D.T.2.3.2 FIRST PART OF THE FEASIBILITY STUDY (STEP 1 + 2) FOR THE PILOT PROPOSED - GERMANY

Project Title: REEF2W Increased renewable energy and energy efficiency by integrating, combining and empowering urban wastewater and organic waste management systems

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Table of content

List of figures

List of tables

Abbreviations

EE	energy efficiency
RE	renewable energy
WWTP	Waste water treatment plant
ISA	Integrated Sustainability Assessment
LCA	Life Cycle Assessment

1. Introduction

1.1. The REEF 2W Project

In the wake of the “Energiewende”, an increased focus is concentrating on the yet unexploited energy-saving potential of the wastewater sector. Wastewater treatment plants (WWTPs) are large consumers of energy and often have key shares in the carbon footprint of municipalities and urban governments. Their energy consumption usually accounts for the bulk of operational costs of wastewater utilities, sometimes up to 60 per cent. However, despite being a large source of electricity and heat, sewage is generally overlooked. In fact, the amount of energy it contains can be 10 times bigger than is required to treat it. Lately an increasing number of wastewater operators have deployed energy-efficiency measures and novel technologies to better harness the energy of sewage. Evaluations of pioneering projects show that utilities are not only capable of becoming energy self-sufficient, but also suppliers of energy thereby diversifying the local mix.

The project Reef 2W recognizes that wastewater is an integral part of the water-energy nexus. The project is funded by the European Development Bank’s Interreg Central Europe Programme and is carried out through 11 research institutes and wastewater utilities from Italy, Czech Republic, Germany, Croatia, and Austria. The projects main objective is to drive up energy efficiency and renewable energy production of wastewater treatment plants. It provides an innovative approach in integrating organic waste and wastewater streams and infrastructures. Where beneficial, bio-waste will be used to enrich sewage sludge, helping to elevate outputs of heat and electricity in a process called co-fermentation. To prove that the new technologies can be technically feasible and economically viable, project partners will develop a comprehensive assessment tool in close collaboration with utility operators in- a series of workshops. Another key task of Reef 2W is to investigate the legal and policy framework conditions and to advocate for policy alternatives that spur the large-scale use of wastewater-to-energy solutions.

1.2. Scope of the deliverable

Purpose

The purpose of this deliverable is to analyse the energy efficiency (EE) and the potential to produce renewable energy (RE) at the Schönerlinde WWTP in Berlin, Germany, one of the five projetc’s pilots. These form the first two steps of the Integrated Sustainability Assessment (ISA). Implementing the first part of the feasibility study will allow to understand how much energy the WTTPs currently use, and at what level of efficiency. Furthermore it will provide a quantitative understanding about the potential to increase energy outputs. The (fictitious) technological upgrades defined for this pilot are measures to optimise existing processes and to install new RE technologies (see Figure 1 below).

