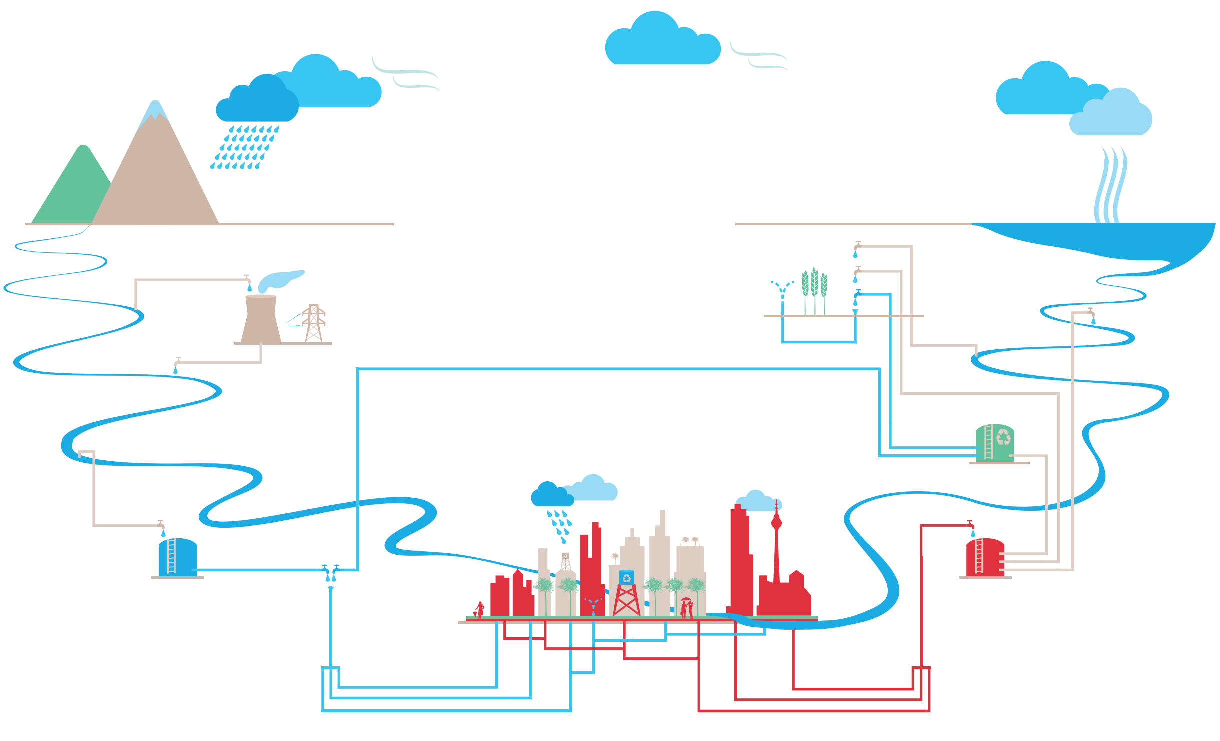
Water and Wastewater Companies for Climate Mitigation

WaCCliM

Introduction to ECAM 2.2

Assessing Energy Performance and Carbon Emissions within the Water Sector



Abbreviations

BOD	Biological Oxygen Demand
CH_4	Methane
CO_2	Carbon Dioxide
CO_2 eq	CO_2 equivalent
COD	Chemical Oxygen Demand
COP	Conference of Parties
EE	Energy Efficiency
GHG	Greenhouse Gas
KPI	Key Performance Indicator
MRV	Monitoring, Reporting and Verification
N_2O	Nitrous Oxide
NAMA	Nationally Appropriate Mitigation Action
NDC	Nationally Determined Contribution
UNFCCC	United Nations Framework Convention on Climate Change
WWU	Water and Wastewater Utility

Content

ECAM Exercises

What is the ECAM-Training about?

The ECAM-Training is a dynamic, interactive training concept. Its overall objective is to provide support that will enable water professionals to assess and monitor energy performance and carbon emissions within the water sector and receive an overview of the potentials and opportunities to reduce greenhouse gases (GHGs).

Specific learning objectives of the training are:

- Understand the overall global climate change context and GHG emission sources within the urban water cycle.
- Apply web-based ECAM tool to assess and monitor baseline GHG emissions and identify opportunities for reduction.
- Understand and be able to explain to others the purpose and approach of the ECAM tool.

Who should get involved?

The primary target group for **ECAM-Trainings** is the staff of water and wastewater utilities and other professionals working in the water sector.

This may include:

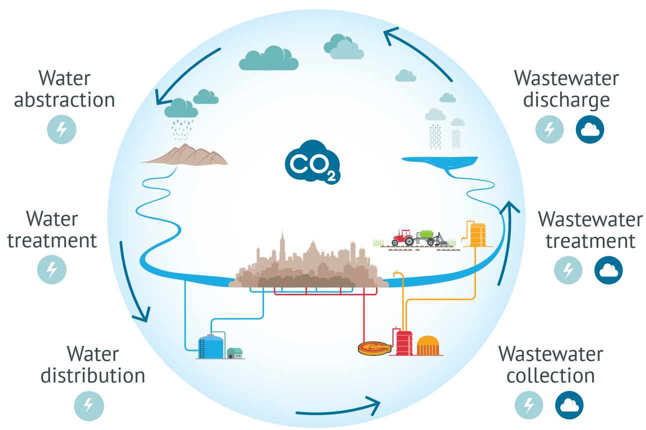
In addition, decision-makers and staff from international institutions as well as other governmental or non-governmental entities interested in climate mitigation, could also receive the training.

- **Technical utility staff and managers**
- **Regulators and prospective local decision-makers**
- **University researchers, practitioners (and future trainers)**

Greenhouse Gas Reductions in the Water Sector

The Energy Performance and Carbon Emissions Assessment and Monitoring Tool (ECAM) enables utilities to quantify their Greenhouse Gas emissions and contributions to Nationally Determined Contributions and offers solutions for reducing emissions from energy use and wastewater management.

Limiting climate change to 1.5 °C requires substantial reductions in GHG emissions in all sectors. The urban water sector has under-recognized opportunities to reduce carbon emissions, mitigate climate change and contribute to the successful implementation of the Paris Agreement by accounting for the Nationally Determined Contributions (NDCs) of supporting countries. Global demand for water will increase by 55 % by 2050, while water availability will decrease by 40 %. While the water sector has to cope with the impacts of climate change, it also contributes 3 – 5 % of global CO_2 (emissions) from energy consumption as well as methane and nitrous oxide emissions from wastewater. If appropriate measures are not implemented in the sector, emissions could increase by at least 50 % by 2050.

