GUIDELINES FOR USING THE
SMART ENERGY MANAGEMENT SELF AUDIT TOOL

Developed in the framework
of the project IWAMA – Interactive Water Management

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**Supplementing documentation of the auditing process
as part of the smart energy management audit concept**

This document offers more detailed information and explanations about important aspects of filling the smart energy management audit tool. Guidelines are given about the structure of the audit tool, technical tips for filling the tool, explanations for content of automatic calculations and definitions for used terms.

The smart energy management audit concept was developed to measure the effectiveness of the process applied at wastewater treatment plants and outline the potential for improvements of these plants. The tool can be used by municipal wastewater treatment plants of all sizes, but is not meant for plants treating a high share of industrial wastewater. In this case, results might be misleading. The audit tool provides an opportunity for operators to perform self-auditing at their WWTPs, comparing the energy efficiency of the current installation with ideal values. The optimization potential is visualized on a detailed level. Based on the evaluated saving potentials, a compilation of general hints and suggestions is offered. The compilation is intended to support development of specific optimization measures.

The smart energy management audit concept including the tool, the report and this guideline has been developed as a part of the Interreg BSR co-funded IWAMA project.

We issue no guarantee on the correctness and completeness of the information and results in this tool. Liability claims referring to material or immaterial damages, which are caused by use or non-use of the presented information or the application of incorrect or incomplete information, are categorically excluded. Due to varying set-ups of WWTPs specific optimization measures need individual design and calculations, which is not part of the auditing process.

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1   INTRODUCTION

Evaluating the energetic situation of a WWTP with lots of different processes is a complex task. The energy audit tool shall enable operators to perform an energy audit with their own resources. The tool describes both the current status of the selected reference year as well as optimization potentials based on calculated ideal values. The tool has been developed based on Microsoft Excel. Macros have to be enabled. This guideline describes the usage of the tool itself and the equations used internally for calculation and evaluation.

The energy analysis tool is structured in several sheets (Table 1). In order to perform the audit it is necessary to insert requested data on sheets Data input and List of Consumers. Results of the evaluation are published on the sheets Evaluation, Evaluation Graph I / Graph II, Heat balance, Energy key figures and Optimization.

In order to localize the tool, a second language may be selected. The translations are displayed additional to the English terms (Sheet Data Input) or replacing the original language.

Table 1 – Structure of the Energy Self Audit Tool

Sheet	Function
Disclaimer	- general information
Manual	- short instructions on using the tool
Symbols & Abbreviations	- explanation of symbols and abbreviations
Data input	- choice of existing operational processes and plant components - determining amounts of aggregates to be listed as consumers - collection of relevant parameters to calculate plant related ideal values
List of consumers	- calculation of aggregate-specific and total annual electricity consumption - comparison of calculated and real electricity consumption
Evaluation	- comparison of calculated electricity consumption and plant related ideal values - indicating saving potentials - evaluation of cogeneration plant from electrical point of view
Evaluation | Graph 1	- visualisation of saving potentials of four main treatment stages
Evaluation | Graph 2	- visualisation of saving potentials of all existing process steps
Heat balance	- overview of heat consumption and production - evaluation of cogeneration plant from thermal point of view
Key figures	- brief energy check - comparison of plant related key figures with medians of Baltic Sea Region
Optimization	- general hints and suggestions to develop specific optimization measures
Attachments	- database for background calculations, informative

2   DATA INPUT

The sheet *Data input* serves several functions: First, the user can select between several options to reproduce the operational processes as precise as possible and to identify which plant components should be considered in the evaluation. Second, the sheet *Data input* serves as basis to determine the amount of blank lines for aggregates to be shown in the *List of consumers*. Third function is to collect all relevant parameters, which are needed to calculate plant specific ideal values.

The data entry is structured in following sections:

  1.) general data

  2.) general operating data

  3.) feed pump station

  4.) mechanical cleaning stage

  5.) biological treatment stage

  6.) secondary clarifier

  7.) post-treatment

  8.) sludge treatment

  9.) sludge dewatering

  10.) exhaust air cleaning

  11.) cogeneration plant

  12.) heat consumption and production

  13.) other

  14.) remarks

In order to keep the data input as simple as possible, most of the required data input fields are only displayed if necessary according to the process.
The tool merges different aggregates to blocks (e.g. pumps of feed pump station, scrapers in mechanical treatment, aeration aggregates in biological treatment etc.). The blocks are marked with yellow-labelled abbreviations. These groups re-appear in the List of consumers.

Data input is organized via drop-down list, tick boxes and input of numbers. In order to distinguish between data necessary to describe current status and data necessary to calculate ideal values, different shades of blue are used. It is recommended to complete to fill at least all data required for description of current status before moving to the List of consumers.

To be noticed: Only input data that refers to selected options are shown in the sheet *Data input*, sometimes step by step. Input data, which refers to options that have not been selected, will remain hidden. This means if for example the question "feed pump station existing?" is answered with "no" via drop-down-menu, all further data inquiries regarding feed pump stations will remain hidden.

Usability note: Each entry in the blue fields needs to be confirmed either by a random click or by using the enter key. Otherwise, the data entry is not updated.
A successful audit is based on the amount and quality of inserted data. A brief checklist (Annex I) provides an overview of data expected. It is recommended to get familiar with the checklist and start collecting documents and files in order to save time and efforts.

To delete data of a single section individual "reset" buttons are arranged on the right side. Furthermore, clicking the "reset all data" button on top of the page deletes all inserted data within the sheet *Data input* at once and expanded lines will be hidden again.

The reference period for energy audit is usually a whole year. Therefore, yearly sums or yearly average values are requested.

The calculation of ideal values is based on certain pre-defined groups of aggregates. An overview, which aggregates should be included in which treatment unit in the sheet "Data input" and consequently in the sheet "List of consumers" is provided in Annex II. Since most of the aggregates can be easily assigned to the respective sections, they will not be mentioned here.

2.1. Brief walk-through of Data input

General operating data

- **Mean daily wastewater flow Q_d [m³/d]:**

  For the mean daily wastewater inflow it is recommended to have a mean of 365 days of the inflow to the wastewater treatment plant.

- **Annual average COD load in inflow $B_{d,COD,aM}$ [kgCOD/d]:**

  The daily COD load is calculated by multiplying the daily flow (Q_d) with the corresponding daily COD concentration and then calculate the annual average load:

$$B_{d,COD,aM} = \frac{\sum(Q_d \cdot C_{COD})}{n} = \frac{kgCOD}{d} \tag{1}$$

- **Purchased electricity $E_{el,ext}$ [kWh/a]:**

  The sum of bills of electricity purchased in one year.

Pump stations

A general note on pumping stations: Main pumps (e.g. feed pumps at the inlet of a WWTP, return activated sludge pumps, excess sludge pumps) should be combined to pumping stations. In this way, pump characteristics like delivery head and pumped volumes will be considered when determining respective ideal value.