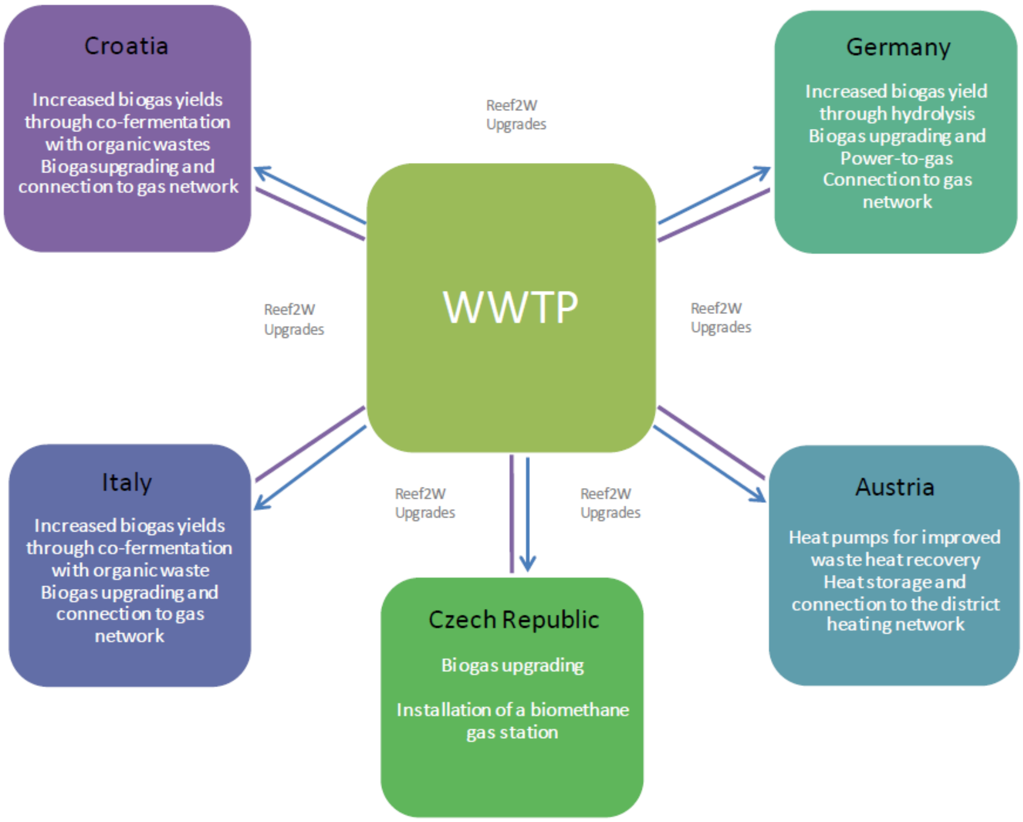

Figure 1: Presentation of the Reef 2W upgrades in the five European pilot plants.

Relation to previous deliverables

The ISA methodology was developed in Deliverable DT.1.4.1-3. and has been tested during the training courses. While the feedback gathered from the participants is being integrated, the present Feasibility Study is the first organized attempt to test the ISA tool. The results for applying the first two steps of the ISA tool will provide the data required to conduct the second part of the Feasibility Study. The results will also be important for other communicational purposes. For example, they provide evidence of the potential of wastewater-to-energy solutions, which is demonstrated in the Regional Strategies (DT2.5.1) and the MOUs (DT.2.5.2).

Structure and approach

There will be five reports using the following approach. First the background chapter introduces the ISA-methodology and its five steps, as well as the benefits that can be generally expected of the REEF 2W-solutions. The second part, mostly building on previous deliverables, describes technological characteristics of the WTTP and the envisioned (fictitious) technological upgrades investigated during REEF 2W. Based on that, chapter 4 analyses the energy performance of the WTTP and evaluates the current level of energy efficiency. Chapter 5 analyses the energetic yields that result from deploying the RE solutions. Lastly, the final part will distil key results, shortcomings of the methodology and data.

2. Background

2.1. The Integrated Sustainability Assessment

The ISA tool is used to systematically assess technical innovations for energy optimisation of WWTPs on different sustainability criteria. The instrument allows for making predictions about potentials to improve energy performance, the technical feasibility or the environmental sustainability of the Reef 2W solutions. For more detailed information, please check DT.1.4.1-3.

The ISA instrument, which was developed as an Excel spreadsheet and online tool, comprises five core steps, of which only the results of steps I and II are presented in this study.

I: EE is determined through a comparative analysis that measures current energy consumption against recognized efficiency standards. This benchmarking shows the optimization potential for heat and electricity savings.