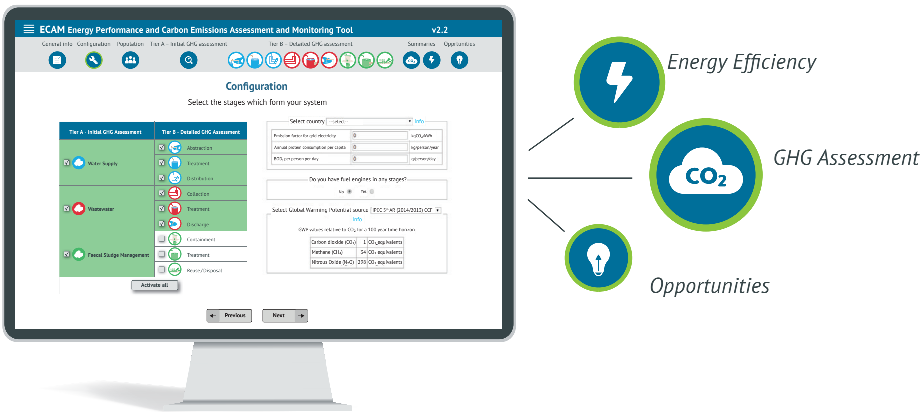


The Urban Water Cycle

Energy Performance & Carbon Emissions Assessment & Monitoring Tool

ECAM 2.2

Energy Performance & Carbon Emissions Assessment & Monitoring Tool



What ECAM offers water and wastewater utilities:

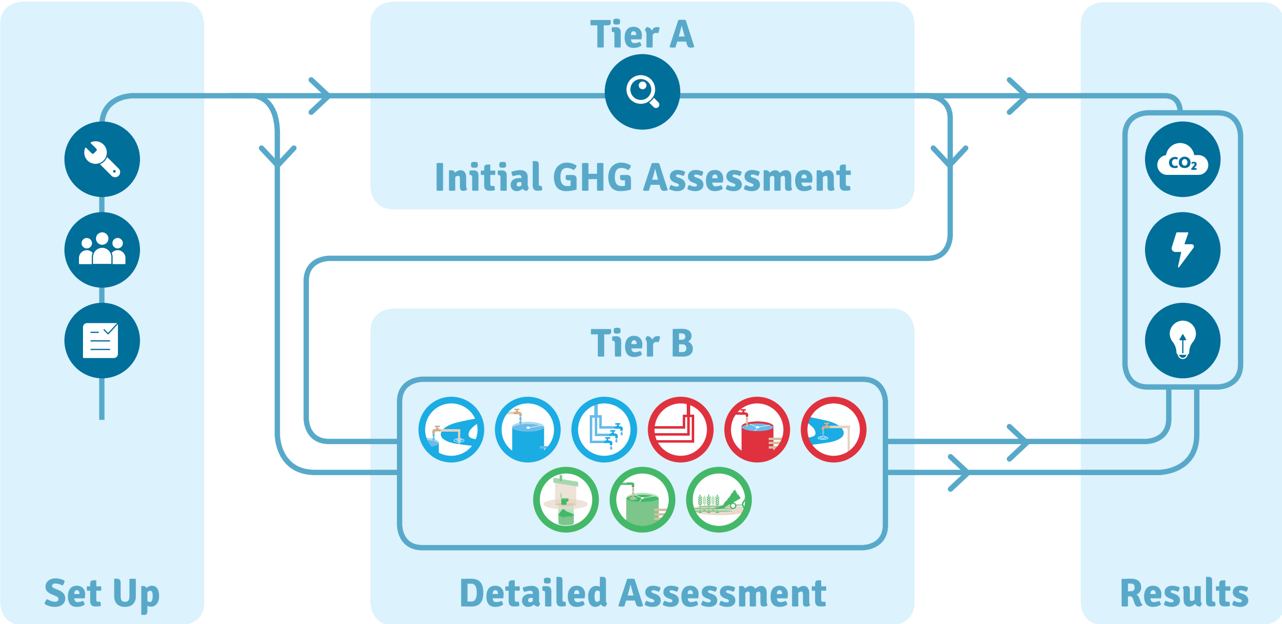
- ECAM is a tool for GHG reduction.
- ECAM is a tool to assess carbon footprint, energy consumption and service levels.
- ECAM is a tool to reduce operational costs.
- ECAM is a tool to strengthen performance monitoring and decision making.

What ECAM offers the water sector:

- ECAM is a tool for monitoring, reporting and verifying the water sector's GHG reduction contribution to the NDCs.
- ECAM only requires data typically available in utilities of developing and emerging economies.
- ECAM facilitates national benchmarking and knowledge exchange between utilities.

Overview of ECAM Elements

ECAM follows a tiered approach with an increasing level of detail from Tier A to Tier B. Tier A can be used with limited data inputs for an initial assessment, whereas Tier B can be applied with detailed data for each stage of the urban water cycle for a more accurate assessment.



Description of ECAM Elements

General Information

Enter the **assessment period, file name, currency** and if desired, make comments. The specified assessment period will affect the results that are stated per annum.

Configuration

Activate the elements of the urban water cycle that are going to be assessed. Selecting a **country** will set standard literature values for the **grid emission factor, annual protein consumption** and **BOD_5 loads** per person. Different global warming potentials for **CH_4** and **N_2O** can be selected by chosing the respective IPCC assessment report. Activating the option for **fuel engines** will add corresponding input fields in Tier A and Tier B.

Population

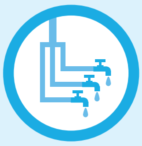
Set the numbers for **resident population** and **serviced population**; for the wastewater system, the **connected population to the sewerage** and the **population with on-site treatment**. Estimations of wastewater loadings and corresponding emissions are based on specified populations.

Set Up

Initial Assessment

Use the Initial GHG Assessment (Tier A) when available data or time is limited. Tier A provides an overview of GHG emissions and energy consumption, using readily known data and accesible to utility managers and operators, and provides complementary basic assumptions.

Tier A



Abstraction

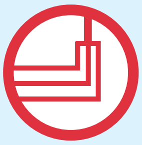
Insert the **energy consumed** and, if available, the **volume of abstracted water**. Assessments of pump efficiency, energy production and GHG reduction potential with new pumps are optional.

Treatment

Specify the **energy consumed** and, if available, the **volume of treated water**. Pump efficiency evaluation is optional.

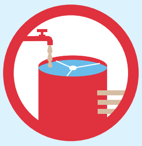
Distribution

Insert the **energy consumed** and, if available, the **volumes of water injected to the distribution system**, the **authorized consumption** and **billed metered consumption**. By providing a value for the different volumes of water, the fraction of water losses and non-revenue-water are calculated. Assessments of service performance, topographic energy, pump efficiency and new pumps are optional.



Collection

Enter the **energy consumed** and **volume of wastewater conveyed**. If desired, the predefined country-specific values for **BOD_5 loads** and annual **protein consumption** per person can be modified. Water efficiency, pumping efficiency and new pumps assessment is optional.



Treatment

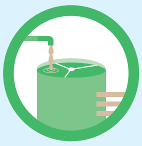
Enter the **volume of treated wastewater, energy consumed**, the **treatment technology** and **BOD_5 influent** and **effluent loads**. If desired the estimated value for **BOD_5** removed as sludge can be adapted. Assessment of treatment performance, pump efficiency, biogas production and valorization and sludge management is optional.

Discharge / Reuse

Specify the **volume of discharged wastewater, energy consumed, total nitrogen in the effluent** and, if applicable, **volume of reused water** and the corresponding transport. Pumping efficiency assessment is optional.

Containment

Set the values for the **influent BOD load**, the **emission factor** depending on the system type as well as the **density of the faecal sludge**. It is assumed that the trucks extracting the sludge consume either diesel, petrol or gas for transportation.



Treatment

Modify the values for the **consumed energy**, the **methane emission factor** depending on the treatment technology as well as the **BOD load**. Again, you can specify the type of the fuel and the amount of it being consumed by trucks.

Reuse/Desposal

Besides possible modifications of the **energy consumption** and the **fuel type for transportation**, you may clarify in which way the treated sludge is going to be reused or disposed of into the environment. For that, you can set the **type of faecal sludge** which is disposed of. Since urine could have an enormous effect on the growth of crops, you can also modify the amount of nitrogen contained in urine.

