$	**Equation 162**
With:	
wsd_nrg_cons [kWh]	Electric energy consumption from the grid for water distribution during the entire assessment period
wsd_KPI_nrg_cons_new [kWh]	Energy consumption with expected new pump efficiency

Energy consumption per authorized consumption – Water Distribution

Energy consumption per authorized consumption	*wsd_KPI_nrg_per_m3*
Unit energy consumption per authorized consumption in water distribution.	
$wsd\_KPI\_nrg\_per\_m3\ [kWh/m^3] = \frac{wsd\_nrg\_cons}{wsd\_auth\_con}$	**Equation 163**
With:	
wsd_nrg_cons [kWh]	Electric energy consumption from the grid for water distribution during the entire assessment period
wsd_auth_con [m^3]	Sum of the volume of metered and/or non-metered water that, during the assessment period, is taken by registered customers, by the water supplier itself, or by others who are implicitly or explicitly authorised to do so by the water supplier, for residential, commercial, industrial or public purposes. It includes water exported

Percentage of topographic energy – Water Distribution

Percentage of topographic energy	*wsd_KPI_nrg_topgraph*
Percentage of energy provided to the system due to the terrain topography. It can be used for an eventual energy balance of the facility, where it will be considered how much energy the system already has without counting the pressure energy of pumps.	
$wsd\_KPI\_nrg\_topgraph\ [\%] = \frac{100 \cdot wsd\_nrg\_topo}{wsd\_nrg\_supp}$	**Equation 164**
With:	
wsd_nrg_topo [kWh]	This is the energy supplied to the system because its irregular topography
wsd_nrg_supp [kWh]	The energy provided to a system can be natural and shaft (pumping energy). With the provided expression the energy is precisely calculated

Standardized Energy Consumption – Water Distribution

Standardized Energy Consumption	*wsd_KPI_std_nrg_cons*
It is the average amount of energy consumed per m^3 at a pump head of 100 m. Since it is a standardized energy efficiency indicator it can be used for comparisons between utilities and facilities. See **Table 26** for its benchmarking values and sources.	
$wsd\_KPI\_std\_nrg\_cons\ [kWh/m^3/100m] = \frac{wsd\_nrg\_pump}{(wsd\_vol\_pump \cdot wsd\_pmp\_head)/100}$	**Equation 165**
With:	
wsd_nrg_pump [kWh]	Energy consumed from the grid (pumping)

wsd_vol_pump [m³]	Volume of water in the drinking water distribution system which requires pumping, for each distribution unit
wsd_pmp_head [m]	Pump head

Standardized energy consumption of new pump – Water Distribution

Standardized energy consumption of new pump *wsd_KPI_std_nrg_newp*

It is the average amount of energy consumed per m³ at a pump head of 100 m for a new pump. Since it is a standardized energy efficiency indicator it can be used for comparisons between utilities and facilities. In this case, it can also be used for comparison with the old pump.

$$wsd\_KPI\_std\_nrg\_newp\ [kWh/m^3/100m] = \frac{wsd\_KPI\_nrg\_elec\_eff}{wsd\_pmp\_exff \cdot wsd\_KPI\_std\_nrg\_cons}$$ **Equation 166**

With:

wsd_KPI_nrg_elec_eff [%]	Electromechanical efficiency of existing pump
wsd_pmp_exff [%]	Expected electromechanical efficiency of new pump
wsd_KPI_std_nrg_cons [kWh/m³/100m]	Standardized energy consumption

Unit head loss – Water Distribution

Unit head loss *wsd_KPI_un_head_loss*

Represents fluid energy per unit of pipe measurement. It can be used as an additional component to assess the energy efficiency of an installation. It can be used for operational control or projections. See **Table 26** for its benchmarking values and sources.

$$wsd\_KPI\_un\_head\_loss\ [m/km] = \frac{1000 \cdot (wsd\_pmp\_head - wsd\_sta\_head)}{wsd\_main\_len}$$ **Equation 167**

With:

wsd_pmp_head [m]	Pump head
wsd_sta_head [m]	Static head
wsd_main_len [m]	Total transmission and distribution mains length (service connections not included), for each water distribution unit at the reference date

Non revenue water per mains length – Water Distribution

Non revenue water per mains length *wsa_KPI_water_losses*

Total water losses (apparent and real), expressed in terms of annual volume lost per mains length. It is used to evaluate both service management (real and apparent losses) and energy efficiency, since physical water losses reflect on energy consumption. See Table 26 for its benchmarking values and sources.

$$wsd\_KPI\_water\_losses\ [m^3/km] = \frac{Math.\max\,(0.1000 \cdot (wsd\_vol\_dist - wsd\_auth\_con)}{wsd\_main\_len}$$ **Equation 168**

With:

wsd_vol_dist [m³]	The water volume entering the distribution system from the water treatment or directly from abstraction during the assessment period
wsd_auth_con [m³]	Sum of the volume of metered and/or non-metered water that, during the assessment period, is taken by registered customers, by the water supplier itself, or by others who are implicitly or explicitly authorised to do so by the water supplier, for residential, commercial, industrial or public purposes. It includes water exported

wsd_main_len [m]	Total transmission and distribution mains length (service connections not included), for each water distribution unit at the reference date

Continuity of supply – Water Distribution

Continuity of supply *wsd_SL_cont_sup*

Percentage of delivery points (one per service connection) that receive and are likely to receive adequate pressure. It is used for operational control.

$$wsd\_SL\_cont\_sup\ [\%] = \frac{100 \cdot wsd\_time\_pre}{24}$$ **Equation 169**

With:

wsd_time_pre [hours/day]	Amount of time of the year the system is pressurised

Non revenue water – Water Distribution

Non revenue water *wsd_SL_nr_water*

Non revenue water includes: water losses + unbilled authorized consumption. It is used to evaluate both service management (real and apparent losses) and energy efficiency, since physical water losses reflect on energy consumption. Attention: this indicator should be used with caution for comparisons between systems, as it can make utilities with high levels of consumption, or compact networks, look to be better performing than those with low levels of consumption or extensive networks.

$$wsd\_SL\_nr\_water\ [\%] = \frac{100 \cdot (wsd\_vol\_dist - wsd\_bill\_con)}{wsd\_vol\_dist}$$ **Equation 170**

With:

wsd_vol_dist [m^3]	The water volume entering the distribution system from the water treatment or directly from abstraction during the assessment period
wsd_bill_con [m^3]	Authorized consumption which are billed and generate revenue (also known as revenue water). It is equal to billed metered consumption plus Billed Unmetered Consumption

Percentage of supply pressure adequacy – Water Distribution

Percentage of supply pressure adequacy *wsd_SL_pres_ade*

Percentage of delivery points (one per service connection) that receive and are likely to receive adequate pressure. It is used for operational quality control.

$$wsd\_SL\_pres\_ade\ [\%] = \frac{100 \cdot wsd\_deli\_pts}{wsd\_ser\_cons}$$ **Equation 171**

With:

wsd_deli_pts [number]	Number of delivery points that receive and are likely to receive pressure equal to or above the guaranteed or declared target level at the peak demand hour (but not when demand is abnormal)
wsd_ser_cons [number]	Total number of service connections, at the reference date

Water losses – Water Distribution

Water losses *wsd_SL_water_loss*

Water losses include: unauthorized consumption + customer meter inaccuracies and data handling errors + leakage in transmission and distribution mains + storage leaks and overflows from water storage tanks + service connections leaks up to the meter. Attention: this indicator should be used with caution for comparisons between systems, as it can make utilities with high levels of consumption, or compact networks, look to be better performing than those with low levels of consumption or extensive networks.

$$wsd\_SL\_water\_loss\ [\%] = \frac{100 \cdot (wsd\_vol\_dist - wsd\_auth\_con)}{wsd\_vol\_dist}$$

Equation 172

With:

wsd_vol_dist [m³]	The water volume entering the distribution system from the water treatment or directly from abstraction during the assessment period
wsd_auth_con [m³]	Sum of the volume of metered and/or non-metered water that, during the assessment period, is taken by registered customers, by the water supplier itself, or by others who are implicitly or explicitly authorised to do so by the water supplier, for residential, commercial, industrial or public purposes. It includes water exported

Minimum required energy for the system to operate by users (theoretical) – Water Distribution

Minimum required energy for the system to operate by users (theoretical) *wsd_nrg_mini*

This energy takes into account the node consumption elevation plus the minimum pressure required by the users. It is used for an eventual energy balance to be performed by the utility. From this indicator, it is possible to assess whether the system is supplying energy in excess, when compared to the minimum necessary to serve the final consumer.