Smaller pumps (e.g. grit and grease pumps, reject water pumps, discharge pumps for certain aggregates/ treatment steps) do not need to be labelled as pumping stations in the audit tool but can be sorted to "other aggregates" in the respective plant sections. In this case, however, aggregate specific ideal values will not be calculated. Their actual energy consumption will be recorded nonetheless.

Typical types of pumps are predefined in the drop-down menus. It is possible to define different boundary conditions (e.g. delivery heads, see Figure 1) if different types of pumps are used in one station. If neither of the listed pumps exist at the respective pumping station, choose the option "other" to enter individual specifications (e.g. pump efficiency, motor efficiency).
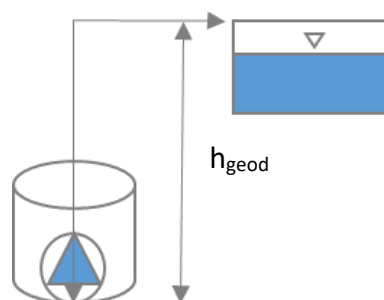

Figure 1 – Delivery head between pumping and discharge point

Biological treatment stage

Different types of treatment processes are already predefined in the tool such as activated sludge, trickling filter, and membrane bioreactor. For the trickling filter system, only the type of pump and their correspondence data must be given. For the membrane bioreactor, only the number of aggregates is required. However, for the activated sludge system more data is required as shown below.

- **Operating data aeration ($t_{aerated}$, T_{AT}, t_{ss}):**

The annual period of the aerated phase ($t_{aerated}$) does not represent the sum of operating hours of the blowers but represents the hours in which aeration of the biological reactor is ensured. If no value is entered here, it will be assumed that there is a constant aeration throughout the day and year:
24 h/d · 365 d/a = 8.760 h/a (maximum input value).

Additionally, the average annual temperature of the wastewater in the aeration tank (TAT) and the average annual sludge age (t_{ss}) should be filled in.
In a further step, the pollutants concentration (C_{COD}, C_{TN}, X_{TSS}, S_{NO3}) of the wastewater should be entered. Here it is favourable to fill in the concentration of pollutants entering the aeration tank at measuring point X as shown in Figure 2.
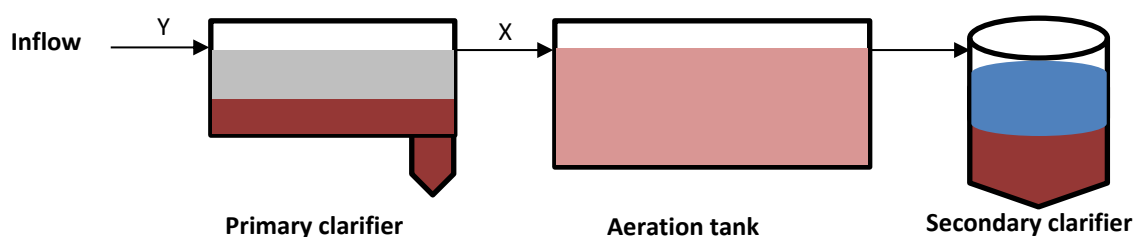
Figure 2 – Pollutants concentration based on the sampling points X or Y

If concentrations at the measuring point X are not available, concentrations at the inflow of the wastewater treatment plant (measuring point Y) might be used as substitution. In this case, inlet concentrations will be reduced according to expected removal efficiencies based on the retention time in primary clarification (see table 1). A retention time less than 0,75 h is regarded as if primary clarification is non-existent.

Table 2 – Elimination ratios of primary clarification dependent on the retention time [DWA-A 131 (2016)]

	Retention time in primary clarification tank (t_{PC})		
Elimination in %	0,75 – 1 h	1,5 – 2 h	> 2,5 h
C_{COD}	30	35	40
X_{TSS}	50	60	65
C_{TN}	10	10	10

3 LIST OF CONSUMERS

The *List of consumers* aims at calculating the annual electricity consumption of each aggregate as well as comparing the <u>calculated</u> total electricity consumption according to the *List of consumers* with the <u>real</u> electricity consumption according to the WWTP's energy bill.

3.1. Mode of operation

With respect to the treatment stage and the number of aggregates inserted in the sheet *Data input*, empty lines automatically appear in the sheet *List of consumers*. However, the button "update whole sheet" on top of the sheet needs to be pressed first in order to transfer the inserted data. This computing process may take a little while, which is why it is recommended to complete filling in *Data input* at first and then proceed to *List of consumers* in order to avoid updating the sheet over and over.

Whenever there were adjustments made in the sheet *Data input*, e.g. changing the number of aggregates, the procedure "update whole sheet" needs to be repeated. This also applies for missing or redundant lines: If an aggregate/ a line needs to be added or deleted, this can only(!) be done by adjusting the information given in *Data input*. Inserting or deleting a line within the sheet List of consumers via right click and choosing "insert row" or "delete row" is not possible!

3.2. Data entry and background calculations

In the displayed lines, name of the aggregates should be filled in order to avoid misunderstandings. Year of construction and system code can be inserted optionally. Each line represents one aggregate – except for the sections cogeneration plant, sludge drying, sludge incineration, premises and workshops/ laboratories. In these sections, one line represents the whole unit and thus, energy consumption needs to be inserted as a whole since aggregates are not listed here individually.

If an energy measurement is already in place, follow procedure a). If not, motor data/ connected values and the operating hours are mandatory to calculate annual electricity consumption of each aggregate:

a) If the electricity consumption of an aggregate is available through individual electricity measurement, the value should be inserted into the column "annual consumption". The value needs to be fixed by choosing "X" in the drop-down-menu of column "fix value". This is the most accurate and thus most preferable approach to determine the annual electricity consumption.

b) If amperage measurement [A] of an aggregate is available, it should be filled into the column "electricity actual state". Besides, other technical data according to the formula below is required:

$$W_{el} = (U \cdot I \cdot \sqrt{3} \cdot cos\varphi \cdot \alpha_{FC} \cdot t) \left[\frac{kWh}{a} \right]$$

U: nominal voltage [V]	according to aggregate's name plate
I: electricity actual state [A]	according to amperage measurement
cosϕ: phase angle/ power factor [-]	according to aggregate's name plate
α_{FC}: reduction ratio for aggregates with frequency converter [-]	0,95 (fixed in VBA code)
t: operating hours [h/a]	according to measurement or auxiliary approximation

c) If neither aggregate-specific electricity nor amperage measurement is available, the annual electricity consumption is calculated according to the following simplified formula:

$$W_{el} = (P_{nom} \cdot \eta \cdot \alpha_{FC} \cdot \beta) \cdot t \quad \left[\frac{kWh}{a}\right]$$

P_{nom}: nominal power [kW]	according to aggregate's name plate
η: total efficiency [%]	according to efficiency category on the aggregate's name plate
α_{FC}: reduction ratio for aggregates with frequency converter [-]	0,95 (fixed in VBA code)
β: reduction ratio for aggregates with P_{nom} < or ≥ 5 kW [-]	according to table on the top right side of *List of consumers;* default setting: P_{nom} < 5 kW: β = 1,0 P_{nom} ≥ 5 kW: β = 0,85
t: operating hours [h/a]	according to measurement or auxiliary approximation

The column "annual consumption" will be calculated automatically as soon as required data is inserted in the *List of consumers* and "update whole sheet" button is clicked. In the same computing process, the column "proportion" of total electricity consumption will be automatically calculated for each inserted aggregate.