Tier B

Greenhouse Gas Summary

See the **total emissions** and how they are distributed across the water and wastewater system and the different stages. Understand what the sources of emissions are and what their relative contribution is with the graphs. Identify to what UNFCCC (United Nations Framework Convention on Climate Change) category the emissions are attributed.

Energy Summary

View where and how much **energy** is **consumed across the stages**, water and wastewater system and in total. If substages are assessed, their relative energy consumption can be seen.

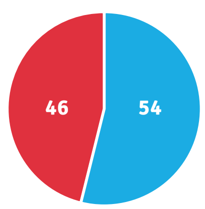
Opportunities

Get an overview of the **potentials** and **opportunities** to reduce GHGs. The potentials are based on the proceeding assessment.

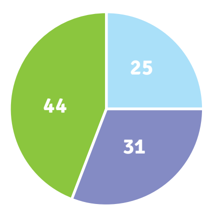
Tiered Approach for Increasing Accuracy

Tier A: Initial GHG Assessment

GHG emissions by water and wastewater system
total 9000 t CO_2eq (%)

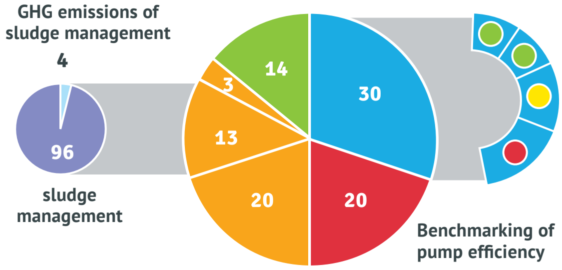


GHG emissions by source
total 9000 t CO_2eq (%)



Tier B: Detailed GHG Assessment

GHG emissions by stage and by substage
total 9000 t CO_2eq (%)



Tier A is an **Initial GHG Assessment** that helps utilities to understand their overall energy usage and total GHG emissions at system-wide level (potable water and wastewater). Tier A uses a number of assumptions that allows the user to reduce the amount of data inputs.

Tier B is a **Detailed GHG Assessment** looking at energy use and GHG emissions at the individual stage level of the urban water cycle (i.e. abstraction, drinking water treatment, distribution, collection, wastewater treatment, wastewater discharge), providing a more thorough assessment.

Main Assumptions in Tier A

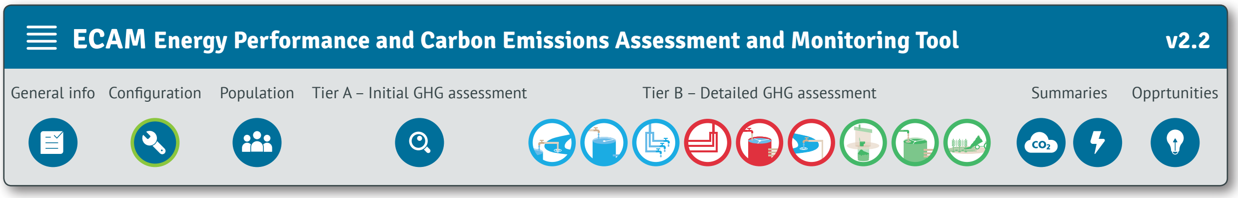
- Influent and effluent BOD_5 loads
- Mass of BOD_5 removed as sludge
- CH_4 emission factor of technology
- Mass of produced sludge
- Volume of produced biogas
- Volume of valorized biogas
- Dry weight of disposed sludge
- Temperature in fluidized bed reactor (only for sludge incineration)

Advanced Assessment in Tier B

Tier B allows the user to display additional input fields that can be optionally used for an advanced assessment. Depending on the stage, this advanced assessment includes pumping performance, the use of topographic energy, water efficiency, sludge management, treatment performance, biogas production and more.

In Tier B you will find pre-filled input fields with values based on the assumptions from Tier A. Values can be edited if more accurate data is available.

How to fill in Data?



ECAM Navigation Bar

Navigate through ECAM by clicking on the icons.

Setup and Configuration of Data

Initial GHG Assessment	Detailed GHG Assessment
☑ Water Supply	☑ Abstraction
	☑ Treatment
	☑ Distribution
☑ Wastewater	☑ Collection
	☑ Treatment
	☑ Discharge
☑ Faecal Sludge Management	☐ Containment
	☐ Treatment
	☐ Reuse/Disposal

Activate all

Advanced Assessment

Do you want to evaluate treatment performance?	No ◉	Yes ○
Do you want to evaluate pump efficiency?	No ○	Yes ◉
Are you producing biogas from anaerobic digestion?	No ○	Yes ◉
Are you valorizing biogas?	No ◉	Yes ○
Evaluate sludge management (SM)?	No ○	Yes ◉
SM Evaluate sludge storage in WWTP?	No ◉	Yes ○
SM Is sludge sent to composting?	No ◉	Yes ○
SM Is sludge sent to incinerate?	No ◉	Yes ○
SM Is sludge sent to land application?	No ○	Yes ◉
SM Is sludge sent to landfilling?	No ◉	Yes ○
SM Is sludge sent to stockpiling?	No ◉	Yes ○
SM Do you truck transport sludge to disposal site?	No ○	Yes ◉

Use the advanced assessment questions to display additional input fields.

Inputs - Enter values from your system

Water supply	185000 I 190000	
Energy consumed from the grid	15,000,000	kWh
Volume of water injected to distribution	9,000,000	m^3
Volume of authorized consumption	5,000,000	m^3
Volume of billed metered consumption	4,500,000	m^3
Running costs	7,000,000	USD
Energy costs	3,500,000	USD

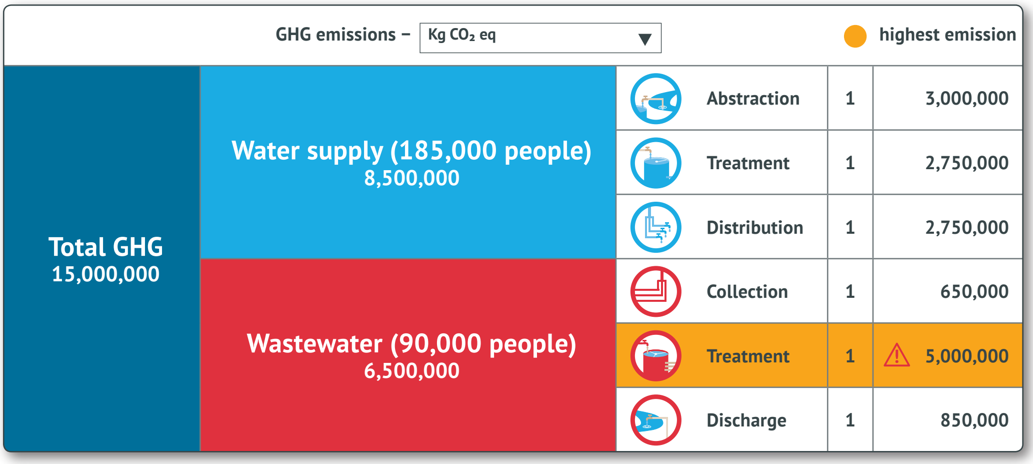
Water supply	90000 I 90000 I 190000	
Energy consumed from the grid	2,000,000	kWh
Volume of treated wastewater	2,000,000	m^3
Volume of discharged wastewater to water body	2,000,000	m^3
Running costs	0	USD
Energy costs	0	USD
Average Total Nitrogen at discharge	0	mg/L
Are you producing biogas?	No ◉	Yes ○
Are you valorizing biogas?	No ◉	Yes ○
Select main treatment type	Activated Sludge – Minor poorly areated zones ▼	
Select sludge disposal method	None ▼	

Find self explanatory input fields, tick boxes and drop down selections in Tier A and Tier B to fill in data.