$$wsd\_nrg\_mini\ [kWh] = \frac{ct\_gravit \cdot wsd\_auth\_con \cdot (wsd\_min\_pres + wsd\_av\_no\_el - wsd\_lo\_no\_el)}{3600000}$$

Equation 173

With:

ct_gravit [kg/(s².m²)]	9.810
wsd_auth_con [m³]	Sum of the volume of metered and/or non-metered water that, during the assessment period, is taken by registered customers, by the water supplier itself, or by others who are implicitly or explicitly authorised to do so by the water supplier, for residential, commercial, industrial or public purposes. It includes water exported
wsd_min_pres [m]	According the standards, a minimum pressure must be provided to the consumers (20 - 30 m), for each water distribution unit
wsd_av_no_el [m asl]	The average elevation of the network. If necessary it could be calculated as sum of lowest and the highest node elevation of the network divided by two, for each water distribution unit
wsd_lo_no_el [m asl]	Is the elevation of the lowest node of the stage, for each water distribution unit

Natural energy provided (gravity energy from supply to distribution) – Water Distribution

Natural energy provided (gravity energy from supply to distribution) *wsd_nrg_natu*

Sum of natural energy provided for all the input reservoirs and tanks of the stage. Intermediate tanks are not considered. It can be used to carry out an eventual energy balance by the utility. It can be used in conjunction with the minimum energy to assess whether the system is providing excess pressure energy (from pumps).

$$wsd\_nrg\_natu\ [kWh] = \frac{ct\_gravit \cdot wsd\_vol\_dist \cdot (wsd\_wt\_el\_no - wsd\_lo\_no\_el)}{3600000}$$

Equation 174

With:

ct_gravit [kg/(s².m²)]	9.810
wsd_vol_dist [m³]	The water volume entering the distribution system from the water treatment or directly from abstraction during the assessment period
wsd_wt_el_no [m]	It is the elevation of the water table to calculate the natural energy provided to the system, for each water distribution unit

wsd_lo_no_el [m asl]	Is the elevation of the lowest node of the stage, for each water distribution unit

Total supplied energy to the network (natural plus shaft), real system – Water Distribution

Total supplied energy to the network (natural plus shaft), real system *wsd_nrg_supp*

The energy provided to a system can be natural and shaft (pumping energy). With the provided expression the energy is precisely calculated. It can be used to carry out an eventual energy balance by the utility. It can be used in conjunction with the minimum energy to assess whether the system is providing excess pressure energy (from pumps).

$$wsd\_nrg\_supp\ [kWh] = wsd\_nrg\_cons + wsd\_nrg\_natu$$

Equation 175

With:

wsd_nrg_cons [kWh]	Electric energy consumption from the grid for water distribution during the entire assessment period
wsd_nrg_natu [kWh]	Sum of natural energy provided for all the input reservoirs and tanks of the stage. Intermediate tanks are not considered

Topographic energy supplied to the system – Water Distribution

Topographic energy supplied to the system *wsd_nrg_topo*

This is the energy supplied to the system because its irregular topography. It can be used to carry out an eventual energy balance by the utility. It can be used in conjunction with the minimum energy to assess whether the system is providing excess pressure energy (from pumps).

$$wsd\_nrg\_topo\ [kWh] = \frac{ct\_gravit \cdot wsd\_vol\_dist \cdot (wsd\_hi\_no\_el - wsd\_av\_no\_el)}{3600000}$$

Equation 176

With:

ct_gravit [kg/(s².m²)]	9.810
wsd_vol_dist [m³]	The water volume entering the distribution system from the water treatment or directly from abstraction during the assessment period
wsd_hi_no_el [m asl]	Is the elevation of the highest node of the network, for each water distribution unit
wsd_av_no_el [m asl]	The average elevation of the network. If necessary it could be calculated as sum of lowest and the highest node elevation of the network divided by two, for each water distribution unit

Calculated water power – Water Distribution

Calculated water power *wsd_pmp_pw*

It is used to calculate the electromechanical efficiency of an existing pump.

$$wsd\_pmp\_pw\ [kW] = \frac{wsd\_pmp\_flow \cdot wsd\_pmp\_head \cdot ct\_gravit}{1000}$$

Equation 177

With:

wsd_pmp_flow [m³/s]	Measured pump flow
wsd_pmp_head [m]	Pump head
ct_gravit [kg/(s².m²)]	9.810

Sanitation – General

Serviced population – Sanitation

Serviced population	*ww_serv_pop*
Serviced population is referred to the number of inhabitants, within the area of service managed by the utility, which are connected to the sanitation system and are receiving the service. It can be used for operational control or projections.	

$$ww\_serv\_pop\ [people] = wwt\_serv\_pop + wwo\_onsi\_pop$$ **Equation 178**

With:

wwt_serv_pop [people]	Serviced population is referred to the number of inhabitants (or inhabitant equivalents), within the area of service managed by the utility, which are connected to a sewer system and which wastewater are receiving treatment in a WWTP
wwo_onsi_pop [people]	Serviced population refers to the number of inhabitants within the assessment area for faecal sludge management that has access to some sort of sanitation facility

Serviced population with wastewater treatment (%) – Sanitation

Serviced population with wastewater treatment (%)	*ww_SL_serv_pop*
Percentage of the resident population that are connected to the sewer systems and which wastewater is treated by the utility. Used to assess service coverage.	

$$ww\_SL\_serv\_pop\ [\%] = \frac{100 \cdot ww\_serv\_pop}{ww\_resi\_pop}$$ **Equation 179**

With:

ww_serv_pop [people]	Serviced population
ww_resi_pop [people]	Number of permanent residents within the area of service for wastewater services managed by the utility (whether they are connected or not), at the reference date

Energy consumed from the grid (Collection+Treatment+Onsite) – Sanitation

Energy consumed from the grid (Collection+Treatment+Onsite)	*ww_nrg_cons*
Total electric energy consumed from the grid related to wastewater management within the service area managed by the utility during the entire assessment period. It can be used for operational control or projections.	

$$ww\_nrg\_cons\ \ [kWh] = wwc\_nrg\_cons + wwt\_nrg\_cons + wwo\_nrg\_cons$$ **Equation 180**

With:

wwc_nrg_cons [kWh]	Energy consumed during the assessment period by each pumping station for conveying wastewater to treatment managed by the utility
wwt_nrg_cons [kWh]	Total energy consumed during the assessment period by all wastewater treatment plants managed by the utility
wwo_nrg_cons [kWh]	Energy consumed from the grid during the assessment period

Total GHG emissions avoided – Sanitation

Total GHG emissions avoided	*ww_GHG_avoided*
Total GHG emissions avoided in Sanitation stages. Note: these emissions are not subtracted from the total emissions	

$$ww\_GHG\_avoided\ [kgCO2eq] = wwt\_ghg\_avoided + wwo\_ghg\_avoided$$ **Equation 181**

With:

wwt_ghg_avoided [$kgCO_2eq$]	GHG emissions avoided in wastewater treatment
wwo_ghg_avoided [kgCO2eq]	GHG emissions avoided in onsite sanitation

Sanitation – Collection

Energy consumption per wastewater conveyed to treatment – Sanitation Collection

Energy consumption per wastewater conveyed to treatment *wwc_KPI_nrg_per_m3*

Amount of energy consumed to bring one m^3 of wastewater from the sources to the wastewater treatment plant. It is used to evaluate the energy efficiency of the system.

$$wwc\_KPI\_nrg\_per\_m3\ [kWh/m^3] = \frac{wwc\_nrg\_cons}{wwc\_vol\_coll\_tre}$$ **Equation 182**

With:

wwc_nrg_cons [kWh]	Energy consumed during the assessment period by each pumping station for conveying wastewater to treatment managed by the utility
wwc_vol_coll_tre [m^3]	Volume of collected wastewater conveyed to treatment

Standardized Energy Consumption – Sanitation Collection

Standardized Energy Consumption *wwc_KPI_std_nrg_cons*

It is the average amount of energy consumed per m^3 at a pump head of 100 m. Since it is a standardized energy efficiency indicator it can be used for comparisons between utilities and facilities. See Table 26 for its benchmarking values and sources.

$$wwc\_KPI\_std\_nrg\_cons\ [kWh/m^3/100m] = \frac{wwc\_nrg\_pump}{(wwc\_vol\_pump \cdot wwc\_pmp\_head)/100}$$ **Equation 183**