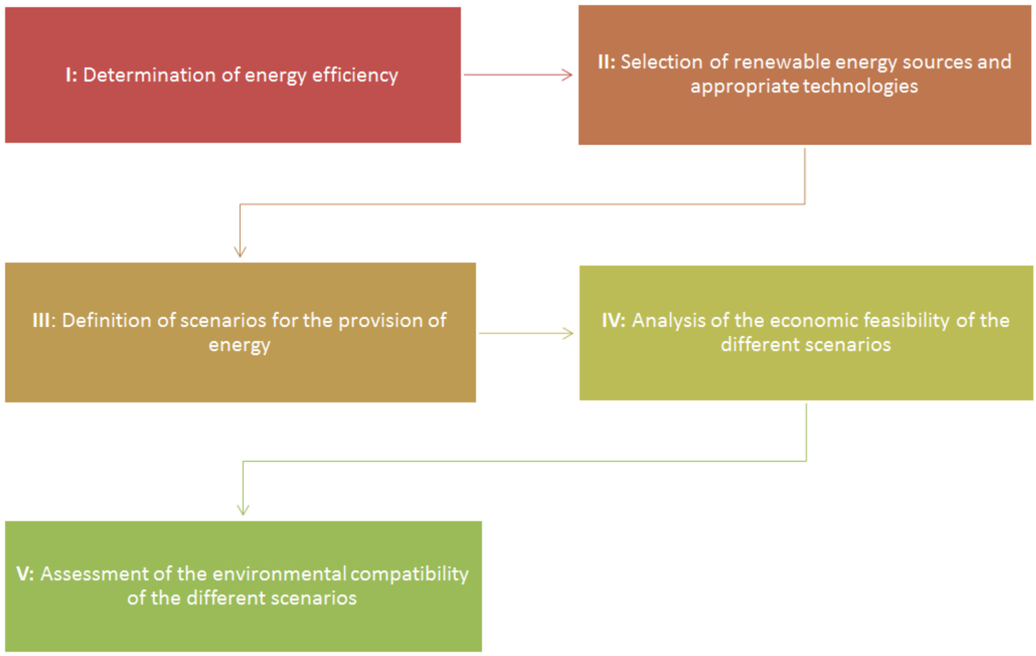

Figure 2: The five steps of the ISA method

II: Suitable technologies are selected through a potential analysis that compares different RE sources. Emphasis in the project is set on improving heat and biogas yields while increasing the efficiency of subsequent uses such as biogas upgrading.

III: Different scenarios demonstrate how excess energy can be used for self-supply of the WWTP and feed-in into the gas, electricity and heat grid. These take into account the amount of available surplus energy, energy consumption and energy demand of neighbouring settlements as well as existing grid infrastructures.

IV: The economic feasibility assessment of planned measures will be carried out through a life-cycle cost analysis incorporating generated revenues from energy savings and sales, and investment and maintenance costs.

V: To assess the environmental impacts, a Life Cycle Assessment (LCA) focusing on CO_2-reduction potentials is carried out for each scenario.

2.2. The Expected Benefits

The implementation of REEF 2W technologies entails several advantages from an energetic, economic and environmental point of view.

Table 1: Energetic, economic and environmental benefits of the REEF 2W technological solutions

Energy optimization	Economic feasibility	Environmental sustainability
Additional process steps such as thermal hydrolysis or co-fermentation with organic substances increase biogas yields. **Additional heat production is achieved by heat pumps in the sewer.** **A more efficient utilization of biogas is achieved by Combined Heat and Power or biogas upgrading.** **More efficient energy consumption, increased energy yields and the production of storable biomethane increase system security and flexibility.**	Energy savings and self-supply of energy and heat lead to a reduction in operating costs. Sales of excess heat, electricity and biomethane allows for additional revenues. Reduced sewage sludge volumes reduce disposal costs, especially where cost-intensive waste incineration is the only option. Optimized economics of wastewater treatment plants lead to financial savings for municipalities.	Energy savings and reduced use of fossil fuels result in a lower CO2-footprint of WWTPs. Biogas obtained from sewage is a more environmentally friendly biogas compared to crop-based feedstocks. Recycling of organic waste in sewage treatment plants replaces the CO2-intensive disposal on landfills. The wastewater sector increases its contributions to a sustainable energy transition and climate protection.