Add substage

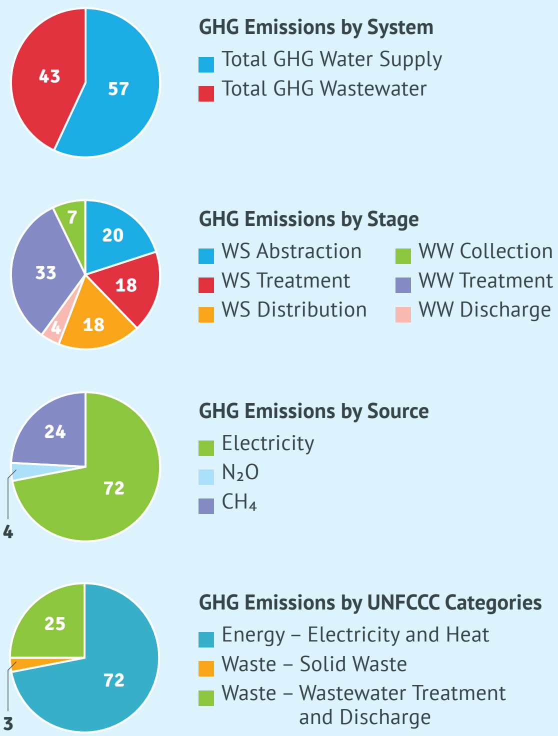
Add substages in order to seperately assess different pumping stations, treatment facilities, etc.

How are the Results presented?



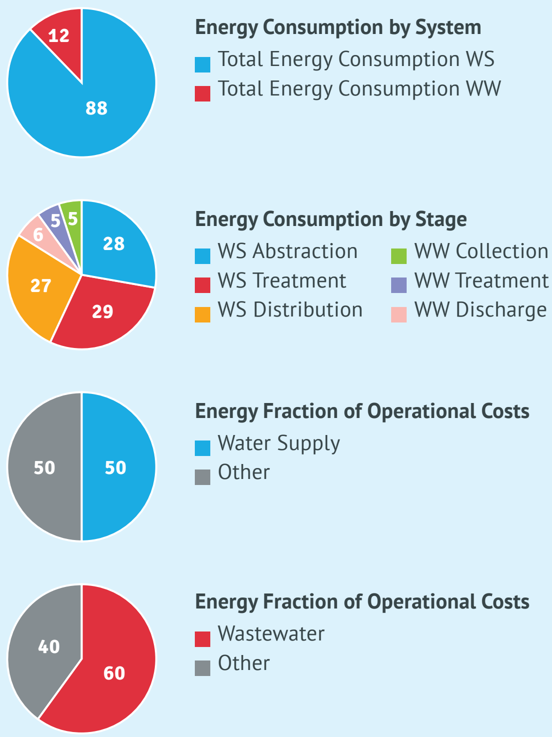
Greenhouse Gas Emissions

Sources of emissions and their distribution within the urban water cycle is shown graphically. The UNFCCC category to which the emissions are attributed is also displayed (in %).



Energy Consumption

Where and how much energy is consumed within the urban water cycle is displayed. The contribution of energy costs to total operational costs is indicated (in %).



Note that benchmarking results and performance indicators are shown within Tier B in the advanced assessment.

ECAM Exercises

1 Tier A – Initial GHG Assessment

Task I *Initial Data*

The utility New Watervision of the city Waterscarcity located in Waterland has decided to take actions to increase *operational efficiency, energy efficiency* and *GHG emissions reduction*. To get an understanding of its performance in the last calendar year, New Watervision asked you to conduct an assessment using the ECAM Tool.

Waterscarcity has 600,000 inhabitants: A portion of 500,000 inhabitants receive water supply services and are connected to the sewer system at the same time. However, only the wastewater of 400,000 people out of the whole population is conveyed to the treatment plant and treated consequently. 500 people have on-site sanitation. Waterland happens to have the same energy mix, food consumption patterns and wastewater characteristics as Mexico.

The **water supply system** has a total energy consumption of 17 GWh/year. Wells extract 25 Mio. m³/year of groundwater which are treated and distributed to customers. The total running costs of the water supply system are 10 Mio. EUR/year, while energy costs make up 6 Mio. EUR/year.

The **wastewater system** consumes 10,000 MWh/year of electricity from the grid in total. 17 Mio. m³/year of wastewater are treated and discharged to a river while the effluent contains an average of 50 mg/L of Nitrogen. The total running costs are 8 Mio. EUR/year, while the energy costs make up 3.5 Mio. EUR/year.

The **faecal sludge management** system of Waterscarcity is mainly composed by communal pit latrines without flush water and consumes in total 600 MWh/year. There is no groundwater infiltration to the system. Around 10,500 L of diesel are used for the transport of the faecal sludge to the treatment site, where the sluge is conducted to an anaerobic digester. It is estimated that only 50 % of the pit latrines are emptied during the assessment period. After the treatment, the treated sludge is used for land application. The anaerobic digestion system does not produce biogas.

In the following exercises please calculate your results by assuming that a year has 364 days.

	Group 1	Group 2	Group 3	Group 4
Main treatment technology	Activated sludge – minor poorly aerated zones	Activated sludge – not well managed	Anaerobic Reactor – recovery not considered	Trickling filter
Biogas from anerobic digestion	No	Yes	No	No
Biogas valorisation	No	No	No	No
Sludge disposal	Landfilling	Stockpilling	Landfilling	Landfilling

Assignments

1. **How high are the total emissions in kg CO_2 of the water, wastewater and faecal sludge management systems per year? Determine the proportions of the water, the wastewater and the faecal sludge management systems of the total emissions in percent.**
2. **What main sources of emissions occur and what is their fraction of the overall emissions in percent?**
3. **Can you think of some potential ways of reducing emissions?**

2 Tier B – Detailed GHG Assessment

➔ **Please consider the tasks for your group.**

Group 1

Task II *Data for the urban water cycle*

New Watervision has given you the following additional data:

In the **water supply system,** the energy consumption is shared as follows: 10 GWh/year by water abstraction, 1 GWh/year by water treatment and 6 GWh/year by water distribution. Additionally, about 1000 L of diesel are used for water trucks, delivering water to the remote serviced population.

In the **wastewater system**, 9 GWh/year of electrical energy is consumed for treating the wastewater and 1 GWh/year for discharging the effluent. Due to a new high-efficient wastewater collection system, the energy consumed from the grid in the wastewater collection stage can be neglected.

In the **faecal sludge management system**, 0.5 GWh/year is consumed during the treatment stage, whereas 0.1 GWh/year of electricity is consumed for the disposal. The electricity consumed from the grid in the containment stage can be neglected.

Assignments 1. **Complete the information for each stage of the urban water cycle in Tier B.**

Task II a *Evaluation of pump efficiency*

In the stage of **water abstraction**, New Watervision uses *10 groundwater wells*. The main data of the pump stations is available, and shown in the table:

Start by inserting the volumes of water and electricity consumed for pumps 1 – 4. **Pumps 5 – 10 shall not be assessed** at this point.

Pump	**Water Volume** (m^3/year)	**Energy** (kWh/year)
1	1,300,000	1,200,000
2	1,100,000	850,000
3	2,000,000	850,000
4	100,000	190,000
5 – 10	20,500,000	6,910,000

Note: Volumes of water and energy consumed of each pump at sub-stage level are automatically summed up and form the values of the stage. It is therefore necessary to create 1 sub-stage for pumps 5 – 10 and insert the volume and energy as well.