With:

wwc_nrg_pump [kWh]	Energy consumed from the grid (pumping)
wwc_vol_pump [m^3]	Volume of pumped wastewater
wwc_pmp_head [m]	Pump head

Unit head loss – Sanitation Collection

Unit head loss *wwc_KPI_un_head_loss*

Represents fluid energy per unit of pipe measurement. It can be used as an additional component to assess the energy efficiency of an installation. It can be used for operational control or projections.

$$wwc\_KPI\_un\_head\_loss\ [m/km] = \frac{1000 \cdot (wwc\_pmp\_head - wwc\_sta\_head)}{wwc\_coll\_len}$$ **Equation 184**

With:

wwc_pmp_head [m]	Pump head
wwc_sta_head [m]	Static head
wwc_coll_len [m]	Collector length

Electromechanical efficiency of existing pump – Sanitation Collection

Electromechanical efficiency of existing pump	*wwc_KPI_nrg_elec_eff*
Estimate for pump and motor efficiency evaluation.	

$$wwc\_KPI\_nrg\_elec\_eff\ [\%] = \frac{100 \cdot wwc\_pmp\_pw}{(wwc\_pmp\_volt \cdot wwc\_pmp\_amps \cdot \sqrt{3} \cdot \frac{wwc\_pmp\_pf}{1000})}$$ **Equation 185**

With:

wwc_pmp_pw [kW]	Calculated water power
wwc_pmp_volt [V]	Measured pump voltage
wwc_pmp_amps [A]	Measured pump current
wwc_pmp_pf [ratio]	Power factor

Standardized energy consumption of new pump – Sanitation Collection

Standardized energy consumption of new pump	*wwc_KPI_std_nrg_newp*
It is the average amount of energy consumed per m³ at a pump head of 100 m for a new pump. Since it is a standardized energy efficiency indicator it can be used for comparisons between utilities and facilities. In this case, it can also be used for comparison with the old pump.	

$$wwc\_KPI\_std\_nrg\_newp\ [kWh/m^3/100m] = \frac{wwc\_KPI\_nrg\_elec\_eff}{wwc\_pmp\_exff \cdot wwc\_KPI\_std\_nrg\_cons}$$ **Equation 186**

With:

wwc_KPI_nrg_elec_eff [%]	Electromechanical efficiency of existing pump
wwc_pmp_exff [%]	Expected electromechanical efficiency of new pump
wwc_KPI_std_nrg_cons [kWh/m³/100m]	Percentage of energy consumed in wastewater collection with regards to the total energy consumed from the grid and self produced in the water and wastewater systems

Energy consumption with expected new pump efficiency – Sanitation Collection

Energy consumption with expected new pump efficiency	*wwc_KPI_nrg_cons_new*
Energy consumption with expected new pump efficiency. It can be used for operational projections.	

$$wwc\_KPI\_nrg\_cons\_new\ [kWh] = \frac{wwc\_vol\_pump \cdot wwc\_KPI\_std\_nrg\_newp}{100 \cdot wwc\_pmp\_head}$$ **Equation 187**

With:

wwc_vol_pump [m³]	Volume of pumped wastewater
wwc_KPI_std_nrg_newp [kWh/m³/100m]	Standardized energy consumption of new pump
wwc_pmp_head [m]	Pump head

Estimated electricity savings – Sanitation Collection

Estimated electricity savings	*wwc_KPI_nrg_estm_sav*
Estimated electricity savings related to a new pump. It can be used for operational projections.	

$wwc\_KPI\_nrg\_estm\_sav\ [kWh] = wwc\_nrg\_cons - wwc\_KPI\_nrg\_cons\_new$	**Equation 188**
With:	
wwc_nrg_cons [kWh]	Energy consumed during the assessment period by each pumping station for conveying wastewater to treatment managed by the utility
wwc_KPI_nrg_cons_new [kWh]	Energy consumption with expected new pump efficiency

Estimated GHG reduction per assessment period – Sanitation Collection

Estimated GHG reduction per assessment period	*wwc_KPI_ghg_estm_red*
Estimated GHG reduction associated with equipment replacement. It can be used for operational projections.	
$wwc\_KPI\_ghg\_estm\_red\ [kgCO2eq] = wwc\_KPI\_nrg\_estm\_sav \cdot wwc\_conv\_kwh$	**Equation 189**
With:	
wwc_KPI_nrg_estm_sav [kWh]	Estimated electricity savings
wwc_conv_kwh [$kgCO_2eq/kWh$]	Emission factor for grid electricity (indirect emissions)

Sanitation – Treatment

BOD_5 mass removed – Sanitation Treatment

BOD_5 mass removed	*wwt_bod_rmvd*
This is calculated from the difference in BOD_5 mass from the influent with BOD_5 mass from the effluent over the assessment period. It is used to calculate energy efficiency indicators.	
$wwt\_bod\_rmvd\ [kg] = wwt\_bod\_infl - wwt\_bod\_effl$	**Equation 190**
With:	
wwt_bod_infl [kg]	BOD_5 load entering the WWTP during the assessment period. It can be estimated by multiplying the average BOD_5 concentration in the influent by the volume entering the plant. If this is done daily and summed over the duration of the assessment period, the value will be more accurate.
wwt_bod_effl [kg]	BOD_5 load at the effluent of the WWTP during the assessment period. It can be estimated by multiplying the average BOD_5 concentration in the effluent by the effluent volume of the plant. If this is done daily and summed over the duration of the assessment period, the value will be more accurate.

Energy consumption per treated wastewater – Sanitation Treatment

Energy consumption per treated wastewater	*wwt_KPI_nrg_per_m3*
Energy consumption per treated wastewater. It can be used for operating cost projections and energy efficiency assessment. Caution should be exercised when using this indicator for comparisons with other utilities, since it neglects differences in the quality of the treated effluent.	
$wwt\_KPI\_nrg\_per\_m3\ [kWh/m^3] = \frac{wwt\_nrg\_cons}{wwt\_vol\_trea}$	**Equation 191**
With:	
wwt_nrg_cons [kWh]	Total energy consumed during the assessment period by all wastewater treatment plants managed by the utility
wwt_vol_trea [m^3]	Volume of treated wastewater over the assessment period

Energy consumption per BOD_5 mass removed – Sanitation Treatment

Energy consumption per BOD_5 mass removed *wwt_KPI_nrg_per_kg*

Energy consumed in wastewater treatment per mass of BOD_5 removed. This is a classic indicator of energy efficiency in the sanitation sector, which can be used for comparisons between utilities and facilities as it is normalized by the amount of BOD removed. See Table 26 for its benchmarking values and sources.

$$wwt\_KPI\_nrg\_per\_kg\ [kWh/kgBOD] = \frac{wwt\_nrg\_cons}{wwt\_bod\_rmvd}$$ **Equation 192**

With:

wwt_nrg_cons [kWh] — Total energy consumed during the assessment period by all wastewater treatment plants managed by the utility

wwt_bod_rmvd [kg] — This is calculated from the difference in BOD_5 mass from the influent with BOD_5 mass from the effluent over the assessment period

Capacity utilization – Sanitation Treatment

Capacity utilization *wwt_KPI_capac_util*

Percentage of treatment capacity utilized. It is a physical operational indicator for the wastewater treatment facility, since use very close to maximum capacity may indicate the need to expand the facility. On the other hand, it can also be used for energy efficiency evaluation, since the energy consumption will be less optimized if the use of the plant is very small in relation to its design.

$$wwt\_KPI\_capac\_util\ [\%] = \frac{100 \cdot wwt\_vol\_trea}{wwt\_trea\_cap}$$ **Equation 193**

With:

wwt_vol_trea [m^3] — Volume of treated wastewater over the assessment period

wwt_trea_cap [m^3] — Treatment capacity of each WWTP that are the responsibility of the wastewater utility, during the assessment period

Percentage of quality compliance – Sanitation Treatment

Percentage of quality compliance *wwt_SL_qual_com*

Percentage of water quality tests carried out in wastewater treatment plants that comply with discharge consents. It is used for operational control.

$$wwt\_SL\_qual\_com\ [\%] = \frac{100 \cdot wwt\_tst\_cmpl}{wwt\_tst\_cond}$$ **Equation 194**

With:

wwt_tst_cmpl [number] — Number of tests in each wastewater treatment plant that comply with discharge consents during the assessment period

wwt_tst_cond [number] — Number of tests carried out in each treated wastewater treatment plant during the assessment period