3. Description of pilot site (status quo)

3.1. Characteristics of the WTTP

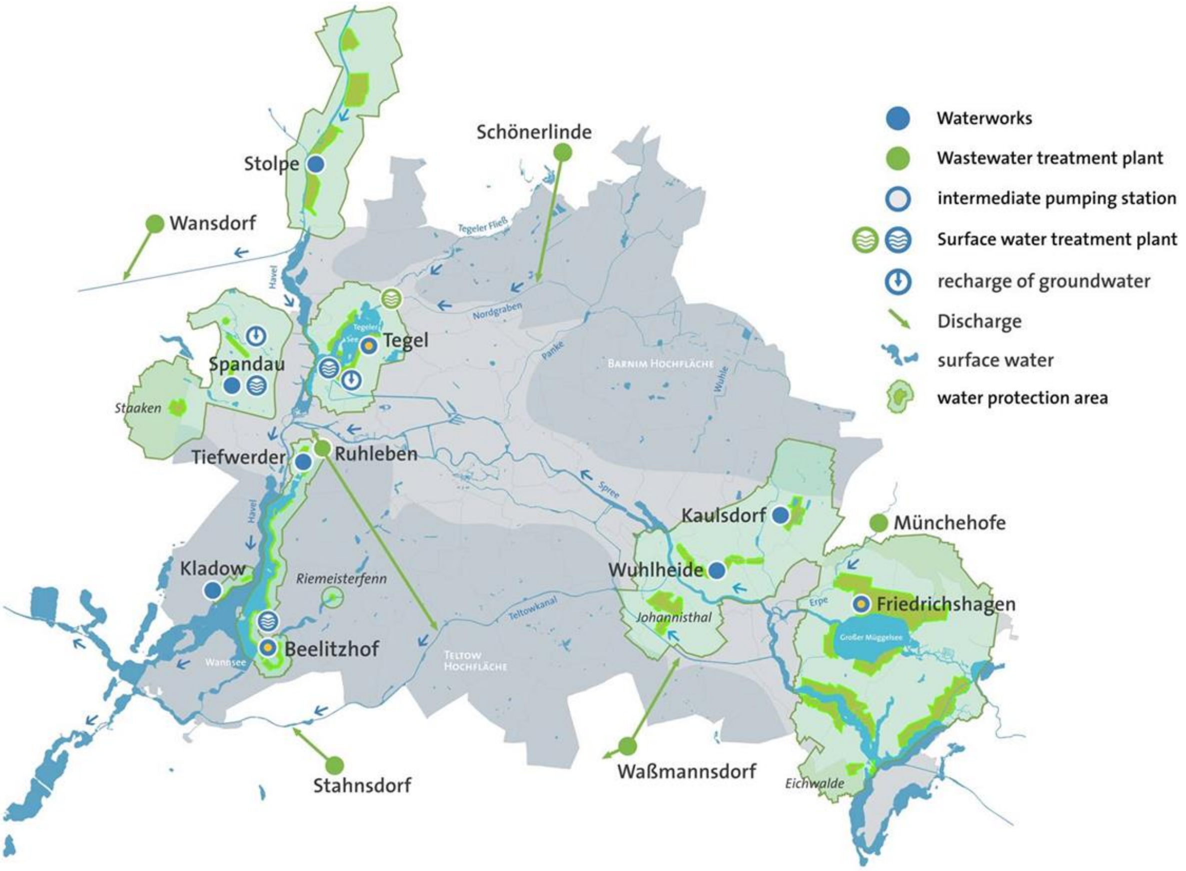

Figure 3: The location of Schönerlinde WWTP in Berlin (Source: BWB)

The WWTP Schönerlinde is part of Berlin's Water Works (Berliner Wasserbetriebe – BWB). It provides 3.7 million people in Berlin and Brandenburg with drinking water, as well as collection and advanced biological wastewater treatment. The wastewater in Schönerlinde is treated by mechanical and biological processes with biological phosphate elimination in combination with nitrification and denitrification. The sewage sludge is digested in digesters with mesophilic digesting at approx. 35°C and subsequently drained in centrifuges. Figure 2 gives an overview of the treatment process at Schönerlinde sewage treatment plant. The following technical dates are from the information sheet of BWB (BWB, 2019).