Please note that column "group" is already filled and should not be changed, since it refers to the yellow marked blocks from *Data input* and is connected to the *Evaluation* sheet.

In addition, the columns "efficiency" and "power calculated" should not be filled manually. These values are either redundant (approach a) and b) of calculating energy consumption) or in case of approach c), values are generated automatically based on the chosen efficiency category and the installed power using the table "efficiency of electric motors according to the eco-design directive" (see *Attachments*).

The efficiency category is set to "IE1" by default but can be changed by selecting the appropriate category from the drop-down-menu.

The calculated power derives from the formula:
$$P_{calc} = (P_{nom} \cdot \eta) \cdot t \quad [kW]$$

P_{nom}: nominal power [kW]	according to aggregate's name plate
η: total efficiency [%]	according to amperage measurement
t: operating hours [h/a]	according to measurement or auxiliary approximation

In the column "frequency converter" the standard setting is "no". If a frequency converter is installed, the setting can be changed into "yes" via drop-down-menu. In this case, the annual electricity consumption of the aggregate is reduced by 5 % (α_{FC} = 0,95). This value is fixed in the code.

In case that annual electricity consumption is calculated using approach c), a further reduction ratio for aggregates with nominal power ≥ 5 kW is applied ($\beta_{\geq 5kW}$). Default setting for this reduction ratio is $\beta_{\geq 5kW}$ = 0,85. Adaptions can be made by changing the ratios in the table on the top right side of the sheet "*List of consumers*".

Important note: If aggregates are added or motor data/ connected values are changed, the calculation will only be updated when the button "update whole sheet" is pressed. This avoids that calculations are processed during

data entry, which would slow down the whole process. The treatment stage-specific "refresh" buttons only process updates connected with the operating hours which is why their computing process is running faster.

3.3. Comparison of calculated and real electricity consumption

On the bottom of the sheet *List of consumers* a table called "comparison of calculated and real electricity consumption" is arranged.

In the first line produced and sold electricity is listed according to the data stated in *Data input*. A reduction of 1,5 % energy losses caused by switchgears, transformers etc. is taken into account. The second line refers to the external electricity consumption according to the energy supply company. 3 % reduction due to energy losses is considered here. The third line "real total electricity consumption" is a sum of the both previous lines. The fourth line is a sum of all calculated aggregate-specific annual energy consumptions and thus the "calculated electricity consumption according to list of consumers". The comparison of third and fourth line will probably result in a variance, which is listed underneath. If the difference exceeds 10 %, a note appears indicating that the deviation is too high and that the consumption list needs to be reviewed.

If filling in the *List of consumers* is completed and the variance of calculated and actual energy consumption lowered to less than 10 %, the data entry is finished.

4 EVALUATION

The *Evaluation* sheet serves as comparison of "electricity consumption (actual value)" with the plant related lower- and upper ideal values. If there are no ideal values known for certain aggregates (e.g. "other aggregates"), the actual energy consumption (according to *List of consumers*) is taken as a substitute. In this way, saving potentials can be revealed and optimisation approaches can be developed. The evaluation sheet is shown in Figure 3 below.

consumer or plant section:	electricity consumption (actual value)	specific electricity consumption	proportion of total electricity consumption	plant related ideal value				actual value/ plant related ideal value		saving potential	
				lower value		upper value				min.	max.
	kWh/a	kWh/(PE·a)	%	kWh/a	kWh/(PE·a)	kWh/a	kWh/(PE·a)	min. %	max. %	kWh/a	kWh/a
feed pump stations	0	0.00	0.0	0	0.0	0	0.0	-	-	0	0
mechanical cleaning stage	0	0.00	0.0	0	0.0	0	0.0	-	-	0	0
biological treatment stage	0	0.00	0.0	0	0.0	0	0.0	-	-	0	0
secondary clarifier	0	0.00	0.0	0	0.0	0	0.0	-	-	0	0
posttreatment	0	0.00	0.0	0	0.0	0	0.0	-	-	0	0
wastewater treatment total	0	0.00	0.0	0	0.0	0	0.0	-	-	0	0
sludge treatment	0	0.00	0.0	0	0.0	0	0.0	-	-	0	0
sludge dewatering	0	0.00	0.0	0	0.0	0	0.0	-	-	0	0
premises	0	0.00	0.0	0	-	0	-	-	-	-	-
workshops, laboratories, etc.	0	0.00	0.0	0		0					
SUM:	0	0.00	0.0	0	0.0	0	0.0	0	0	0	0

Figure 3 – The sheet "Evaluation" in the energy audit tool.

In the sheet *Evaluation* no data needs to be inserted. All values are calculated in the background. To update the *Evaluation* sheet, a random click or pressing the enter key is necessary. The evaluation sheet consists of the following elements:

1. Plant section:

   The blocks chosen and filled in the sheet *Data input* will appear in the *Evaluation* sheet.

2. Electricity consumption (actual value)

   The electricity consumption is transferred for each block as sum from the list of consumers. This means if you have 3 aerated grit chamber/grease trap, the sum of their electricity consumption will appear in the block "aeration of grit chamber/grease trap"

3. Specific electricity consumption (kWh/(PE·a)]

The specific electricity consumption [kWh/(PE·a)] takes the total number of inhabitants and population equivalents into account. PE calculation refers to a basic load of 120 g COD/(PE·d) as shown in the formula below. A size category based on HELCOM recommendations is chosen accordingly.

$$e_{spec} = \frac{\text{annual energy consumption}}{PE_{COD,\,120}}$$

Furthermore, the share of each block in the total electricity consumption is transferred from the List of consumers.

4. Plant related ideal value (lower value/upper value)

For the calculation of the plant specific ideal values, data from the sheet *Data input* (e.g. delivery heads, friction losses, amount of wastewater or sewage sludge) and *Attachments* (efficiencies, specific electricity consumptions) is considered. Lower and upper ideal values result from the fact that required parameters are often declared as a range of values (e.g. see *Attachments*). Therefore, a minimum and maximum ideal value can be determined for each treatment unit. The aggregates which are listed under "others" have no ideal values, therefore their ideal values are the same as the actual "electricity consumption (actual value)". The calculations of ideal values are mainly based on the DWA Set of Rules, most of them integrated in the German Standard DWA-A 216 "Energy Check and Energy Analysis". An overview of formulas is included in Annex A.3 incl. a short reference. As an example, the formula to calculate the ideal value for a pump stations is given below:

$$E = \frac{Q \cdot h \cdot 2{,}7}{(\eta_{pump} \cdot \eta_{motor})} = \frac{Q \cdot h \cdot 2{,}7}{[\eta_{tot}]} = Q \cdot h \cdot e_{spec} \ [kWh/a]$$

5. Actual value/plant related ideal value and saving potentials.

To identify optimisation potential, calculated/ actual electricity consumptions are compared to individual plant related ideal values for each plant section. In this way, minimum and maximum saving potentials can be read from the last columns of the evaluation table. Two diagrams are placed on the bottom of the *Evaluation* sheet in the energy audit tool. Figure 1 displays the shares of electricity consumption per process step. Figure 2 illustrates the comparison of actual electricity consumption and plant related ideal values and thus visualises overall minimum and maximum saving potential

Below the electricity evaluation table, a further brief evaluation of a potentially existing cogeneration plant is given indicating if the electricity production is within an ideal range or not.