Energy consumption for wastewater pumping to treatment – Sanitation Treatment

Energy consumption for wastewater pumping to treatment *wwt_KPI_nrg_per_pump*

Energy consumption for wastewater pumping to treatment. Caution should be exercised when using this indicator for comparisons, as it may vary according to the reality of each system. An example is the topographic conditions of the system, which may demand greater or lesser energy intensity. However, the evaluation of the individual history of this indicator for each system can provide information regarding years with better or worse energy performance.

$$wwt\_KPI\_nrg\_per\_pump\ [kWh/m^3] = \frac{wwt\_nrg\_pump}{wwt\_vol\_pump}$$ **Equation 195**

With:

wwt_nrg_pump [kWh]	Energy consumed from the grid (pumping)
wwt_vol_pump [m³]	Volume of pumped wastewater

Standardized Energy Consumption – Sanitation Treatment

Standardized Energy Consumption *wwt_KPI_std_nrg_cons*

It is the average amount of energy consumed per m³ at a pump head of 100 m. Since it is a standardized energy efficiency indicator it can be used for comparisons between utilities and facilities. See Table 26 for its benchmarking values and sources.

$$wwt\_KPI\_std\_nrg\_cons\ [kWh/m^3/100m] = \frac{wwt\_nrg\_pump}{(wwt\_vol\_pump \cdot wwt\_pmp\_head/100)}$$ **Equation 196**

With:

wwt_nrg_pump [kWh]	Energy consumed from the grid (pumping)
wwt_vol_pump [m³]	Volume of pumped wastewater
wwt_pmp_head [m]	Pump head

Unit head loss – Sanitation Treatment

Unit head loss *wwt_KPI_un_head_loss*

Represents fluid energy per unit of pipe measurement. It can be used as an additional component to assess the energy efficiency of an installation. It can be used for operational control or projections. See Table 26 for its benchmarking values and sources.

$$wwt\_KPI\_un\_head\_loss\ [m/km] = \frac{1000 \cdot (wwt\_pmp\_head - wwt\_sta\_head)}{wwt\_coll\_len}$$ **Equation 197**

With:

wwt_pmp_head [m]	Pump head
wwt_sta_head [m]	Static head
wwt_coll_len [m]	Collector length

Electromechanical efficiency of existing pump – Sanitation Treatment

Electromechanical efficiency of existing pump *wwt_KPI_nrg_elec_eff*

Estimate for pump and motor efficiency evaluation.

$$wwt\_KPI\_nrg\_elec\_eff\ [\%] = \frac{100 \cdot wwt\_pmp\_pw}{(wwt\_pmp\_volt \cdot wwt\_pmp\_amps \cdot \sqrt{3} \cdot \frac{wwt\_pmp\_pf}{1000})}$$ **Equation 198**

With:

wwt_pmp_pw [kW]	Calculated water power
wwt_pmp_volt [V]	Measured pump voltage
wwt_pmp_amps [A]	Measured pump current
wwt_pmp_pf [ratio]	Power factor

Standardized energy consumption of new pump – Sanitation Treatment

Standardized energy consumption of new pump *wwt_KPI_std_nrg_newp*

It is the average amount of energy consumed per m³ at a pump head of 100 m for a new pump. Since it is a standardized energy efficiency indicator it can be used for comparisons between utilities and facilities. In this case, it can also be used for comparison with the old pump.

$$wwt\_KPI\_std\_nrg\_newp\ [kWh/m^3/100m] = \frac{wwt\_KPI\_nrg\_elec\_eff}{wwt\_pmp\_exff \cdot wwt\_KPI\_std\_nrg\_cons}$$ **Equation 199**

With:

wwt_KPI_nrg_elec_eff [%]	Electromechanical efficiency of existing pump
wwt_pmp_exff [%]	Expected electromechanical efficiency of new pump
wwt_KPI_std_nrg_cons [kWh/m3/100m]	Standardized energy consumption

Energy consumption with expected new pump efficiency – Sanitation Treatment

Energy consumption with expected new pump efficiency *wwt_KPI_nrg_cons_new*

Energy consumption with expected new pump efficiency. It can be used for operational projections.

$$wwt\_KPI\_nrg\_cons\_new\ [kWh] = \frac{wwt\_vol\_pump \cdot wwt\_KPI\_std\_nrg\_newp}{100 \cdot wwt\_pmp\_head}$$ **Equation 200**

With:

wwt_vol_pump [m³]	Volume of pumped wastewater
wwt_KPI_std_nrg_newp [kWh/m3/100m]	Standardized energy consumption of new pump
wwt_pmp_head [m]	Pump head

Estimated electricity savings – Sanitation Treatment

Estimated electricity savings *wwt_KPI_nrg_estm_sav*

Estimated electricity savings. It can be used for operational projections.

$$wwt\_KPI\_nrg\_estm\_sav\ [kWh] = wwt\_nrg\_cons - wwt\_KPI\_nrg\_cons\_new$$ **Equation 201**

With:

wwt_nrg_cons [kWh]	Total energy consumed during the assessment period by all wastewater treatment plants managed by the utility
wwt_KPI_nrg_cons_new [kWh]	Energy consumption with expected new pump efficiency

Estimated GHG reduction per assessment period – Sanitation Treatment

Estimated GHG reduction per assessment period *wwt_KPI_ghg_estm_red*

Estimated GHG reduction associated with equipment replacement. It can be used for operational projections.

$$wwt\_KPI\_ghg\_estm\_red\ [kgCO2eq] = wwt\_KPI\_nrg\_estm\_sav \cdot wwt\_conv\_kwh$$ **Equation 202**

With:

wwt_KPI_nrg_estm_sav [kWh]	Estimated electricity savings
wwt_conv_kwh [$kgCO_2eq/kWh$]	Emission factor for grid electricity (indirect emissions)

Moles of biogas produced – Sanitation Treatment

Moles of biogas produced *wwt_moles_biogas_produced*

Moles of biogas produced. Biogas composition is assumed to be CH_4 and CO_2. If n and m are the number of moles of each gas, then n+m = moles of biogas produced. It is used to calculate biogas GHG emission. It can also be used for operational control.

$$wwt\_moles\_biogas\_produced\ [moles] = \frac{P \cdot V}{R \cdot T}$$ **Equation 203**

With:

P [Pa]	1.013e5
V	wwt_biog_pro (Biogas produced during the assessment period by the wastewater treatment plant managed by the utility)
R [J/K.mol]/	8.31446261815324
T [°C]	273.15

Usage of the biogas produced – Sanitation Treatment

Usage of the biogas produced *wwt_biogas_usage*

Usage of the biogas produced. It has to add up to 100%, showing “unsatisfactory” if it´s not 100%.

$$wwt\_biogas\_usage\ [\%] = wwt\_biog\_fla + wwt\_biog\_val + wwt\_biog\_lkd + wwt\_biog\_sold$$ **Equation 204**

With:

wwt_biog_fla [%]	Biogas flared (% volume)
wwt_biog_val [%]	Biogas valorised in the treatment plant to heat the digesters or the building and/or to run a co-generator to generate heat and electricity
wwt_biog_lkd [%]	Biogas leaked to the atmosphere (% volume)
wwt_biog_sold [%]	Biogas sold (% volume)

Total energy content of biogas valorised (theoretical maximum) – Sanitation Treatment

Total energy content of biogas valorised (theoretical maximum) *wwt_nrg_biog_val*

Sum of energy content of biogas used in a cogenerator or a boiler during the assessment period by all wastewater treatment plants managed by the utility.

$$wwt\_nrg\_biog\_val\ [kWh] = \frac{wwt\_biog\_pro \cdot wwt\_biog\_val \cdot wwt\_ch4\_biog \cdot ct\_ch4\_nrg}{10000}$$ **Equation 205**

With:

wwt_biog_pro [Nm^3]	Biogas produced during the assessment period by the wastewater treatment plant managed by the utility

wwt_biog_val [%]	Biogas valorised in the treatment plant to heat the digesters or the building and/or to run a Co-generator to generate heat and electricity
wwt_ch4_biog [%]	Percent of the methane content in the produced biogas
ct_ch4_nrg [kWh/Nm³]	11

Energy production per treated wastewater – Sanitation Treatment

Energy production per treated wastewater *wwt_KPI_nrg_biogas*

Energy production from biogas valorization per volume of treated wastewater. See **Table 26** for its benchmarking values and sources.

$$wwt\_KPI\_nrg\_biogas\ [kWh/m^3] = \frac{wwt\_nrg\_biog}{wwt\_vol\_trea}$$ **Equation 206**

With:

wwt_nrg_biog [kWh]	Energy produced from biogas valorization during the assessment period by each wastewater treatment plant managed by the utility
wwt_vol_trea [m³]	Volume of treated wastewater over the assessment period