Assignments
1. **Compare the outputs for energy consumption per abstracted water (in kWh/m^3) and prioritise which pumps should be further investigated.**
2. **Can you think of a measure to reduce energy consumption?**

Task II b *Evaluation of pump efficiency*

Include the pump heads, specify pump type and size based on the information from the table. Observe the performance indicator and benchmark for standardised energy consumption for each pump.

Note: The pump head can ideally be calculated based on hydraulic measurements. Alternatively, the design pump head can also be used as an approximation.

Pump	Type	Head (HB) (m)
1	Submergible, 156 kW (212 HP)	200
2	Submergible, 180 kW (250 HP)	200
3	Submergible, 92kW (125 HP)	100
4	Submergible, 22 kW (30 HP)	270

Assignments

1. **Select three pumps that should be further investigated (including electrical parameters) and explain why.**
2. **Can you already think of a measure to reduce energy consumption?**

Task II c *Evaluation of pump efficiency*

After having decided which pumps should be further investigated, you have conducted measurements and obtained the pump flow rates, the electrical voltages and electrical currents. Use these measurement data to evaluate the electromechanical efficiency of the pumps.

The power factor is 0.95 for all the pumps.

Pump	Flow (L/s)	Voltage (line to line) (V_{LL})	Current (A)
1	51	470	220
2	57	450	230
3	63	450	130
4	4.6	440	40

Assignments

1. **How high are the electromechanical efficiencies (in %) of the pumps and which pump has the lowest efficiency?**

Task II d *Evaluation of pump efficiency*

You are now able to approximate the energy savings and reduced GHG emissions by replacing the current pumps with more efficient pumps. For this purpose, assume the following electrometrical efficiencies for the new pumps.

New Pump	Electromechanical efficiency (%)
1	71
2	72
3	70
4	58

Assignments

1. **How high are the expected electric energy savings (in GWh) and GHG reductions (in tCO_2eq) by replacing the pumps?**
2. **If you could replace only 2 pumps, which ones would it be?**

Group 1

Task III a *Wastewater Treatment*

The Initial GHG Assessment of the emissions coming from New Watervision's **Wastewater** facilities is based on several estimations. After on-site measurements, more detailed data is available. The following should be updated for a more adequate **Detailed GHG Assessment**:

- The influent BOD_5 load is 6,000 t/year, the BOD_5 removal efficiency is 85 %.
- No details on how much BOD_5 is removed as sludge are available. Therefore, a fraction of 65 % of the influent load should be assumed.
- The total sludge production at the treatment plant is 2,700 t/year.
- The dry weight of the produced sludge (before any dehydration) is 4 %, which means, dry weight of the sludge sent to stockpiling is 108 t/year.

Assignments

1. **How high are the emissions from sludge management in tCO_2eq/year after inserting the more detailed data?**
2. **How high are the total emissions in tCO_2eq/year of the wastewater treatment stage?**

Task III b *Wastewater Treatment*

New Watervision started to operate the anaerobic digestion of the produced sludge. The sludge is now undergoing a digestion process in which the original volume is reduced by about 40 %. With the help of this process, a total sludge of 1,600 t is produced per year. Due to the lower sludge volume, only 4,320 L of fuel per year are necessary for the sludge disposal (diesel). The dry weight of the sludge equals 6 %, i.e. 96 t/year.

The anaerobic digestion process produces about 2 Mio m^3 of biogas with a CH_4 concentration of 59 %; the biogas is however so far not valorised, only flared.

Assignments

1. **How high are the emissions in tCO_2eq/year from sludge management after implementing the anaerobic digestion?**
2. **How much were emissions reduced in tCO_2eq/year by implementing the anaerobic digestion?**
3. **Can you explain why the emissions are now lower?**
4. **How high are the emissions due to flaring of biogas in tCO_2eq/year?**

Task III c *Wastewater Treatment*

New Watervision has decided to install cogeneration and to stop biogas flaring, but instead valorising it for electricity generation. The total electricity produced by the cogeneration allows lowering the energy consumed from the grid by 4.5 GWh/year.

Assignments

1. **How high are the total emissions in tCO_2eq/year of the wastewater treatment stage after implementing cogeneration?**
2. **How high were emissions reduced in tCO_2eq/year compared to the result of task III a, i.e. before the implementation of anaerobic digestion and cogeneration?**
3. **What was the main measure leading to this reduction?**

Group 2

Task II *Data for the urban water cycle*

New Watervision has given you the following additional data:

In the **water supply system,** the energy consumption is shared as follows: 10 GWh/year by water abstraction, 1 GWh/year by water treatment and 6 GWh/year by water distribution. Additionally, about 1000 L of diesel are used for water trucks, delivering water to the remote serviced population.

In the **wastewater system**, 9 GWh/year of electrical energy is consumed for treating the wastewater and 1 GWh/year for discharging the effluent. Due to a new high-efficient wastewater collection system, the energy consumed from the grid in the wastewater collection stage can be neglected.

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Assignments **1. Complete the information for each stage of the urban water cycle in Tier B.**

Task II a *Evaluation of pump efficiency*

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Note: Volumes of water and energy consumed of each pump at sub-stage level are automatically summed up and form the values of the stage. It is therefore necessary to create 1 sub-stage for pumps 5 – 10 and insert the volume and energy as well.

Assignments

1. **Compare the outputs for energy consumption per abstracted water (in kWh/m³) and prioritise which pumps should be further investigated.**
2. **Can you think of a measure to reduce energy consumption?**

Group 2

Task II b *Evaluation of pump efficiency*

Include the pump heads, specify pump type and size based on the information from the table. Observe the performance indicator and benchmark for standardised energy consumption for each pump.

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2. **If you could replace only 2 pumps, which ones would it be?**

Task III a *Wastewater Treatment*

The **Initial GHG Assessment** of the emissions coming from New Watervision's **Wastewater** facilities is based on several estimations. After on-site measurements, more detailed data is available. The following should be updated for a more adequate **Detailed GHG Assessment**:

- The influent BOD_5 load is 6,000 t/year, the BOD_5 removal efficiency is 50 %.
- No details on how much BOD_5 is removed as sludge are available. Therefore, a fraction of 40 % of the influent load should be assumed.
- The total sludge production at the treatment plant is 1,600 t/year.
- The dry weight of the produced sludge (before any dehydration) is 6 %, which means, dry weight of the sludge sent to stockpiling is 96 t/year.
- The anaerobic digestion produces about 2 Mio m^3 of biogas with a CH_4 concentration of 59 %; all the biogas is subsequently flared.

Assignments

1. **How high are the emissions in tCO_2eq, only resulting from the treatment process in the wastewater treatment stage, per year?**
2. **How high are the emissions in tCO_2eq from electricity consumption in the wastewater treatment stage per year?**
3. **How high are indirect emissions in tCO_2eq from the wastewater discharge to the water body per year? What do you think where those indirect emissions come from?**

Group 2

Task III b *Wastewater Treatment*

The low treatment performances of the activated sludge plant have caused New Watervision to invest in new equipment to improve the aeration and mixing conditions in the activated sludge plant.

With new aerators, the dissolved oxygen concentrations in the aeration tank have been increased from well below 1 mg/L to 3 mg/L and the mixing conditions have been improved to avoid any dead spots that can produce anaerobic conditions. Hence, the CH_4 emission factor of the activated sludge plant can be set to zero.