5 GRAPHS

Similar to figure 2 of the *Evaluation* sheet, the evaluation | graph 1 highlights the comparison of actual electricity consumption according to *List of consumers* and plant related ideal values for the following treatment stages: mechanical cleaning stage, biological treatment stage, secondary clarifier and sludge treatment.

Evaluation | graph 2 presents a more detailed view on the comparison of actual electricity consumption according to *List of consumers* and plant related ideal values. All existing process steps are included here.

6 HEAT BALANCE

In the sheet *Heat balance* no data needs to be inserted. The *Heat balance* lists heat consumers and producers. Respective lines appear automatically based on the data entered in Data input. If required data was inserted in the *Data input* sheet, the values are either directly transferred to the *Heat balance* sheet or are accounted automatically in the background taking information stated in the *Data input* as basis. In addition, the proportion on the total heat consumption or generation is calculated for each consumer/ producer.

In case that a cogeneration plant is existing, the internal heat supply rate by cogeneration is calculated. Moreover, the cogeneration plant is evaluated from a thermal point of view. Analogue to the *Evaluation* sheet (= electricity evaluation), the heat generation of the cogeneration plant is compared to thermal ideal values. In this way, improvement potentials might be revealed.

To update the *Heat balance* sheet, a random click or pressing the enter key is necessary.

7 ENERGY KEY FIGURES

Determination and comparison of energy key figures is usually done as an initial orienting assessment of the energetic situation of a WWTP and therefore serves as a quick Energy Check. It should usually precede the more detailed Energy Analysis.

In the sheet *Energy key figures* these characteristic energy values are calculated automatically based on the data inserted in the sheets *Data input* and *List of consumers*. Furthermore, plant related key figures can be compared to the medians of the Baltic Sea Region. These medians were ascertained by analysing energy data from up to 66 WWTPs around the Baltic Sea (reference year 2015). For more information check the key figure report.

To update the sheet *Energy key figures*, a random click or pressing the enter key is necessary.

8 OPTIMIZATION

Based on the evaluated saving potentials, a compilation of general hints and suggestions is displayed here based on the following criteria:

a) if the saving potential is ≥ 5 % of the total electricity consumption
b) if the deviation between actual and ideal value is ≥ 150 %

The compilation is intended to support development of specific optimization measures. Due to varying set-ups of WWTPs specific optimization measures need individual design and calculations.

ANNEX

A.1 – Checklist

Check list for required data to perform an energy self-audit at a wastewater treatment plant

☐ **wastewater analysis data of respective reporting year**
at different treatment steps (inflow WWTP, inflow to biological treatment, effluent) as annual average

☐ **basic characteristics of the wastewater treatment plant**
applied technologies, volume of basins, retention time in primary clarification, sludge age, sludge amounts and others

☐ **plots of the layout of the WWTP**

☐ **electricity bill of respective reporting year issued by the power supply company**

☐ **overview of all installed aggregates in specific plant sections**
Amount of aggregates in specific plant sections is needed. Plots of the layout of the WWTP might be helpful. For big electricity consumers such as blowers and pumping stations, more detailed information will be required (see Data input *of the* Energy Analysis Tool*).*

Apart from the amount of installed aggregates, following electrical data of each aggregate is needed to assess its energy consumption:

☐ **electricity measurements from energy meters both from individual aggregates (e.g. blowers) and/ or from plant sections**
Required information is the annual electricity consumption of individual aggregates.

If electricity measurements are not available:
☐ **amperage [A] measurements from individual aggregates**
Electricity actual state [A] and the power factor (cos φ) of each single aggregate is needed to fill in the list of consumers.

If neither electricity nor amperage measurements are available, motor data of each installed aggregate needs to be compiled (e.g. by walking through the plant and collecting required information):
☐ **extended aggregate list with following information for each aggregate:**

◦ nominal voltage [V]
◦ installed/ nominal power [P_{nom}]
◦ efficiency category (IE1/ IE2/ IE3/ EFF1/ EFF2)
◦ operating hours per year [h/a]

☐ **specific values for digester gas production and conversion into electricity/ heat**

☐ **information on heat consumption and production/ supply**

A.2 – Assignment of aggregates to respective plant sections

Plant section	Aggregates to be included	Aggregates NOT to be included
grit chamber, primary and secondary clarifier	scraper engines	heating installations used at cold temperatures
mechanical cleaning stage:		
grid rack and screening plant	coarse and fine screens, sieving aggregates, screen waste conveyors, aggregates for screen washing and pressing	pumps/ hydrophores, screen macerators, grit washing system, grit classifier
other aggregates in mechanical cleaning stage	screen macerators, Grit pumps/ grit transporter engines, grit separator, Grit washing system, grit classifier, grease pumps, grease macerators, primary sludge pumps etc.	
sludge treatment:		
surplus sludge thickening	belt filter presses/ centrifuges, polymer pumps	Feeding and discharge pumps
other aggregates	influent sludge pumps, discharge pumps, aggregates for primary sludge thickening (gravity thickening), reject water pumps	
sludge dewatering:		
(digested) sludge dewatering	screen or filter presses/ centrifuges, feeding pumps, dosing pumps (if existing)	discharge pumps for dewatered sludge, macerators
other aggregates	discharge pumps, macerators, transporter engines, leachate water pumps	

A.3 – Calculation approaches for determination of the plant-related ideal values for electricity consumption