Electrical energy produced per total available energy in biogas – Sanitation Treatment

Electrical energy produced per total available energy in biogas *wwt_KPI_nrg_x_biog*

Unit biogas produced per BOD_5 mass removed in wastewater treatment plants. See **Table 26** for its benchmarking values and sources.

$$wwt\_KPI\_nrg\_x\_biog\ [\%] = \frac{100 \cdot wwt\_nrg\_biog}{wwt\_nrg\_biog\_val}$$ **Equation 207**

With:

wwt_nrg_biog [kWh]	Energy produced from biogas valorization during the assessment period by each wastewater treatment plant managed by the utility
wwt_nrg_biog_val [kWh]	Sum of energy content of biogas used in a cogenerator or a boiler during the assessment period by all wastewater treatment plants managed by the utility

Sludge production (total weight) – Sanitation Treatment

Sludge production (total weight) *wwt_KPI_sludg_prod*

Sludge production per treated wastewater. It is used for operation control. See Table 26 for its benchmarking values and sources.

$$wwt\_KPI\_sludg\_prod\ [kg/m^3] = \frac{wwt\_mass\_slu}{wwt\_vol\_trea}$$ **Equation 208**

With:

wwt_mass_slu [kg]	Amount of raw sludge removed from wastewater treatment as dry mass during the assessment period
wwt_vol_trea [m³]	Volume of treated wastewater over the assessment period

Total volume discharged and reused effluent – Sanitation Treatment

Total volume discharged and reused effluent *wwt_total_m3*

Total volume of effluent generated by WWTP, considering both discharged and reused. Can be used for operational control.

$wwt\_total\_m3\ [m^3] = wwt\_vol\_disc + wwt\_vol\_nonp$	**Equation 209**
With:	
wwt_vol_disc [m^3]	Volume of wastewater discharged by each wastewater treatment plant that are the responsibility of the utility, during the assessment period. This includes all the wastewater collected, whether it is conveyed to treatment or discharged untreated
wwt_vol_nonp [m^3]	Volume of reused effluent

GHG emissions avoided in wastewater treatment – Sanitation Treatment

GHG emissions avoided in wastewater treatment	*wwt_ghg_avoided*
GHG emissions avoided from the following mitigation measures: biogas valorization; nutrient reuse; water reuse; carbon sequestration in sludge management.	

$$wwt\_ghg\_avoided\ [kgCO2eq] = wwt\_ghg\_avoided\_biogas + wwt\_ghg\_avoided\_reuse\_nutrient + wwt\_ghg\_avoided\_reuse\_water + wwt\_ghg\_avoided\_sequestration$$

Equation 210

With:

wwt_ghg_avoided_biogas [$kgCO_2eq$]	GHG emissions avoided due to biogas valorization
wwt_ghg_avoided_reuse_nutrient [$kgCO_2eq$]	GHG emissions avoided due to nutrient reused displacing synthetic fertilizer
wwt_ghg_avoided_reuse_water [$kgCO_2eq$]	GHG emissions avoided due to water reuse eliminating discharge to receiving waters
wwt_ghg_avoided_sequestration [$kgCO_2eq$]	GHG emissions avoided due to carbon sequestration in sludge management

Sanitation – Onsite Sanitation

GHG emissions avoided in onsite sanitation – Onsite Sanitation

GHG emissions avoided in onsite sanitation	*wwo_ghg_avoided*
GHG emissions avoided from the following mitigation measures: biogas valorization; carbon sequestration of land application; carbon sequestration of landfilling; nutrients reuse.	

$$wwo\_ghg\_avoided\ [kgCO2eq] = wwo\_ghg\_avoided\_biogas + wwo\_ghg\_avoided\_landapp + wwo\_ghg\_avoided\_landfil + wwo\_ghg\_avoided\_reuse$$

Equation 211

With:

wwo_ghg_avoided_biogas [$kgCO_2eq$]	GHG emissions avoided due to biogas valorization
wwo_ghg_avoided_landapp [$kgCO_2eq$]	GHG emissions avoided from carbon sequestration of land application
wwo_ghg_avoided_landfil [$kgCO_2eq$]	GHG emissions avoided from carbon sequestration of landfilling
wwo_ghg_avoided_reuse [$kgCO_2eq$]	Amount of CO_2eq emissions avoided due to nutrients reused displacing synthetic fertilizer

Calculated water power – Onsite Sanitation

Calculated water power	*wwo_pmp_pw*
It is used to calculate the electromechanical efficiency of an existing pump.	

$$wwo\_pmp\_pw\ [kW] = \frac{wwo\_pmp\_flow \cdot wwo\_pmp\_head \cdot ct\_gravit}{1000}$$ **Equation 212**

With:

wwo_pmp_flow [m³/s]	Measured pump flow
wwo_pmp_head [m]	Pump head
ct_gravit [kg/(s².m²)]	9.810

Standardized Energy Consumption – Onsite Sanitation

Standardized Energy Consumption	*wwo_KPI_std_nrg_cons*
It is the average amount of energy consumed per m^3 at a pump head of 100 m. Since it is a standardized energy efficiency indicator it can be used for comparisons between utilities and facilities.	

$$wwo\_KPI\_std\_nrg\_cons\ [kWh/m^3/100m] = \frac{wwo\_nrg\_pump}{(wwo\_vol\_pump \cdot wwo\_pmp\_head/100)}$$ **Equation 213**

With:

wwo_nrg_pump [kWh]	Energy consumed from the grid (pumping)
wwo_vol_pump [m³]	Volume of pumped wastewater
wwo_pmp_head [m]	Pump head

Unit head loss – Onsite Sanitation

Unit head loss	*wwo_KPI_un_head_loss*
Represents fluid energy per unit of pipe measurement. It can be used as an additional component to assess the energy efficiency of an installation. It can be used for operational control or projections.	

$$wwo\_KPI\_un\_head\_loss\ [m/km] = \frac{1e3 \cdot (wwo\_pmp\_head - wwo\_sta\_head)}{wwo\_coll\_len}$$ **Equation 214**

With:

wwo_pmp_head [m]	Pump head
wwo_sta_head [m]	Static head
wwo_coll_len [m]	Collector length

Electromechanical efficiency of existing pump – Onsite Sanitation

Electromechanical efficiency of existing pump	*wwo_KPI_nrg_elec_eff*
Estimate for pump and motor efficiency evaluation.	

$$wwo\_KPI\_nrg\_elec\_eff\ [\%] = \frac{100 \cdot wwo\_pmp\_pw}{(wwo\_pmp\_volt \cdot wwo\_pmp\_amps \cdot \sqrt{3} \cdot \frac{wwo\_pmp\_pf}{1000})}$$ **Equation 215**

With:

wwo_pmp_pw [kW]	Calculated water power
wwo_pmp_volt [V]	Measured pump voltage

wwo_pmp_amps [A]	Measured pump current
wwo_pmp_pf [ratio]	Power factor

Estimated GHG reduction per assessment period – Onsite Sanitation

Estimated GHG reduction per assessment period *wwp_KPI_ghg_estm_red*

Estimated GHG reduction associated with equipment replacement. It can be used for operational projections.

$$wwo\_KPI\_ghg\_estm\_red\ [kgCO2eq] = wwo\_KPI\_nrg\_estm\_sav \cdot wwo\_conv\_kwh$$ **Equation 216**

With:

wwo_KPI_nrg_estm_sav [kWh]	Estimated electricity savings
wwo_conv_kwh [$kgCO_2eq/kWh$]	Emission factor for grid electricity (indirect emissions)

Standardized energy consumption of new pump – Onsite Sanitation

Standardized energy consumption of new pump *wwo_KPI_std_nrg_newp*

It is the average amount of energy consumed per m^3 at a pump head of 100 m. Since it is a standardized energy efficiency indicator it can be used for comparisons between utilities and facilities.

$$wwo\_KPI\_std\_nrg\_newp\ [kWh/m^3/100m] = \frac{wwo\_KPI\_nrg\_elec\_eff}{wwo\_pmp\_exff \cdot wwo\_KPI\_std\_nrg\_cons}$$ **Equation 217**

With:

wwo_KPI_nrg_elec_eff [%]	Electromechanical efficiency of existing pump
wwo_pmp_exff [%]	Expected electromechanical efficiency of new pump
wwo_KPI_std_nrg_cons [$kWh/m^3/100m$]	Standardized energy consumption

Energy consumption with expected new pump efficiency – Onsite Sanitation

Energy consumption with expected new pump efficiency *wwo_KPI_nrg_cons_new*

Energy consumption with expected new pump efficiency. It can be used for operational projections.

$$wwo\_KPI\_nrg\_cons\_new\ [kWh] = \frac{wwo\_KPI\_nrg\_elec\_eff}{wwo\_pmp\_exff \cdot wwo\_nrg\_pump}$$ **Equation 218**

With:

wwo_KPI_nrg_elec_eff [%]	Electromechanical efficiency of existing pump
wwo_pmp_exff [%]	Expected electromechanical efficiency of new pump
wwo_nrg_pump [kWh]	Energy consumed from the grid (pumping)

Estimated electricity savings – Onsite Sanitation

Estimated electricity savings *wwo_KPI_nrg_estm_sav*

Estimated electricity savings. It can be used for operational projections.