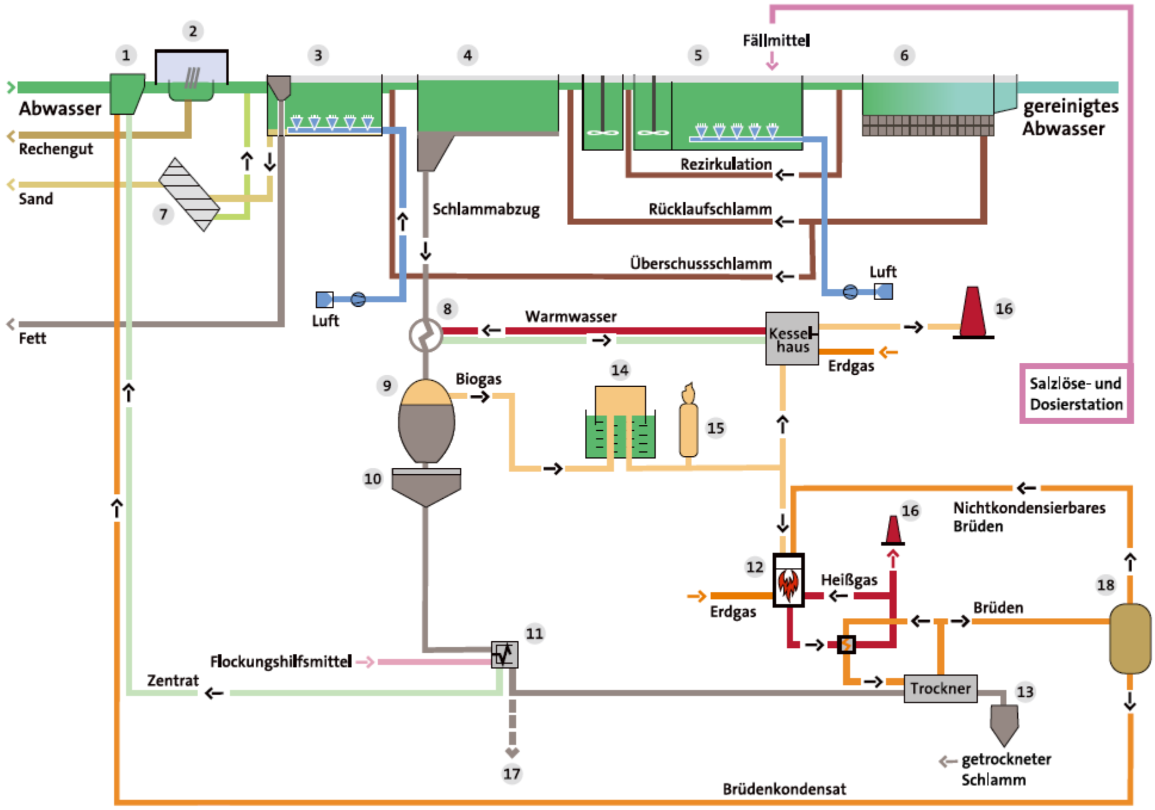

Figure 4: Process scheme of wastewater treatment in Schönerlinde (BWB, 2019)

Mechanical treatment:

Five rake screens remove 1.5 tons of screenings from the wastewater daily. Three aerated double grit chamber classifier approximately two tons of sand per day. Eight rectangular sedimentation tanks are available as Pre-treatment tanks with a total volume of 14,800 cubic meters.

Biological purification:

The aeration tanks consist of eight basins as anaerobic zone, as well as fourteen basins as anoxic and aerobic zone. These have a total volume of 130,500 cubic meters. Aeration systems installed in the activated sludge tank consists of membrane aerators as well as ceramic aerators. As clarification serve twelve rectangular tanks with a total volume of 42,660 cubic meters and two round basins with a total volume of 10,500 cubic meters.

Biogas utilization:

The produced biogas is stored in two gas containers and used for drying the sewage sludge, for heating purposes and for power generation.

3.2. Technology upgrade of the pilot

The integrated approach envisioned in Reef 2W encompasses a wide range of technological steps and processes. Except the enrichment of sludge with bio-waste to enhance biogas yields, many of them are realized at Schönerlinde. The steps will be established to increase the biogas yield through hydrolysis and to convert biogas into bio-methane. Additionally, Power-to-Gas facilities will be installed to take lower-value electricity from the grid in order to produce hydrogen, which will be used together with carbon dioxide from the biogas upgrading sage to generate additional bio-methane.