Treatment process / consumer	Energy consumption calculation E = Yearly energy consumption [kWh/a]	Optimum values / range of values	Factors influencing the energy efficiency	Reference
Screen	$E = e_{spec} \cdot PE_{COD,120}$	$e_{spec} = 0,05 - 0,1$ kWh/($PE_{COD,120} \cdot a$)	Water volume Screening treatment Number of screens	DWA-A 216 (2015)
Grit chamber and grease trap (Aeration)	$E = \dfrac{Q_{air} \cdot \Delta p \cdot t}{\eta_{tot} \cdot 367}$ [kWh/a] $Q_{air} = q_{air,GC} \cdot V_{GC}$ [m³/h] $q_{air,GC}$ = spec. air input [m³/(m³·h)] V_{GC} = grit chamber volume [m³] t = operating hours of blowers [h/a] $\Delta p = h_d + h_{loss}$ [m] h_d = blow-in depth [m] η_{tot} = efficiency of blower and motor	$q_{air,GC} = 0,5 - 1,3$ [m³/(m³·h)] $\eta_{tot} = 0,55 - 0,62$ Rotary blowers	Grit chamber volume Blow-in depth Transmission losses Specific air input Blower efficiency Operating hours	DWA-A 216
Scraper (grit chamber, primary / secondary settling tank)	$E = P \cdot t$ P = Electric power demand [kW] t = operating hours [h/a]	$P_{Scraper} = 0,3 - 1,0$ kW/Tank	Operating hours Number of tanks Scraper resistance	DWA-A 216
Pumps, lifting equipment	$E = \dfrac{Q \cdot h \cdot 2,7}{\eta_{pump} \cdot \eta_{motor}} = \dfrac{Q \cdot h \cdot 2,7}{\eta_{tot}} = Q \cdot h \cdot e_{spec}$ [kWh/a] Q = volume [m³/a] η_{pump} = hydraulic efficiency pump η_{motor} = motor efficiency $h = h_{man} = h_{geod} + h_{loss}$ [m] *centrifugal pumps* $h = h_{geod}$ [m] *screw pumps*	Estimation of η_{tot} or related e_{spec}, η_{pump}, η_{motor} according to sheet Attachments A1), A2)	Delivery head (geodetic head, local and friction losses) Flow (sludge volume, recirculation rate etc.) $\eta_{pumpe} = f(Q,h)$, Motor average load	

Treatment process / consumer	Energy consumption calculation E = Yearly energy consumption [kWh/a]	Optimum values / range of values	Factors influencing the energy efficiency	Reference
Aeration	$E = \dfrac{SOTR \cdot t}{SAE}$ [kWh/a] $E = \dfrac{Q_{air} \cdot \Delta p \cdot t}{\eta_{tot} \cdot 367}$ [kWh/a] SOTR = standard oxygen supply [kg/h] as an average value of the aeration phase SAE = oxygen transfer efficiency in clean-water [kg/kWh] T = annual period of aerated phases [h/a] h_d = blow-in depth [m] h_{loss} = Pressure losses [m] $\Delta p = h_d + h_{loss}$ η_{tot} = $\eta_{blower} \cdot \eta_{motor}$ η_{blower} = Blower efficiency η_{motor} = Motor efficiency 2,72 = Conversion factor units and physical constants Q_{air} = Air volume intake under operating conditions [m³/h]	$C_{O2,\,AT}$= 1 mg/L - 2 mg/L SAE, in clean water, values according to sheet Attachments A3) Efficiencies *rotary blowers* η_{tot}= 0,55 - 0,62 *turbo compressor with control-device* η_{tot}= 0,68 - 0,77 *Turbo compressor with high frequency motor* η_{tot}= 0,77 - 0,8	Average O_2-concentration α-value **aerator**: type, layout (arrangement), aging, pressure admission, occupation density. Common occupation density per tank, which are planned for nitrification/denitrification, are within the range 10% - 15% **Blower efficiency** **Local pressure losses h_{loss}** (Orifice plate, air filter, aerators etc. Approx. 50 -100 mbar = 0.5 m - 1 m water column) **Blow-in depth** (little influence at a usual depth from 3- 6 m)	
Agitator/ mixers/ circulation (aeration tank)	$E = \dfrac{V_{circul.} \cdot e_{spec} \cdot t}{1000}$ [kWh/a] $V_{circul.}$ = volume of circulated tank (m³) t = operating hours (h/a)	$V_{circul.}$ (m³) e_{spec} (W/m³) > 2.000 1,5 > 1.000 – 2.000 2,0 – 1,5 ≥ 500 – 1.000 2,5 – 2,0 ≥ 200 – 500 4,0 – 2,5	Type of agitator; number of agitators; volume and geometry of the aeration tank; Operating hours	

Treatment process / consumer	Energy consumption calculation E = Yearly energy consumption [kWh/a]	Optimum values / range of values	Factors influencing the energy efficiency	Reference
Membrane bioreactor	$E = e_{spec} \cdot PE_{COD,120}$	e_{spec} = 0,73 kWh/m³ - 1,83 kWh/m³ or approx. 49 - 208 kWh/($PE_{COD,120} \cdot a$)	Type of membrane (size of pores, material, construction of modules); the mode of operation (Cross-Flow, Semi-Cross-Flow, Dead-End); The flow to the membranedie Anströmung der Membran (IN-OUT, OUT-IN); The necessary (working) pressure; The selected cycle (e.g. Filtration, Air flushing, permeat flushing, combined air and permeat flushing; The structure oft he drainage area (separate sewers lead to less energy demand due to lower wastewater volume	Krebber, K. (2014): Optimierung der Energiebilanz von Membranbioreaktoren, cited in NRW-Handbook Energy in Wastewater Treatment 2018
Surplus sludge thickening	$E = e_{spec} \cdot Q_{ss}$ Q_{ss} = amount of surplus sludge (m³/a)	**Centrifuge with pFA:** e_{spec} = 0,6 kWh/m³- 1 kWh/m³ ***Centrifuge without pFA (not considered):*** *e_{spec} = 1,0 kWh/m³ - 1,4 kWh/m³* **Dissolved air flotation:** e_{spec} = 0,6 kWh/m³ - 1,2 kWh/m³ **Travelling screen, rotary screen**: e_{spec} = < 0,2 kWh/m³ *minimal value set to 0,05 kWh/m³*	Amount of sludge; TSS- content of surplus sludge; Type of aggregate	

Treatment process / consumer	Energy consumption calculation E = Yearly energy consumption [kWh/a]	Optimum values / range of values	Factors influencing the energy efficiency	Reference
Turnover of digestion tank	$E = \dfrac{V_{DT} \cdot e_{spec} \cdot t}{1000}$ [kWh/a] V_{DT} = volume of digestion tank [m³] t = operating hours of turnover [h/a]	Stirrer (continuously operated), Gas injection (operated from 8 h/d to 16 h/d): e_{spec}= 3 W/m³ - 6 W/m³ *Gas injection is reported with up to 10 W/m³* exterior turnover: e_{spec}= 6 W/m³ - 10 W/m³	Selected circulation rate of the stirrers and pumps Sludge volume Dry residue of the raw sludge Inhabitant specific digester volume	
(Digested) sludge dewatering	$E = e_{spec} \cdot Q_{DS}$ Q_{DS}= Amount of digested sludge (m³/a),	**Centrifuge** e_{spec}= 1,0 - 1,6 (1,6 - 2,2) kWh/m³ **Traveling screen press** e_{spec} = 0,5 - 0,8 (1,1-1,4) kWh/m³ **Membrane filter press** e_{spec} = 1,0 - 1,2 (1,5 - 1,8) kWh/m³ **Hydraulic bag filter press** e_{spec} = 0,7 - 0,9 (1,5 - 1,8) kWh/m³ **Screw press** e_{spec} = 0,2 - 0,5 (0,6 - 1,0) kWh/m³ (values in brackets are valid if feeding pumps and conditioning aggregates are included)	Amount of digested sludge, solids, dewatering aggregate If lime/iron is used for conditioning, values reported for filter presses are: e_{spec} = 1,0 - 1,2 (1,8 - 2,0) kWh/m³	
Membrane for post treatment	$E = e_{spec} \cdot Q_d \cdot 365$	e_{spec} = 0,1 – 0,2 kWh/m³ (Dead-End)		