$wwo\_KPI\_nrg\_estm\_sav\ [kWh] = wwo\_nrg\_cons - wwo\_KPI\_nrg\_cons\_new$	**Equation 219**
With:	
wwo_nrg_cons [kWh]	Energy consumed from the grid during the assessment period
wwo_KPI_nrg_cons_new [kWh]	Energy consumption with expected new pump efficiency

Moles of biogas produced – Onsite Sanitation

Moles of biogas produced	*wwo_moles_biogas_produced*
Moles of biogas produced. Biogas composition is assumed to be CH_4 and CO_2. If n and m are the number of moles of each gas, then n+m = moles of biogas produced. It is used to calculate biogas GHG emission. It can also be used for operational control.	
$wwt\_moles\_biogas\_produced\ [moles] = \frac{P \cdot V}{R \cdot T}$	**Equation 220**
With:	
P [Pa]	1.013e5
V	wwt_biog_pro (Biogas produced during the assessment period by the wastewater treatment plant managed by the utility)
R [J/K.mol]	8.31446261815324
T [°C]	273.15

Usage of the biogas produced – Onsite Sanitation

Usage of the biogas produced	*wwo_biogas_usage*
Usage of the biogas produced. It has to add up to 100%, showing “unsatisfactory” if it´s not 100%.	
$wwt\_biogas\_usage\ [\%] = wwt\_biog\_fla + wwt\_biog\_val + wwt\_biog\_lkd + wwt\_biog\_sold$	**Equation 221**
With:	
wwt_biog_fla [%]	Biogas flared (% volume)
wwt_biog_val [%]	Biogas valorised in the treatment plant to heat the digesters or the building and/or to run a Co-generator to generate heat and electricity
wwt_biog_lkd [%]	Biogas leaked to the atmosphere (% volume)
wwt_biog_sold [%]	Biogas sold (% volume)

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Annex 1 – Data tables

Table 8 - Fuel properties

Fuel	EF CH_4 (kg/TJ)		EF N_20 (kg/TJ)		EF CO_2 (kg/TJ)	FD (kg/L)	NCV (TJ/Gg)
	Engines	Vehicles	Engines	Vehicles			
Diesel	3	3.9	0.6	3.9	74100	0.84	43
Gasoline/Petrol	3	3.8	0.6	1.9	69300	0.74	44.3
Natural Gas	10	92	0.1	0.2	56100	0.75	48

Sources

IPCC (2006b, p. 2.16)
https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf

IPCC (2006b, p. 3.21)
https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf

World Resources Institute (2017)
https://ghgprotocol.org/sites/default/files/Emission_Factors_from_Cross_Sector_Tools_March_2017.xlsx

Table 9 - Pump size

Pump size
5.6 – 15.7 kW
15.7 – 38 kW
39 – 96 kW
> 96 kW

Table 10 - Potabilization chain

Potabilization chain
None
Pre-ox/C/F/S/Filt/Des
Pre-ox/C/F/Filt/Des
C/F/S/Filt/Des
C/F/Filt/Des
Des
Other

Table 11 - CH_4 emission factor for type of effluent discharge

Type of discharge[29]	ch4_efac (kg CH_4/kg BOD)
Discharge undefined	0
Discharge to aquatic environments (Tier 1)	0.068
Discharge to aquatic environments other than reservoirs, lakes, and estuaries (Tier 2)	0.021
Discharge to reservoirs, lakes, and estuaries (Tier 2)	0.114
Stagnant sewer or anaerobic water body	0.3
Flowing sewer (open or closed)	0
Soil infiltration	0
No discharge, inflow to further treatment process (substage)	0

Source — **IPCC (2019b, p. 6.20)**
https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Table 12 - CH_4 emission factor for type of Sewer

Type of sewer	ch4_efac (kg CH4/kg BOD)
Type of sewer undefined	0
Stagnant sewer or anaerobic water body	0.3
Flowing sewer (open or closed)	0

[29] About the concept of "Tier", access the topic "Tier (Level of Information)".

Type of sewer	ch4_efac (kg CH4/kg BOD)
Discharge to reservoirs, lakes, and estuaries (Tier 2)	0.114
Sources	**IPCC (2019b, 6.20)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf **IPCC (2013, p. 6.14)** https://www.ipcc-nggip.iges.or.jp/public/wetlands/pdf/Wetlands_Supplement_Entire_Report.pdf

Table 13 - CH_4 emission factor for type of Treatment

Type of treatment	ch4_efac (kg CH4/kg BOD)
Type of treatment undefined	0
Centralised, aerobic, treatment plant	0.018
Anaerobic eactor – CH_4recovery not considered	0.48
Anaerobic reactor – CH_4 recovery considered	0.14
Anaerobic shallow lagoon and facultative lagoons (<2m depth)	0.12
Anaerobic deep lagoon (>2m depth)	0.48
Anaerobic lagoon covered	0
Wetlands – surface flow	0.24
Wetlands – horizontal subsurface flow	0.06
Wetlands – vertical subsurface flow	0.006
Aerated lagoon	0.06
Trickling filter	0.036
Sources	**IPCC (2019b, p. 6.20)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf **IPCC (2013, p. 6.14)** https://www.ipcc-nggip.iges.or.jp/public/wetlands/pdf/Wetlands_Supplement_Entire_Report.pdf

Table 14 – CH_4 emission factor and BOD removed as sludge for type of onsite treatment

Type of treatment	ch4_efac (kg CH4/kg BOD)	bod_rmvd_as_sludge_estm (%)
Type of treatment undefined	0	0
Anaerobic digester	0.48	0.1
Imhoff tanks	0.48	0.1
Anaerobic reactors – CH_4 recovery not considered	0.48	0.1
Anaerobic reactors – CH_4 recovery considered	0.14	0.1
Stabilization ponds (<2m depth)	0.12	0.3
Stabilization ponds (>2m depth)	0.48	0.1
Sludge drying beds	0	0
Wetlands – surface flow	0.24	0.3
Wetlands – horizontal subsurface flow	0.06	0.65
Wetlands – bertical subsurface flow	0.006	0.65
Composting	0.0013	0
Trickling filter	0.036	0.65
Sources	CH_4 emission factors: **IPCC (2019b, p. 6.20, 6.27f.)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf **(IPCC 2013, p. 6.14)** https://www.ipcc-nggip.iges.or.jp/public/wetlands/pdf/Wetlands_Supplement_Entire_Report.pdf	

Table 15 - N_2O emission factor for type of treatment

Type of treatment	**n2o_efac (kg N2O-N/N)**
Type of treatment undefined	0
Centralised, aerobic, treatment plant	0.016
Anaerobic reactor	0
Anaerobic lagoons	0
Septic tank	0
Septic tank + land dispersal field	0.0045
Latrine	0
Sources	**IPCC (2019b, p. 6.39)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Table 16 - N_2O emission factor for type of effluent discharge

Type of discharge[30]	**n2o_efac (kg N2O-N/N)**
Discharge undefined	0
Freshwater, estuarine, and marine discharge (Tier 1)	0.005
Nutrient-impacted and/or hypoxic freshwater, estuarine, and marine discharge (Tier 3)	0.019
No discharge, inflow to further treatment process (substage)	0
Source	**IPCC (2019b, p. 6.39)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

[30] About the concept of "Tier", access the topic “Tier (Level of Information)”.