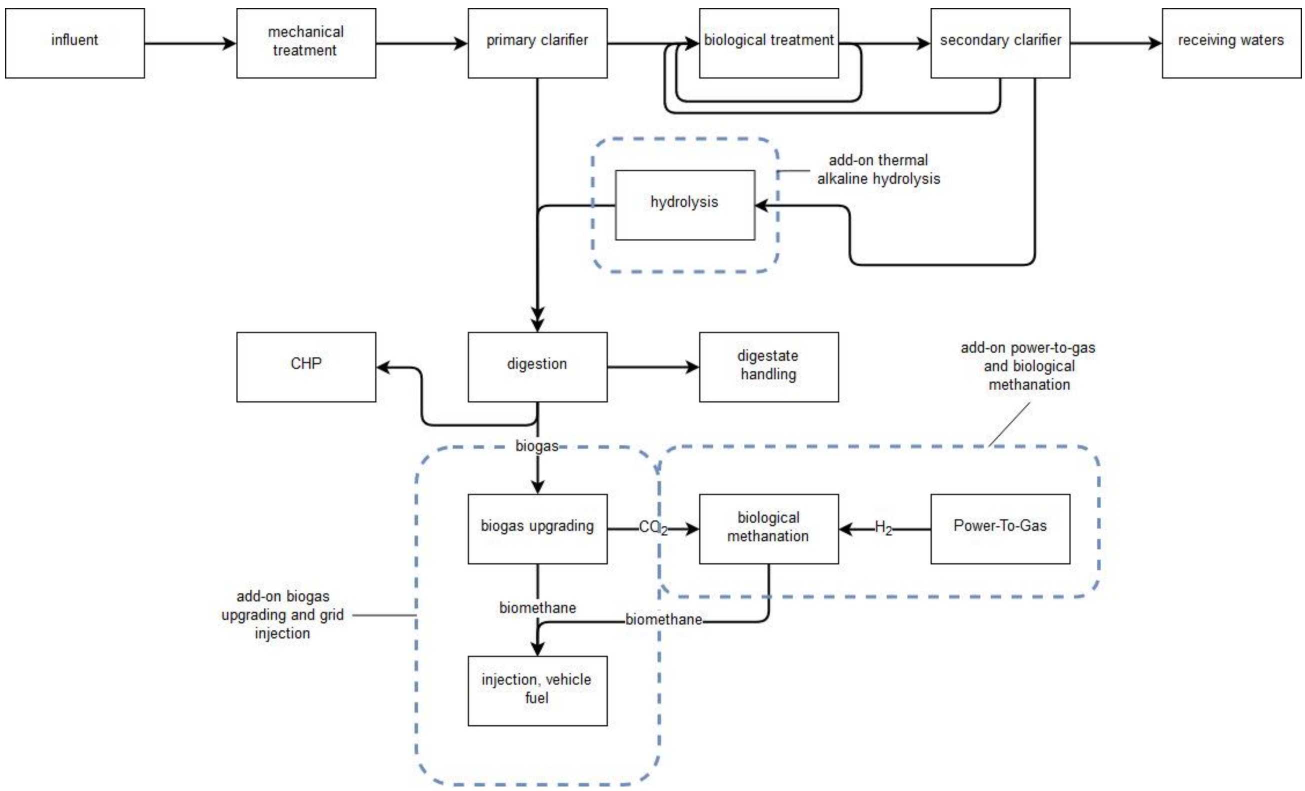

Figure 5: schemata of the new pilot site including the new REEF 2W technologies

Thermal Hydrolysis

- The new pilot site will include a thermal hydrolysis stage which will receive part or all of the seperated sludge flow from the primary clarifiers to increase the biogas yield during anaerobic digestion and to reduce the overall digestate.

Biogas Upgrading

- A biogas upgrading unit will upgrade the biogas produced during anaerobic digestion into high-quality bio-methane. With this technological upgrade, only a small footprint is needed even if the entire biogas produced is processed.

Electrolysis Unit

- The electrolysis unit will use electrical energy from the grid during low demand times or during surplus of renewable energies and produces a stream of hydrogen. The inevitably simultaneously formed oxygen stream will be fed into the biological treatment of the wastewater or can be used for the prospective ozonisation step as fourth treatment stage.

Grid Injection

- Hydrogen produced in the electrolysis stage and the carbon dioxide stream from biogas upgrading will be injected into a biological methanation unit producing high quality bio-methane. The vessel and its accessories only have a small footprint.

Additionally, a grid injection point and associated pipelines will be installed. Both will be owned and operated by the grid owner, who will also be responsible for calorific adjustment and odor, compression and pressure control.

The hydrolysis stage and biogas upgrading can be independently operated and toggled on or off. The electrolysis/methanation stage needs the running biogas upgrading module as CO2 source and for the grid injection.

3.3. Data availability and quality

For the evaluation of the tool, it is important to use high-quality and real data measured at a WWTP. It should be noted that certain errors and inaccuracies in the data cannot be avoided for various reasons such as data imperfections, the use of averages and the neglect of peak loads during a year. Therefore, a deviation between the results of the tool and the actual data is to be expected. Usually, the information requested in the tool can be provided by a WWTP operator, who in the case of Schönerlinde is BWB. For this purpose, a questionnaire in form of an Excel file listing all required input data is available to the tool user, comprising:

- Plant and equipment data
- Operating data in annual average

However, detailed information on individual process steps and equipment such as pumps, motors and screens were not provided by the operator of the WWTP Schönerlinde. For a plant operator, this data is often difficult to collect. Furthermore, some data for processes such as biogas production, heat demand as well as electricity generation are confidential and are kept secret by utilities. This also applies to the WWTP Schönerlinde.