The additional aeration with the new high-efficiency equipment resulted in a total energy consumption from the grid of 10 GWh/year. With the implemented measure, the BOD_5 removal efficiency was increased to 90 %. The BOD_5 removed as sludge can now be assumed to be 65 % of the influent load. The total Nitrogen concentration in the effluent was reduced from 50 mg/L to 30 mg/L.

Assignments

1. **By how much, in tCO_2eq/year, were emissions from the treatment process in the wastewater treatment stage lowered after the implemented measure?**
2. **How high are the indirect emissions in tCO_2eq from the wastewater discharged to the water body per year?**
3. **How high are the emissions in tCO_2eq from electricity consumption in the wastewater treatment stage per year?**
4. **Can you explain why the emissions are now lower even though more electric energy is needed for the new high-efficiency equipment?**

Task III c *Wastewater Treatment*

New Watervision has decided to install cogeneration and to stop biogas flaring, but instead valorising it for electricity generation. The total electricity produced by the cogeneration allows lowering the energy consumed from the grid by 4.5 GWh/year.

Assignments

1. **How high are the emissions in tCO_2eq/year from electricity consumption in the wastewater treatment stage after implementing cogeneration?**
2. **How high were emissions in tCO_2eq/year reduced in total compared to the result from task III a, i.e. before the improvement of aeration and mixing conditions and the implementation of cogeneration?**
3. **What was the main measure leading to this reduction?**

Group 2

Group 3

Task II *Data for the urban water cycle*

New Watervision has given you the following additional data:

In the **water supply system,** the energy consumption is shared as follows: 10 GWh/year by water abstraction, 1 GWh/year by water treatment and 6 GWh/year by water distribution. Additionally, about 1000 L of diesel are used for water trucks, delivering water to the remote serviced population.

In the **wastewater system**, 2 GWh/year of electrical energy is consumed for treating the wastewater and 1 GWh/year for discharging the effluent. The energy consumed from the grid in the wastewater collection stage amounts 7 GWh/year.

In the **faecal sludge management system**, 0.5 GWh/year is consumed during the treatment stage, whereas 0.1 GWh/year of electricity is consumed for the disposal. The electricity consumed from the grid in the containment stage can be neglected.

Assignments **1. Complete the information for each stage of the urban water cycle in Tier B.**

Task II a *Evaluation of pump efficiency*

In the stage of **water abstraction**, New Watervision uses *10 groundwater wells*. The main data of the pump stations is available, and shown in the table:

Start by inserting the volumes of water and electricity consumed for pumps 1 – 4. **Pumps 5 – 10 shall not be assessed** at this point.

Pump	**Water Volume** (m^3/year)	**Energy** (kWh/year)
1	1,300,000	1,200,000
2	1,100,000	850,000
3	2,000,000	850,000
4	100,000	190,000
5 – 10	20,500,000	6,910,000

Note: Volumes of water and energy consumed of each pump at sub-stage level are automatically summed up and form the values of the stage. It is therefore necessary to create 1 sub-stage for pumps 5 – 10 and insert the volume and energy as well.

Assignments

1. **Compare the outputs for energy consumption per abstracted water (in kWh/m³) and prioritise which pumps should be further investigated.**
2. **Can you think of a measure to reduce energy consumption?**

Task II b *Evaluation of pump efficiency*

Include the pump heads, specify pump type and size based on the information from the table. Observe the performance indicator and benchmark for standardised energy consumption for each pump.

Note: The pump head can ideally be calculated based on hydraulic measurements. Alternatively, the design pump head can also be used as an approximation.

Pump	Type	Head (HB) (m)
1	Submergible, 156 kW (212 HP)	200
2	Submergible, 180 kW (250 HP)	200
3	Submergible, 92kW (125 HP)	100
4	Submergible, 22 kW (30 HP)	270

Assignments

1. **Select three pumps that should be further investigated (including electrical parameters) and explain why.**
2. **Can you already think of a measure to reduce energy consumption?**

Task II c *Evaluation of pump efficiency*

After having decided which pumps should be further investigated, you have conducted measurements and obtained the pump flow rates, the electrical voltages and electrical currents. Use these measurement data to evaluate the electromechanical efficiency of the pumps.

The power factor is 0.95 for all the pumps.

Pump	Flow (L/s)	Voltage (line to line) (V_{LL})	Current (A)
1	51	470	220
2	57	450	230
3	63	450	130
4	4.6	440	40

Assignments

1. **How high are the electromechanical efficiencies (in %) of the pumps and which pump has the lowest efficiency?**

Task II d *Evaluation of pump efficiency*

You are now able to approximate the energy savings and reduced GHG emissions by replacing the current pumps with more efficient pumps. For this purpose, assume the following electrometrical efficiencies for the new pumps.

New Pump	Electromechanical efficiency (%)
1	71
2	72
3	70
4	58

Assignments

1. **How high are the expected electric energy savings (in GWh) and GHG reductions (in tCO_2eq) by replacing the pumps?**
2. **If you could replace only 2 pumps, which ones would it be?**

Task III a *Wastewater Treatment*

The **Initial GHG Assessment** of the emissions coming from New Watervision's **Wastewater** facilities is based on several estimations. After on-site measurements, more detailed data is available. The following should be updated for a more adequate **Detailed GHG Assessment**:

- The influent BOD_5 load is 6,000 t/year, the BOD_5 removal efficiency is 85 %.
- The BOD_5 removed as sludge is estimated to be 10 % of the influent load.
- The sludge production at the treatment plant is about 800 t/year, which can be considered as digested.
- The dry weight of the produced sludge (before any dehydration) is 4 %.
- Sludge is transported by trucks consuming 1,440 L of fuel in total.

Assignments

1. **How high are the emissions in tCO_2eq, only resulting from the treatment process in the wastewater treatment stage, per year?**
2. **Why are the emissions from the treatment process so high?**
3. **How high are the emissions in tCO_2eq/year, resulting from sludge management?**
4. **How high the total emissions in tCO_2eq/year, resulting from electricity consumption in the wastewater treatment stage?**

Group 3

Task III b *Wastewater Treatment*

New Watervision has realized the huge mitigation potential of recovering the produced biogas in the Anaerobic Reactor so that New Watervision would like to implement a biogas flare system. Therefore, the CH_4 emission factor should be set to zero. The total amount of biogas produced and flared is 3,600,000 m^3/year; it has a CH_4 concentration of 60 %.

Since the produced sludge by the Anaerobic Reactor contains still high fractions of nutrients, New Watervision has decided to stop the practice of landfilling. The sludge should be composted before making it available for agricultural usages. Since the composting takes place nearby the treatment plant, transport is negligible.

Assignments

1. **How high are the emissions in tCO_2eq/year resulting from the treatment process in the wastewater treatment stage after the implementation of the measure?**
2. **How high are the emissions in tCO_2eq/year resulting from the biogas flaring?**
3. **How high are the emissions in tCO_2eq/year resulting from sludge management?**

Task III c *Wastewater Treatment*

New Watervision has decided to install cogeneration and to stop biogas flaring, but instead valorising it for electricity generation. The total electricity produced by cogeneration allows to lower the energy consumed from the grid by 6 GWh/year.

Hint: **The energy consumed from the grid of the wastewater treatment stage is -4 GWh/year.**

Assignments

1. **How high are the emissions in tCO_2eq/year from electricity consumption in the wastewater treatment stage after implementing cogeneration?**
2. **How high were emissions reduced in total compared to the result from task III a, i.e. before the improvement of biogas recovery and the implementation of cogeneration in tCO_2eq/year?**
3. **What was the main measure leading to this reduction?**

Group 4

Task II *Data for the urban water cycle*

New Watervision has given you the following additional data:

In the **water supply system,** the energy consumption is shared as follows: 10 GWh/year by water abstraction, 1 GWh/year by water treatment and 6 GWh/year by water distribution. Additionally, about 1000 L of diesel are used for water trucks, delivering water to the remote serviced population.