Treatment process / consumer	Energy consumption calculation E = Yearly energy consumption [kWh/a]	Optimum values / range of values	Factors influencing the energy efficiency	Reference
Flocculation filtration	$E = e_{spec} \cdot Q_d \cdot 365 = 0{,}0224 \cdot Q_d \cdot 365$ Ideal 2-step- filtration - lifting up wastewater to 3m height - Flocculants dosage - Washing: Air purging Backwash water - Recycling rejected sludge water	 e_{spec} =15,0 Wh/m³ e_{spec} =0,20 Wh/m³ e_{spec} =1,20 Wh/m³ e_{spec} =3,00 Wh/m³ e_{spec} =3,00 Wh/m³	Air purging pumps and blower, Floating sludge to effluent, Backwashing cycles	NRW Handbook Energy in Wastewater Treatment 1999
UV Disinfection	$E = e_{spec} \cdot Q_d \cdot 365$	e_{spec} = 0,03 – 0,06 kWh/m³	Energy demand is directly connected to intensity (in W/m²) - Necessary reduction of pathogenic germs, bacteria - Matrix of the wastewater (suspended solids, transmission... - Type of UV (low pressure, medium pressure or UV-LEDs) - Flow - Wear of the equipment - Control concept of the UV-disinfection unit	DWA-M 205
Exhaust air cleaning	$E = e_{spec} \cdot Q_{air} \cdot 365$	e_{spec} = 0,005 – 0,008 kWh/m³		DWA-A216 (Draft)

A.4 – Calculation approaches for determination of the plant-related ideal values for electrical energy production

Treatment process / consumer	Energy production calculation E = Yearly energy production [kWh/a]	Optimum values / range of values	Factors influencing the energy efficiency	Reference
CHP (electrical energy)	$E = \eta_{el} \cdot Q_{a,DG} \cdot H_i \cdot N_{CHP}$ [kWh/a] η_{el} = electric efficiency $Q_{a,DG}$ = annual amount of produced digester gas H_i = net calorific value of digester gas N_{CHP} = total percentage of digester gas used for cogeneration	η_{el}: Attachment A8	Size of CHP Type of CHP (Diesel, Otto, Gas, Microturbine) degree of digester gas utilisation (storage possibilities failures, flare losses) type of motor and wear supercharger, mixture-cooling, construction size, degree of utilisation	DWA-A 216

A.5 – Calculation approaches for heat balance

Treatment process / consumer	Heat consumption/production calculation E = Yearly energy consumption [kWh/a]	Optimum values / range of values	Influencing factors	Reference
CHP (heat production)	$E_{th} = \eta_{th} \cdot Q_{a,DG} \cdot H_i \cdot N_{CHP}$ [kWh/a] η_{th} = thermal efficiency $Q_{a,DG}$ = annual amount of produced digester gas H_i = net calorific value of digester gas N_{CHP} = total percentage of digester gas used for cogeneration	η_{th} Attachment A9		DWA-A 216
Sludge heating	$E_{th} = Q_{PS+SS} \cdot \Delta T \cdot e_{spec}$ [kWh/a] Q_{PS+SS} = raw sludge volume [m³/a] ΔT_{PS+SS} = Temperature difference between raw sludge and digester (K) e_{spec} = specific heat demand = 1,16 kWh/(m³·K)		Raw sludge volume and temperature; Degree of raw sludge pre-thickening; Digester temperature	

Sludge drying
Further on-site heating
	$E_{th} = \eta_{th} \cdot Q_{\text{heating oil or natural gas or wood pellets}}$ [kWh/a]
	    or
	    $\eta_{th} \cdot Q_{a,DG} \cdot H_i \cdot N_{CHP}$ [kWh/a]
	
	n_{th} = 0,95 (fix)
	$H_{i,source}$ = Calorific value of heat energy source
	$Q_{\text{heating oil or natural gas or wood pellets or digester gas}}$ = annual amount
		$H_{i,source}$: Attachment A10		

Sludge incineration	$E_{th} = Q \cdot 1000 \cdot H_{i,sludge} \cdot 0{,}277778$ [kWh/a]	Net calorific values of incinerated sludge is considered (attachment A11	TS content, type of sludge	

A.6 – Calculation approach for determination of the plant-related ideal value for the aeration of biological reactor

Plant-related ideal values for the aeration in the biological reactor can be determined as follows:

$$E = \frac{SOTR \cdot t_{aerated}}{SAE} \quad \left[\frac{kWh}{a}\right] \tag{1}$$

The **Standard Aeration Efficiency (SAE)** is given below and can also be found in table A3 of the sheet "Attachments" within the Energy Audit Tool.

Table 3 – guideline values for compressed air and surface aeration systems according to DWA-M 229-1 (2013)

performance table for pressure aeration systems *		
	favourable	medium
System	**SAE**	**SAE**
Area-wide aeration	4,2 – 4,5	3,3 – 3,4
Aeration plus turnover	3,7 – 4,2	3,2 – 3,3
performance table for surface aeration		
Gyroscopic and cylinder aerators	1,8 – 2,0	1,6 – 1,8

* all values at pure water conditions up to blow-in-depth of 6m

The **Standard Oxygen Transfer Rate in clean water (SOTR)** can be determined as follows:

$$SOTR = \frac{f_d \cdot C_{S,20}}{\alpha \cdot \left(f_d \cdot C_{S,T} - C_{02,AT}\right) \cdot \theta^{(T_w - 20)}} \cdot OU_h \quad \left[\frac{kgO_2}{h}\right] \tag{2}$$

$f_d = 1 + \dfrac{h_d}{20,7} \cdot \left(1 + \dfrac{0,5 \cdot h_d}{10,33}\right) \quad [-] \quad for\ pressure\ aeration$	(3)
$f_d = 1 + \dfrac{h_{w,AT}}{150} \quad [-] \quad for\ surface\ aeration$	(4)
$C_{S,T} = \dfrac{2234,34}{(T_W + 45,93)^{1,31403}} \quad \left[\dfrac{mg}{L}\right]$	(5)
$C_{S,20} = C_{S,T}$ at a wastewater temperature of 20 °C	
$C_{O2,AT} = 1 \dots 2 \quad \left[\dfrac{mg}{L}\right]$ (range which causes lower and upper ideal value)	(6)
$\theta = 1,024$	(7)
α according to table 3 (only load case 1 is considered)	