Therefore, a more detailed analysis on this data is not possible. Only the energy efficiency of the plant as a whole was evaluated and compared with benchmark values (see next section 4).

Generally, the user is allowed to enter data from any WWTP of choice or to use the default value collected during the tool development (offered in pop-up windows). The data used for this feasibility study refer to the annual average value of Schönerlinde WWTP in 2016. Both parts of the REEF 2W tools (energy efficiency (EE) of WWTP and generation of renewable energy (RE)) were evaluated and the results are described in the next section 4.

4. Energy performance of pilot WTTP

4.1. Current energy consumption and production

In 2016, the WWTP Schönerlinde had a total energy consumption of 22 GWh of which 8.2 GWh were generated from biogas and sludge (Schwieger, 2017). The daily capacity amounts to 117,000 cubic meters per day wastewater (dry weather), which equates to approx. 950,000 PE (based on BOD_5 value). As mentioned above, detailed information on individual process steps and equipment such as pumps, motors and screens is one of the gaps in the available data. However, based on the values of measuring devices, connection values and operating hours, the proportional energy consumption of the individual processes was estimated by the WWTP operator as follows (Schwieger, 2017):

- Mechanical cleaning 3 %,
- Biological purification 69.1 %
- Sludge utilization (digestion, drainage, drying) 15.5 %
- Superior 8.9 %
- Rest 3.5 % three wind turbines, each with a rated output of 2 MW, are located on site.

In 2012, BWB installed three wind turbines, each with an output of 2 MW at the Schönerlinde WWTP. Considering this fact, this WWTP already covers 83 % of its energy requirement by using energy from sewage sludge and wind. The annual generation of thermal energy is so large that not only 100 per cent of the heat demand of the WWTP can be covered, but also large quantities of surpluse heat are availabe. However, the excess thermal energy is released into the environment unused due to a lack of external consumers (BWB).

4.2. Evaluation of energy effciency

The evaluation of the energy performance can be divided into two categories: EE of WWTP and generation of RE. The first part of the tool can provide a simple and rapid performance analysis without requiring detailed input information. The EE tool indicates that a well-managed WWTP consumes between 20 and 50 kWh of electrical energy per year and per PE120. PE120 is equivalent to the population, assuming 120 g chemical oxygen demand per PE per day. Specific thermal energy consumption of state-of-the-art WWTPs should be between 0 and 30 kWh/PE120/a. These ranges refer to power consumption and do not consider on-site power generation. To compare the electrical energy performance of each step, the annual energy consumption of the Schönerlinde WWTP was multiplied with the estimations listed in the previous section 4.1. The result of electrical energy efficiency is shown in Table 2.

Table 2: Electric energy efficiency of the selected WWTP

Electric energy consumption		***Standard range***	
WWTP total [kWh/PE120/a]	23,27	***20,00***	***50,00***
1) inflow pumping station and mechanical pre-treatment [kWh/PE120/a]	1,05	***2,50***	***5,50***
2) mechanical-biological treatment [kWh/PE120/a]	17,60	***14,50***	***33,00***
3) sludge treatment [kWh/PE120/a]	3,50	***2,00***	***7,00***
4) infrastructure [kWh/PE120/a]	1,12	***1,00***	***4,50***

As shown in Table 2, all main treatment steps are within the standard range close to the lowest value.

The total EE of the pilot was compared to several benchmarks published by the German water association (DWA) 2015 (Figure 6).