In the **wastewater system**, 2 GWh/year of electrical energy is consumed for treating the wastewater and 1 GWh/year for discharging the effluent. The energy consumed from the grid in the wastewater collection stage amounts 7 GWh/year.

In the **faecal sludge management system**, 0.5 GWh/year is consumed during the treatment stage, whereas 0.1 GWh/year of electricity is consumed for the disposal. The electricity consumed from the grid in the containment stage can be neglected.

Group 4

Assignments **1. Complete the information for each stage of the urban water cycle in Tier B.**

Task II a *Evaluation of pump efficiency*

In the stage of **water abstraction**, New Watervision uses *10 groundwater wells*. The main data of the pump stations is available, and shown in the table:

Start by inserting the volumes of water and electricity consumed for pumps 1 – 4. **Pumps 5 – 10 shall not be assessed** at this point.

Pump	**Water Volume** (m^3/year)	**Energy** (kWh/year)
1	1,300,000	1,200,000
2	1,100,000	850,000
3	2,000,000	850,000
4	100,000	190,000
5 – 10	20,500,000	6,910,000

Note: Volumes of water and energy consumed of each pump at sub-stage level are automatically summed up and form the values of the stage. It is therefore necessary to create 1 sub-stage for pumps 5 – 10 and insert the volume and energy as well.

Assignments
1. **Compare the outputs for energy consumption per abstracted water (in kWh/m^3) and prioritise which pumps should be further investigated.**
2. **Can you think of a measure to reduce energy consumption?**

Task II b *Evaluation of pump efficiency*

Include the pump heads, specify pump type and size based on the information from the table. Observe the performance indicator and benchmark for standardised energy consumption for each pump.

Note: The pump head can ideally be calculated based on hydraulic measurements. Alternatively, the design pump head can also be used as an approximation.

Pump	Type	Head (HB) (m)
1	Submergible, 156 kW (212 HP)	200
2	Submergible, 180 kW (250 HP)	200
3	Submergible, 92kW (125 HP)	100
4	Submergible, 22 kW (30 HP)	270

Assignments

1. **Select three pumps that should be further investigated (including electrical parameters) and explain why.**
2. **Can you already think of a measure to reduce energy consumption?**

Task II c *Evaluation of pump efficiency*

After having decided which pumps should be further investigated, you have conducted measurements and obtained the pump flow rates, the electrical voltages and electrical currents. Use these measurement data to evaluate the electromechanical efficiency of the pumps.

The power factor is 0.95 for all the pumps.

Pump	Flow (L/s)	Voltage (line to line) (V_{LL})	Current (A)
1	51	470	220
2	57	450	230
3	63	450	130
4	4.6	440	40

Assignments

1. **How high are the electromechanical efficiencies (in %) of the pumps and which pump has the lowest efficiency?**

Task II d *Evaluation of pump efficiency*

You are now able to approximate the energy savings and reduced GHG emissions by replacing the current pumps with more efficient pumps. For this purpose, assume the following electrometrical efficiencies for the new pumps.

New Pump	Electromechanical efficiency (%)
1	71
2	72
3	70
4	58

Assignments

1. **How high are the expected electric energy savings (in GWh) and GHG reductions (in tCO_2eq) by replacing the pumps?**
2. **If you could replace only 2 pumps, which ones would it be?**

Group 4

Task III a *Wastewater Treatment*

The **Initial GHG Assessment** of the emissions coming from New Watervision's **Wastewater** facilities is based on several estimations. After on-site measurements, more detailed data is available. The following should be updated for a more adequate **Detailed GHG Assessment**:

- The influent BOD_5 load is 6,000 t/year, the BOD_5 removal efficiency is 70 %.
- No details on how much BOD_5 is removed as sludge are available. Therefore, a fraction of 65 % of the influent load should be assumed.
- The sludge production at the treatment plant is about 7,000 t/year.
- The dry weight of the produced sludge (before any dehydration) is 4 %.
- There is no anaerobic digestion and all the sludge produced is therefore undigested.
- The sludge is transported by trucks consuming 7,200 L of fuel (diesel).

Assignments

1. **How high are the emissions in tCO_2eq/year from sludge management after inserting the more detailed data?**
2. **How high are the emissions in tCO_2eq, only resulting from the treatment process in the wastewater treatment stage, per year?**
3. **How high are the emissions in tCO_2eq/year of the electricity consumption in the wastewater treatment stage?**

Group 4

Task III b *Wastewater Treatment*

New Watervision started to operate an anaerobic digestion of the produced sludge. Additionally, the energy supply was optimised through the implementation of cogeneration. The sludge is now undergoing a digestion process in which the original volume is reduced by about 40 %. Due to the lower sludge volume, only 2,592 L of fuel per year are necessary for the sludge disposal (diesel). The dry weight of the sludge equals 6 %.

The anaerobic digestion process produces about 2 Mio. m^3 of biogas with a CH_4 concentration of 59 %. The electricity produced from valorising the biogas in the cogeneration plant is 4.5 GWh/year.

Hint: If you add the 4.5 GWh in the field Electrical energy produced from biogas valorisation, it just accounts for the avoided GHG emissions and does not automatically change the net electricity consumption of the treatment stage. Hence, you must modify the net electricity consumption of the treatment stage to -2.5 GWh/year manually.

Assignments

1. **How high are the emissions, only resulting from the treatment process in the wastewater treatment stage, after implementing the anaerobic digestion and cogeneration in tCO_2eq/year?**
2. **How high are the emissions from electricity consumption in the wastewater treatment stage in tCO_2eq/year?**
3. **Can you explain why the emissions from electricity consumption are now negative?**
4. **By how much in tCO_2eq/year were emissions reduced by implementing the anaerobic digestion, i.e. compared with task III a?**

Task III c *Wastewater Treatment*

The sludge produced by New Watervision has been disposed of so far in a regular landfill. To reduce the emissions of GHG, the landfill has been equipped with a gas collection system. After the gas is collected, it is subsequently flared.

Due to the lowered sludge volume following the implementation of the anaerobic digestion and improved dewatering, the fuel consumption of the sludge transport was lowered to 4,200 L.
In addition, New Watervision has started to sell water to the municipality for its reuse for public works, i.e. roads.
The volume of water reused is 5,000,000 m^3 per year and hence the volume of water discharged to the water body is only 12,000,000 m^3 per year. To transport the water for reuse about 1,000 L of diesel are required.

Assignments

1. **How high are the emissions in tCO_2eq from sludge management, after adding the measures, per year?**
2. **How high are the total GHG emissions in tCO_2eq/year for the whole process in the wastewater treatment stage?**
3. **How much were emissions reduced compared to the result of task III a), i.e. before the implementation of anaerobic digestions and cogeneration?**
4. **Determine the indirect emissions from discharge to the water body before and after the implementation of reuse in tCO_2eq/year.**

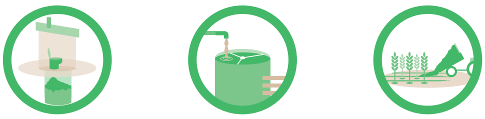
3 Tier B – Faecal Sludge Management

➔ **This section can be solved without any information given in the document before.**

Task IV *Initial Information*

In an informal settlement located 280 km away from Waterscarcity, most of the people have little or no access to basic urban services. There are no accessible roads, most access ways are via unpaved footpaths and only a small percent of the resident population has legal water connections with irregular water supply. Nearly all others, largely poor households, obtain water from kiosks, water delivery services and illegal connections.