*Table 4 – guide numbers of α-value according to DWA-M 229-1 (2017)*

aeration system and process variations	guide numbers		
	load case 2 (maximal oxygen demand in the actual state)	load case 1 (average oxygen demand in the actual state)	load case 3 (minimal oxygen demand in the actual state)
	α_{min}	α_{medium}	α_{max}
surface aeration	0,90	**0,925**	0,95
pressure aeration:			
nitrogen elimination with continuous flow	0,60	**0,75**	0,85
nitrogen elimination in SBR	0,50	**0,65**	0,80
simultaneous aerobic stabilisation	0,70	**0,80**	0,90
carbon elimination	0,35	**0,50**	0,60

Another essential part to determine the **Standard Oxygen Transfer Rate in clean water (SOTR)** is the oxygen demand. Three different load cases can be calculated here as well. However, only load case 1 is considered since it is the most relevant load case to determine the annual energy consumption of the aeration system:

$$OU_h = \frac{(OU_{d,C} - OU_{d,D}) + OU_{d,N}}{24} \quad \left[\frac{kgO_2}{h}\right] \tag{8}$$

(load case 1: average oxygen demand in the actual state)

The oxygen demand is strongly connected to the fractionation of COD and nitrogen:
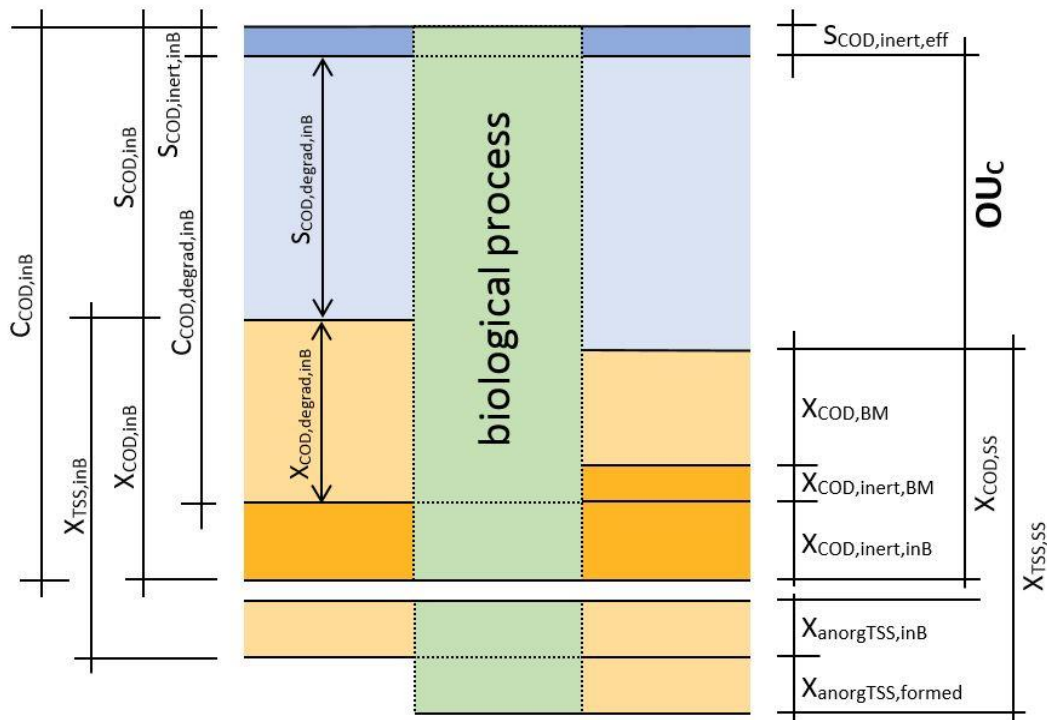
$$C_{COD,inB} = S_{COD,inB} + X_{COD,inB} \quad [mg/l]$$

Relevant formulas to calculate daily oxygen uptake for carbon removal:

$OU_{d,C} = Q_d \cdot OU_C \ / \ 1.000 \quad \left[\frac{kg_{O_2}}{d}\right]$	(9)
$OU_C = C_{COD,degrad,inB} + C_{COD,dos} - X_{COD,BM} - X_{COD,inert,BM} \quad \left[\frac{mgO_2}{L}\right]$	(10)
$C_{COD,degrad,inB} = C_{COD,inB} - S_{COD,inert,outS} - X_{COD,inert,inB} \quad \left[\frac{mg}{L}\right]$	(11)
$S_{COD,inert,outS} = S_{COD,outS} = S_{COD,inert,inB} = f_S \cdot C_{COD,inB} \quad \left[\frac{mg}{L}\right]$	(12)
f_S - share of inert dissolved COD (0,05 … 0,1); recommendation $f_S = 0,05$ for municipal wastewater	(13)
$X_{COD,inert,inB} = f_A \cdot X_{COD,inB} = f_A \cdot (C_{COD,inB} - S_{COD,inB}) \quad \left[\frac{mg}{L}\right]$	(14)
f_A – share of inert particulate COD (0,2 … 0,35); recommendation $f_A = 0,3$ for municipal wastewater	(15)
$S_{COD,inB} = C_{COD,inB} - X_{COD,inB} \quad \left[\frac{mg}{L}\right]$	(16)
$X_{COD,inB} = X_{TSS,inB} \cdot 1,6 \cdot (1 - f_B) \quad \left[\frac{mg}{L}\right]$	(17)
f_B - share of inorganic residue of filterable solids; recommendation $f_B = 0,3$ (raw wastewater) or $f_B = 0,2$ (primary clarified wastewater)	(18)

$$X_{COD,BM} = \left(C_{COD,degrad,inB} \cdot Y + C_{COD,dos} \cdot Y_{COD,dos}\right) \cdot \frac{1}{1 + b \cdot t_{TTS} \cdot F_T} \quad \left[\frac{mg}{L}\right] \tag{19}$$

$$X_{COD,inert,BM} = 0{,}2 \cdot X_{COD,BM} \cdot t_{TSS} \cdot b \cdot F_T \quad \left[\frac{mg}{L}\right] \tag{20}$$

Relevant formulas to calculate daily oxygen uptake for carbon removal, which is covered by denitrification:

$$OU_{d,D} = Q_d \cdot 2{,}86 \cdot S_{NO3,D} \ / \ 1.000 \quad \left[\frac{kg_{O_2}}{d}\right] \tag{21}$$

$$S_{NO3,D} = C_{N,inB} - S_{orgN,outS} - S_{NH4,outS} - S_{NO3,outS} - X_{orgN,BM} - X_{orgN,inert} \quad \left[\frac{mg}{L}\right] \tag{22}$$

$$X_{orgN,BM} = 0{,}07 \cdot X_{COD,BM} \quad \left[\frac{mg}{L}\right] \tag{23}$$

$$X_{orgN,inert} = 0{,}03 \cdot \left(X_{COD,inert,BM} + X_{COD,inert,inB}\right) \quad \left[\frac{mg}{L}\right] \tag{24}$$