Table 17 - Removal of organic component from wastewater as sludge (KREM) according to treatment type

Type of treatment	K_rem (kg BOD/kg dry mass sludge)
Mechanical treatment plants (primary sedimentation sludge)	0.5
Aerobic treatment plants with primary treatment (mixed primary and secondary sludge, untreated or treated aerobically)	0.8
Aerobic treatment plants with primary treatment and anaerobic sludge digestion (mixed primary and secondary sludge, treated anaerobically)	1
Aerobic wastewater treatment plants without separate primary treatment	1.16
Source	**IPCC (2019b, p. 6.27)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Table 18 - Wastewater treatment organics resulting fractions after removal (centralized)

Type of treatment	bod_effl (%)	N_effl (%)
Untreated systems	100	100
Primary (mechanical treatment plants)	60	90
Primary + secondary (biological treatment plants)	15	60
Primary + secondary + tertiary (advanced biological treatment plants)	10	20
Source	**IPCC (2019b, p. 6.28, 6.43)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf	

Table 19 - Wastewater treatment organics resulting fractions after removal (onsite[31])

Type of treatment	N_effl (%)
Untreated systems	100
Septic tank/septic system	85
Septic tank/septic system + land dispersal field	32
Latrines – dry climate, groundwater table lower than latrine, small family (2-5 persons)	88
Latrines – dry climate, groundwater table lower than latrine, communal (many users)	88
Latrines – wet climate/flush water use, groundwater table higher than latrine	88
Source	**IPCC (2019b, p. 6.43)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

Table 20 - Sludge removed from the liquid phase, according to the treatment type

Type of treatment	gSS_inh_day (gSS/inhab.day)
Type of treatment undefined	0
Primary treatment (conventional)	40
Primary treatment (septic tanks)	25
Facultative pond	22.5
Anaerobic pond – facultative pond (anaerobic pond)	32.5
Anaerobic pond – facultative pond (facultative pond)	8
Anaerobic pond – facultative pond (total)	40.5
Facultative aerated lagoon	10.5
Complete-mix aerat. lagoon – sedim, pond	12
Septic tank + anaerobic filter (septic tank)	25
Septic tank + anaerobic filter (anaerobic filter)	8
Septic tank + anaerobic filter (total)	33
Conventional activated sludge (primary sludge)	40
Conventional activated sludge (secondary sludge)	30
Conventional activated sludge (mixed sludge)	70
Activated sludge extended aeration	42.5
High rate trickling filter (primary sludge)	40
High rate trickling filter (secondary sludge)	25
High rate trickling filter (mixed sludge)	65
Submerged aerated biofilter (primary sludge)	40
Submerged aerated biofilter (secondary sludge)	30
Submerged aerated biofilter (mixed sludge)	70
UASB reactor	15
UASB reactor + activated sludge (anaerobic sludge (UASB))	15
UASB reactor + activated sludge (aerobic sludge (activated sludge))	11
UASB reactor + activated sludge (mixed sludge)	26
UASB reactor + aerobic biofilm reactor (anaerobic sludge (UASB))	15
UASB reactor + aerobic biofilm reactor (aerobic sludge (aerobic reactor))	9
UASB reactor + aerobic biofilm reactor (mixed sludge)	24
Source	**Andreoli et al. (2007), Table 2.2 (page 21)**

[31] The adopted BOD fractions are the same as Table 18.

Table 21 - Type of sludge disposed

Type of sludge disposed	f_ch4 (%)	N_cont (% of dry weight)	TVS (% of dry weight)
	0	0	0
Non-digested	53	3	70
Digested	6	4	51
Sources	**N content based on expert judgment, assuming a density of 1100 mg/L and considering total nitrogen from Odey et al. (2017):** https://link.springer.com/article/10.1007/s11356-017-0151-7 **TSV data from CCME (2009a, p. 148):** https://climatesmartwater.org/wp-content/uploads/sites/2/2018/03/The-Biosolids-Emissions-Assessment-Model-BEAM.pdf		

Table 22 - Type of faecal sludge

Type of faecal sludge	N_content (%)	TVS (%)	total_solids (%)
Untreated faecal sludge	0.24	70	0.04
Treated faecal sludge	3	40	0.22
Pit humus	4	65	0.07
Dehydrated faeces	3	70	0.27
Compost	3	80	0.08
Septic tank sludge	0.03	60	0.02
Sources	N content : Untreated faecal sludge data calculated based on: **Radford and Sugden (2014), assuming a density of untreated sludge= 1243kg/m³ (from Bösch and Schertenleib (1985))** TVS and TS data from: **Metcalf and Eddy (1991) and Seck et al. (2014)** Compost data from: **Yadav (2012)** Septic tank data from: **Klingel et al. (2002)**		

Table 23 - Type of landfill

Type of landfill	
Type of landfill	**Methane Correction Factor (MCF)**
Landfill	1
Landfill (with gas recovery)	0.02
Landfill (flaring)	0
Sources	Landfill data **IPCC (2019b, p. 3.1 – 3.25)** https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_3_Ch03_SWDS.pdf Gas recovery data from: **Krause et al. (2016) and Zhao (2019)**

Table 24 - Soil type

Type of soil	f_la
Soil type undefined	0
Fine-textured (>30% clay)	0.023
Coarse-textured (<305 clay)	0.005
Source — **CCME (2009a, p. 168f.)** https://climatesmartwater.org/wp-content/uploads/sites/2/2018/03/The-Biosolids-Emissions-Assessment-Model-BEAM.pdf	

Table 25 - Type of containment

Type of containment	ch4_efac (kg CH4/kg BOD)	ch4_efac_flooding (kg CH4/kg BOD)	BOD_conc_FS [kg/m³]	fs_density
Containment undefined	0	0	0	0
No containment (open defecation)	0.027	0.027	67.8	1400
Pit latrine without flush water (lined or unlined) + household	0.06	0.42	67.8	1400
Pit latrine without flush water (lined or unlined) + communal	0.3	0.42	67.8	1400
Pit latrine without flush water use (lined or unlined)	0.42	0.42	67.8	1400
Septic tank (with or without dispersal field)	0.3	0.42	1.35	1100
Fully lined tank without flush water use – not water tight	0.3	0.42	67.8	1400
Fully lined tank without flush water use – water tight	0.42	0.42	67.8	1400
Fully lined tank with flush water use – water tight or untight[3]	0.42	0.42	67.8	1400
Urine diverting dry toilet (UDDT)	0	0.42	67.8	1400
Composting toilet	0.0013	0.42	67.8	1400
Imhoff tank	0.48	0.42	67.8	1400
Sources	Most of the EF are based on **IPCC (2019b, p. 20)**, assuming similarities in conditions for pit latrines, septic tanks, and UDDT. https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf Open defecation data based on: **Winrock (2008)** BOD concentration in Faecal Sludge data is based on experiences of GIZ in Lusaka. OD loads and faecal sludge density, were calculated as average values from different studies and methodologies, including sampling of onsite sanitation systems in Lusaka, Zambia. Mainly from: **Strande et al. (2014), Wasaza (2017) and Leverenz et al (2010)**			

Annex 2 – Benchmark table

Table 26 – Benchmarks values and sources

Energy Benchmarking Parameter (Reference)	Units	Code	Values
Water Abstraction			
Standardized Energy Consumption **Sources** Compilation of the following authors: • **Cabrera, et al., 2014** • **Loureiro et al., 2020** • **Reference values from the Portuguese Water and Waste Services Regulation Authority (ERSAR)** https://www.ersar.pt/pt/site-publicacoes/Paginas/edicoes-anuais-do-RASARP.aspx	kWh/m³/100m	wsa_KPI_std_nrg_cons	Standardized energy consumption • *Submersible pumps:* ○ ***5.6 - 15.7 kW*** *SEC >= 0.7877: "Unsatisfactory"* *0.7877 > SEC > 0.5013: "Acceptable"* *SEC <= 0.5013: "Good"* ○ ***15.7 - 38 kW*** *SEC >= 0.5866: "Unsatisfactory"* *0.5866 > SEC > 0.4447: "Acceptable"* *SEC <= 0.4447: "Good"* ○ ***39 - 96 kW*** *SEC >= 0.4837: "Unsatisfactory"* *0.4837 > SEC > 0.4115: "Acceptable"* *SEC <= 0.4115: "Good"* ○ ***> 96 kW*** *SEC >= 0.4673: "Unsatisfactory"* *0.4673 > SEC > 0.4054: "Acceptable"* *SEC <= 0.4054 : "Good* • *External pumps:* ○ ***5.6 - 15.7 kW*** *SEC >= 0.5302: "Unsatisfactory"* *0.5302 > SEC > 0.3322: "Acceptable"* *SEC <= 0.3322: "Good"*