This year, the government of Waterland decided to develop a Faecal Sludge Management (FSM) plan for the poorest community of the settlement, where today all the sewage produced by the circa 20.000 inhabitants remains untreated, posing a severe problem for public health.



Containment **Treatment** **Reuse / Disposal**

The FSM plan is expected to provide on-site treatment to the entire resident population.

Even though pit latrines seem to be the easiest option, the Government wants to evaluate different options to guarantee not only a safe environment for all, but also low GHG emissions. In order to find the best solution, you were asked to undertake a technical analysis. For this assessment, you can assume that the settlement has a similar energy mix and food consumption patterns as Togo.

With the intention of obtaining a more accurate assessment of the current situation in the community, the Government financed a preliminary study by a research group of the Waterland University, which revised aspects related to the sludge characteristics, rate of production and local conditions. The data obtained is presented below. You will use this information as input data for the following Tasks.

Hints:

- **Since the FSM system is expected to serve the entire resident population (20,000 inhabitants), the Resident and Population with onsite treatment are the same.**
- **For this section, you are requested to evaluate only the options for on-site treatment. Therefore, you only need to activate the Faecal Sludge Management system in the Configuration page of ECAM.**
- **Please calculate your results by assuming that a year has 364 days.**

Assignments

1. **Can you think of other on-site treatment alternatives for managing the faecal sludge of the community different from pit latrines?**
2. **Why would you expect GHG emissions from on-site treatment?**

Task IV a *Evaluation of Faecal Sludge Containment*

➔ **Depending on your assigned group, please consider the parameters given in the table below for the assessment of the FSM system.**

	Group 1	Group 2	Group 3	Group 4
Main containment technology	Pit latrine without flush water at communal level	Pit latrine without flush water at household level	Pit latrine with flush water use	Septic tanks
Percentage of containment that must be emptied in one year (%)	40 %	30 %	50 %	30 %
Expected volume of faecal sludge to be emptied per year (m^3)	650	485	750	580
Expected BOD concentration of faecal sludge (kg/m^3)	67.8	67.8	67.8	1.35
Expected BOD removed as faecal sludge (t)	46	30	50	0.9

The following parameters are common between all containment types:

- The influent BOD load coming from the 20.000 inhabitants is approximately 300 t/year.
- The local low precipitation rate prevents local flooding and groundwater infiltration.
- The containment stage is expected to consume energy from the grid up to 200 MWh/year.
- The sludge is to be transported by trucks consuming on average 7,500 L of diesel per year.

Assignments

1. **How high are the total emissions in kg CO_2 of the containment stage of the FSM system per year?**
2. **Is the use of electricity the main cause of GHG emissions? If not, what produces the highest amount of GHG emissions?**
3. **Can you think of some potential ways of reducing emissions?**

Task IV b *Evaluation of Faecal Sludge Containment*

➔ This task must be developed by all Groups (1 – 4) considering the results obtained in Task IVa

Regardless of the type of containment selected, it is foreseen that the sludge collected will be further transported to a faecal sludge treatment plant. There, the total sludge will be divided into two equal flows and treated separately in two anaerobic digesters, one of which shows better energy performance. The two digesters can be thus considered as substages. Consider the following energy performance:

Digester (Substages)	**Energy consumed from the grid** (MWh/year)
1	350
2	480

- The total energy consumed from the grid during the treatment stage is approximately the sum of the energy consumed by the two substages.
- The influent BOD load for the FS Treatment stage corresponds to the BOD removed as FS during the containment stage.
- The effluent BOD load is expected to be 10 % of the influent BOD load.
- The BOD removed with excess sludge is expected to be 10 % of the influent BOD load.
- Since the influent load is divided into two, each substage treats only half.
- Despite the differences in BOD removal performance, the emission factor can be considered to be the same for both digesters (0.48).
- The transport of the sludge during the treatment process is negligible.
- Biogas is so far not being produced during the treatment process.

Hints:

- Create substages by unfolding the subsection *Advanced Assessment: Substages* at the bottom part of the page.
- You can update the stages values according to the two substages by clicking in the arrows under *Substages total* or *average*.

Assignments

1. **How high are the total emissions in kg CO of the treatment stage of the FSM system per year?**
2. **What causes more emissions between the containment and the treatment stages?**
3. **Does the electricity usage account for a large portion of the emissions?**

Task IV c *Evaluation of Faecal Sludge Containment*

➔ This task must be developed by all Groups (1 – 4) considering the results obtained in Task IV a and IV b.

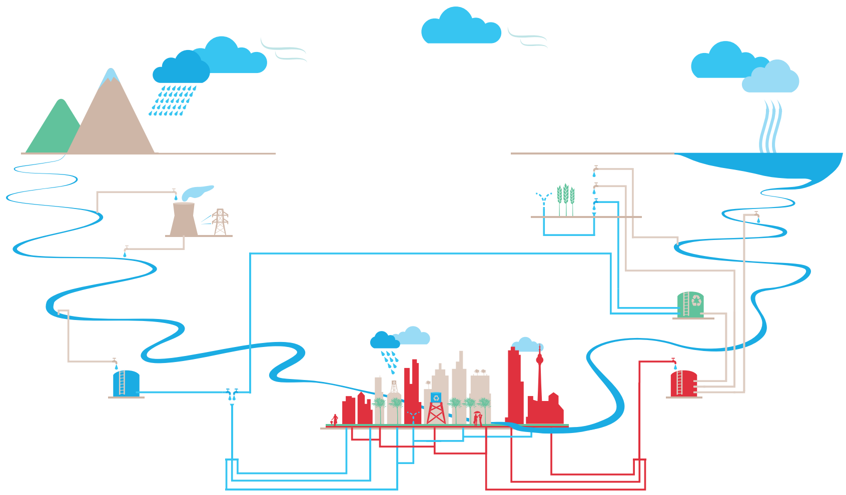
After the anaerobic digesters of the FSM plant, the **treated sludge** will be post-treated in drying beds to get rid of the water fraction and then it will be sent to be **land applied.** The following operating conditions can be considered for the FS disposal:

- The total energy consumption for this stage is 100 MWh.
- The sludge is transported to the final disposal site by trucks, which consumes approximately 25 litres of diesel for every 100 kilometres. The average distance to the land application site is 120 km, and it is estimated that 50 roundtrips are needed per year to transport the sludge to the farm fields.
- Since there is not enough data about the total nitrogen contained in the faecal sludge that is disposed of, an estimation of 3 % (of dry weight) is considered to be a good approximation.
- The clay content of the soil of the farm fields ranges between 40 – 45 %.

	Group 1	Group 2	Group 3	Group 4
Dry weight sent to land application (t)	190	150	220	130
Total Nitrogen reused that displaces synthetic fertilizer (kg)	4,500	3,800	5,600	3,300

Assignments

1. **How high are the total emissions in kg CO_2 of the disposal stage of the FSM system per year?**
2. **Of all the stages of the FSM system (containment, treatment and reuse/disposal), which causes the most emissions?**
3. **What Is the total GHG emissions avoided from reusing nitrogen that displaces synthetic fertilizer? Why do you think there are emissions associated with the use of synthetic fertilizers?**
4. **Discuss with the other groups. In your opinion, what is the best on-site treatment alternative the government should consider for managing the sludge of the 20,000 inhabitants of the community? Can you think of other measures the government should implement concerning lowering the emissions?**



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