Relevant formulas to calculate daily oxygen uptake for nitrification:

$$OU_{d,N} = Q_d \cdot 4{,}3 \cdot \left(S_{NO3,D} - S_{NO3,inB} + S_{NO3,outS}\right) \ / \ 1.000 \quad \left[\frac{kg_{O_2}}{d}\right] \tag{25}$$

Whenever concentrations at the inflow of the aeration tank weren't available, reduced concentrations at the inlet of the WWTP were taken. The reduction was chosen according on the retention time of the primary clarification:

Table 5 – Removal efficiencies of primary clarification

η in %	retention time in primary clarification		
	0,75 – 1,5 h	1,5 – 2 h	> 2,5 h
C_{CSB}	30	35	40
X_{TSS}	50	60	65
C_{TKN}	10	10	10
C_P	10	10	10

Theoretical background on oxygen demand/ oxygen uptake:

When considering an activated sludge process (including nitri- and denitrification) with separate sludge stabilization, there is a demand of free dissolved oxygen in the aerated/ aerobic zones of the biological reactor in order to perform carbon elimination and nitrification. In the anoxic zone however, which is used for denitrification, required oxygen is already available in an undissolved bound matter as NO_3^-. As a result, there is an oxygen output in the form of CO_2 and H_2O. For the determination of the overall oxygen uptake (OU) this means the following:

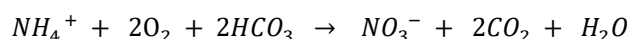$$OU = OU_{C-elimination} - OU_{Denitrification} + OU_{Nitrification}$$

1. C-elimination: Demand of dissolved oxygen to ensure aerobic conditions for the growth of heterotrophic microorganisms which transform dissolved organic wastewater constituents to solid inorganic end-products

                   Oxygen uptake: 1,2 kgO₂/ kgBOD₅ [ATV-DVWK-A 131, 2000]

$$OU_{d,C} = Q \cdot OU_c \ / 1000 \quad \left[\frac{kgO_2}{d}\right]$$

2. Nitrification: $NH_4^+ + 2O_2 + 2HCO_3 \rightarrow NO_3^- + 2CO_2 + H_2O$
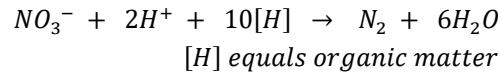
                   Demand of dissolved oxygen to ensure aerobic conditions for the growth of autotrophic bacteria (nitrificants) which perform oxidation of ammonium and nitrite

Oxygen uptake: 4,3 kgO$_2$/ kgN [DWA-A 131, 2016]

$$OU_{d,N} = Q \cdot 4{,}3 \cdot \left(S_{NO3,D} - S_{NO3,inB} + S_{NO3,eff}\right) \ / \ 1000 \quad \left[\frac{kgO_2}{d}\right]$$

3- Denitrification:
$$NO_3^- \ + \ 2H^+ \ + \ 10[H] \ \rightarrow \ N_2 \ + \ 6H_2O$$
$$[H] \ equals \ organic \ matter$$

Demand of undissolved bound oxygen, which is already available due to the end-products of nitrification (NO$_3^-$); reduction of oxidized nitrogen compounds to pure nitrogen through growth of heterotrophic bacteria under anoxic conditions
Oxygen output: 2,86 kgO$_2$/kgS$_{NO3,D}$ [DWA-A 131, 2016]

$$OU_{d,D} = Q \cdot 2{,}86 \cdot S_{NO3,D} \ / \ 1000 \quad \left[\frac{kgO_2}{d}\right]$$

The oxygen uptakes and output were calculated based on the guideline of DWA-A 131 (2016). Especially for determining the oxygen demand for carbon removal, a detailed COD fractioning is essential which will be addressed later. Furthermore, information on biomass and sludge age (see below) is necessary for carbon removal as well as for nitri- and denitrification, while for the latter also data on the nitrogen cycle is essential. In **Error! Reference source not found.** an overview of the influencing parameters for the respective calculations are g iven. Highlighted in blue are the parameters which are indispensable for a proper calculation of the oxygen demand, in light blue the ones which are nice to have but could be substituted. The other listed parameters can be derived from the highlighted ones and from scientifically proven assumptions.

Table 6 – Influencing and indispensable parameters for determining the oxygen demand

Influencing parameters		units	Oxygen uptake during carbon removal	Oxygen uptake during Nitrification	Oxygen output during Denitrification
Flow rate		[m³/d]	✓	✓	✓
$C_{COD,inB}$ (if not available: $C_{COD,inf}$)	*$C_{COD,degrad,inB}$*	[mg/l]	✓	-	-
$S_{COD,inert,inB} = S_{COD,inert,eff} = C_{COD,eff}$		[mg/l]	✓	-	-
$X_{COD,inert,inB} = X_{COD,inert,eff}$		[mg/l]	✓	✓	✓
($C_{COD,dosed}$)		[mg/l]	(✓)	-	-
$X_{COD,inB}$		[mg/l]	✓	-	-
$X_{SS,inB}$ (if not available: $X_{SS,inf}$) (if neither available, Sieker's fractionation approach could be used, which bypasses this parameter)		[mg/l]	✓		-
$X_{COD,BM}$		[mg/l]	✓	✓	✓
$X_{COD,inert,BM}$		[mg/l]	✓	✓	✓
$C_{N,inB}$ (if not available: $C_{N,inf}$)	*$S_{NO3,D}$*	[mg/l]	-	✓	✓
$S_{orgN,eff}$		[mg/l]	-	✓	✓
$S_{NH4-N,eff}$		[mg/l]	-	✓	✓
$S_{NO3-N,eff}$		[mg/l]	-	✓	✓
$X_{orgN,BM}$		[mg/l]	-	✓	✓
$X_{orgN,inert}$		[mg/l]	-	✓	✓
$S_{NO3,inB}$ (if not available, assumption $S_{NO3,inB} = 0$)		[mg/l]	-	✓	-
Volume of aerated tank V_{aer}	*Sludge age t_{SS}*	[m³]	✓	✓	✓
Volume of anoxic tank V_{anox}		[m³]	✓	✓	✓
$MLSS_{AT}$		[g/l]	✓	✓	✓
$B_{BOD5,inB}$ (if not available: $B_{BOD5,inf}$ or daily excess sludge production)		[kg/d]	✓	✓	✓
Temperature in aeration tank		[°C]	✓	✓	✓
Share of municipal/ industrial wastewater	*Influence on factors estimating*	[-]	✓	-	-
Use of primary clarification		[-]	✓	-	-
Retention time in primary clarifiers or volume of primary clarifiers		[h] / [m³]	✓	-	-

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IWAMA project aims at improving wastewater management in the Baltic Sea Region by developing the capacity of the wastewater treatment operators and implementing pilot investments to increase the energy efficiency and advance the sludge handling.

The project is funded by the Interreg Baltic Sea Region Programme 2014–2020.

Budget: EUR 4.6 million

Duration: March 2016–April 2019