			○ ***15.7 - 38 kW*** *SEC >= 0.4923: "Unsatisfactory"* *0.4923 > SEC > 0.3169: "Acceptable"* *SEC <= 0.3169: "Good"* ○ ***39 - 96 kW*** *SEC >= 0.4595: "Unsatisfactory"* *0.4595 > SEC > 0.3080: "Acceptable"* *SEC <= 0.3080: "Good"* ○ ***> 96 kW*** *SEC >= 0.4308: "Unsatisfactory"* *0.4308 > SEC > 0.3080: "Acceptable"* *SEC <= 0.3080: "Good"*
Unit head loss **Sources** Compilation of the following authors: • **Alegre, et al., 2006** • **Loureiro et al., 2020** • **Reference values from the Portuguese Water and Waste Services Regulation Authority (ERSAR)** https://www.ersar.pt/pt/site-publicacoes/Paginas/edicoes-anuais-do-RASARP.aspx	m/km	wsa_KPI_un_head_loss	*Good: UHL ≤ 2* *Acceptable: 2 < UHL ≤ 4* *Unsatisfactory: UHL > 4*
Water treatment			
Energy Consumption Per Treated Water **Sources** Compilation of the following authors: • **Alegre, et al., 2006** • **Loureiro et al., 2020** • **Reference values from the Portuguese Water and Waste Services Regulation Authority (ERSAR)** https://www.ersar.pt/pt/site-publicacoes/Paginas/edicoes-anuais-do-RASARP.aspx	kWh/m^3	wst_KPI_nrg_per_m3	○ ***WTP > 5000 m^3/d*** *Good: ECT ≤ 0.025* *Acceptable: 0.025 < ECT ≤ 0.04* *Unsatisfactory: ECT > 0.04* ○ ***WTP <= 5000 m^3/d*** *Good: ECT ≤ 0.04* *Acceptable: 0.04 < ECT ≤ 0.055* *Unsatisfactory: ECT > 0.055*

			○ ***WTP with Pre-ox > 5000 m^3/d*** *Good: ECT ≤ 0.055* *Acceptable: 0.055 < ECT ≤ 0.07* *Unsatisfactory: ECT > 0.07* ○ ***WTP with Pre-ox <= 5000 m^3/d*** *Good: ECT ≤ 0.07* *Acceptable: 0.07 < ECT ≤ 0.085* *Unsatisfactory: ECT > 0.085* ○ ***WTP (with raw and treated water pumping)*** *Good: ECT ≤ 0.4* *Acceptable: 0.4 < ECT ≤ 0.5* *Unsatisfactory: ECT > 0.5*
Capacity utilization **Sources** Compilation of the following authors: • **Alegre, et al., 2006** • **Loureiro et al., 2020** • **Reference values from the Portuguese Water and Waste Services Regulation Authority (ERSAR)** https://www.ersar.pt/pt/site-publicacoes/Paginas/edicoes-anuais-do-RASARP.aspx	%	wst_KPI_capac_util	*Good: 90 ≤ tE4 ≤ 70* *Acceptable: 100 ≤ tE4 < 90 and 70 < tE4 ≤ 50* *Unsatisfactory: tE4 > 100 and tE4 < 50*
Water distribution			
Standardized Energy Consumption **Sources** Compilation of the following authors: • **Cabrera, et al., 2014** • **Loureiro et al., 2020** • **Reference values from the Portuguese Water and Waste Services Regulation Authority (ERSAR)** https://www.ersar.pt/pt/site-publicacoes/Paginas/edicoes-anuais-do-RASARP.aspx	$kWh/m^3/100m$	wsd_KPI_std_nrg_cons	*Good: 0.2725 ≤ SEC ≤ 0.40* *Acceptable: 0.40 < SEC ≤ 0.54* *Unsatisfactory: SEC > 0.54*

Unit head loss **Sources** Compilation of the following authors: • **Alegre, et al., 2006** • **Loureiro et al., 2020** • **Reference values from the Portuguese Water and Waste Services Regulation Authority (ERSAR)** https://www.ersar.pt/pt/site-publicacoes/Paginas/edicoes-anuais-do-RASARP.aspx	m/km	wsd_KPI_un_head_loss	*Good: UHL ≤ 2* *Acceptable: 2 < UHL ≤ 4* *Unsatisfactory: UHL > 4*
Non-revenue water per mains length **Sources** Compilation of the following authors: • **Alegre, et al., 2006** • **Loureiro et al., 2020** • **Reference values from the Portuguese Water and Waste Services Regulation Authority (ERSAR)** https://www.ersar.pt/pt/site-publicacoes/Paginas/edicoes-anuais-do-RASARP.aspx	m^3/km	wsd_KPI_water_losses	*Good: NRM ≤ 6* *Acceptable: 6 < NRM ≤ 12* *Unsatisfactory: NRM > 12*
Wastewater collection			
Standardized Energy Consumption **Sources** Compilation of the following authors: • **Cabrera, et al., 2014** • **Loureiro et al., 2020** • **Reference values from the Portuguese Water and Waste Services Regulation Authority (ERSAR)** https://www.ersar.pt/pt/site-publicacoes/Paginas/edicoes-anuais-do-RASARP.aspx	kWh/m^3/100m	wwc_KPI_std_nrg_cons	*Good: 0.2725 ≤ SEC ≤ 0.45* *Acceptable: 0.45 < SEC ≤ 0.68* *Unsatisfactory: SEC > 0.68*

Wastewater treatment			
Energy Consumption Per BOD removed **Sources** Compilation of the following authors: • **Silva and Rosa, 2014** • **Loureiro et al., 2020** • **Reference values from the Portuguese Water and Waste Services Regulation Authority (ERSAR)** https://www.ersar.pt/pt/site-publicacoes/Paginas/edicoes-anuais-do-RASARP.aspx	kWh/kg BOD removed	wwt_KPI_nrg_per_kg	*Good: ECMR ≤ 2* *Acceptable: 2 < ECMR ≤ 10* *Unsatisfactory: ECMR > 10*
Energy production per treated wastewater **Sources** Compilation of the following authors: • **Alegre, et al., 2006** • **Silva and Rosa, 2014** • **Loureiro et al., 2020** • **Reference values from the Portuguese Water and Waste Services Regulation Authority (ERSAR)** https://www.ersar.pt/pt/site-publicacoes/Paginas/edicoes-anuais-do-RASARP.aspx	kWh/m^3	wwt_KPI_nrg_biogas	*Good: EPMR ≥ 0.0009* BOD_5 *Acceptable: 0.0009* BOD_5 *> EPMR ≥ 0.0007* BOD_5 *Unsatisfactory: EPMR < 0.0007* BOD_5 *note:* BOD_5 *= influent BOD (mg/L)*
Electrical energy produced per total available energy in biogas **Sources** Compilation of the following authors: • **Silva and Rosa, 2014** • **Loureiro et al., 2020** • **Reference values from the Portuguese Water and Waste Services Regulation Authority (ERSAR)** https://www.ersar.pt/pt/site-publicacoes/Paginas/edicoes-anuais-do-RASARP.aspx	%	wwt_KPI_nrg_x_biog	*EEEB <15%= Unsatisfactory* *15 to 25% = acceptable* *EEEB >25%= good*
Capacity utilization	%	wwt_KPI_capac_util	*Good: 95 ≤ CUWT ≤ 70* *Acceptable:100 ≤ CUWT < 95 and 70 < CUWT ≤ 50*

Sources Compilation of the following authors: • **Alegre, et al., 2006** • **Loureiro et al., 2020** • **Reference values from the Portuguese Water and Waste Services Regulation Authority (ERSAR)** https://www.ersar.pt/pt/site-publicacoes/Paginas/edicoes-anuais-do-RASARP.aspx			*Unsatisfactory: CUWT > 100 and CUWT < 50*
Sludge production (total weight) **Sources** Compilation of the following authors: • **Silva and Rosa, 2014** • **Loureiro et al., 2020** • **Reference values from the Portuguese Water and Waste Services Regulation Authority (ERSAR)** https://www.ersar.pt/pt/site-publicacoes/Paginas/edicoes-anuais-do-RASARP.aspx	kg/m^3	wwt_KPI_sludg_prod	*Good: SP ≤ 0.8* *Acceptable: 0.8 < SP ≤ 1.5* *Unsatisfactory: SP > 1.5*

This project is part of the International Climate Initiative (IKI):
www.international-climate-initiative.com/en

INTERNATIONAL CLIMATE INITIATIVE

On behalf of:

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for the Environment, Nature Conservation,
Nuclear Safety and Consumer Protection

of the Federal Republic of Germany

Implemented by:

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Zusammenarbeit (GIZ) GmbH

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