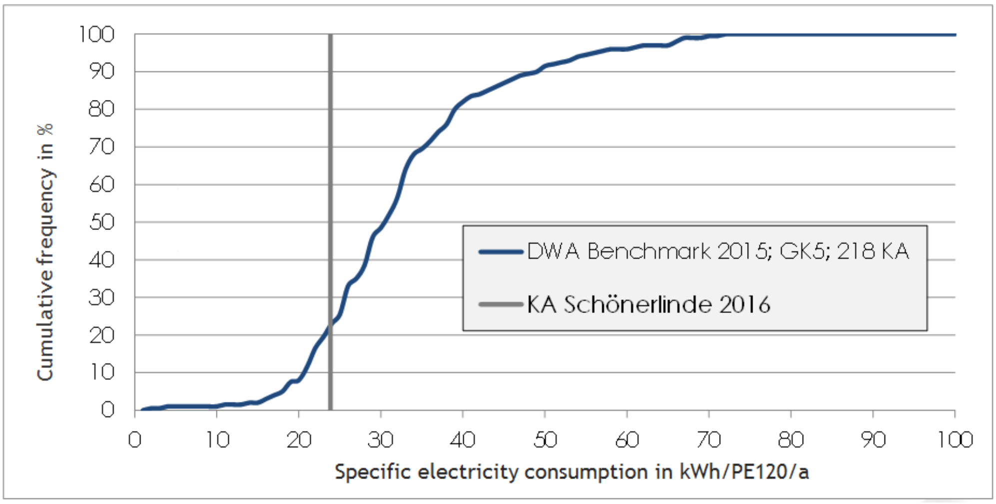

Figure 6: Specific electricity consumption of Schönerlinde compared to DWA benchmark

As shown in Figure 6, the specific electricity consumption of the WWTP Schönerlinde is comparable to the 20 % of the best plants in the DWA benchmark (DWA, 2015). Only 43 WWTPs are more energy efficient.

The result of thermal EE is shown in Table 3.

Table 3: Thermal energy efficiency of the selected WWTP

Thermal energy comsumption		Standard range	
WWTP total [kWh/PE120/a]	13,15	***0,00***	***30,00***
sludge heating [kWh/PE120/a]	10,42	***8,00***	***12,00***
transmission loss, digester tower heating [kWh/PE120/a]	0,54	***0,00***	***4,00***
generation, storage and distrivution loss [kWh/PE120/a]	1,10	***0,00***	***2,00***
heat for buildings [kWh/PE120/a]	1,09	***0,00***	***2,00***

With regard to thermal EE, the selected treatment plant is also within the standard range. With a heat consumption of 13.15 kWh/PE120/a, the WWTP is also in the standard range for thermal EE, in the medium interval range. At this WWTP, excess heat is genrated, which, however, is released unused to the environment due to lack of external consumers.

Considering the EE results, the Schönerlinde WWTP is energetically a well-performed WWTP. However, the energy costs of this plant can still be reduced by improving the EE of wastewater facilities' equipment and operations and by capturing the energy of the wastewater for electricity and heat generation.

Moreover, the integration of new technology such as a thermal hydrolysis stage, which increases the biogas yield during anaerobic digestion and reduces the overall digestate, could be a proper measure to generate more energy from the wastewater and thus to increase the energy self-efficiency (see section 6).

In the next step of the tool, the annual biogas production was compared to the amount of biogas production calculated in the tool. The comparison of biogas production with real data shows a 5 % deviation, which is acceptable.

5. Analysis of the WWTP spatial context

As mentioned above, heat is generated in excess at the Schönerlinde WWTP, and the excess is lost due to the location of the WWTP, which is too far away from potential external consumers. In addition, the provision of thermal energy requires a district heating network. The spatial context of the WWTP and the presence of existing heat consumers determine the potentials for an efficient integration of surplus heat into local energy supply concepts.

The analysis of the spatial context of the WWTP is done via the urban compatibility assessment (UCA). This tool shows whether excess heat and/or electricity are generated at the WWTP, which are available for further use.

The following Figure 7 demonstrates the location of the Schönerlinde WWTP.

Figure 7: Visualization of WWTP Schönerlinde (Source: Google Maps)

As shown in Figure 7, there are not many costumers in the surroundings of this WWTP. After a rough analysis, a small village in the WWTP's surrounding was selected for an evaluation (red square). This village is approximately 2 kilometres away from the WWTP Schönerlinde and has an area of approx. 450,000 m^2, which is equal to 45 hectare.

In order to determine the urban compatibility, the tool requests the user for the distance between consumers and the WWTP. The closer the heat consumer is to the WWTP, the better. Figure 8 shows the estimated distance.

Figure 8: Visualization of distance between WWTP and heat costumer (Source: Google Maps)

This distance between the two areas is estimated at about 1.5 kilometers (outer distance). The user can use the default value for the internal grid connection in the selected area (network connection in the red square).

The result is given as connection density defined in MWh/m, for which different cases are distinguished:

- The value is higher than 2, which means a heat transport is energetically feasible (green color)
- The value is between 0.5 and 2, which means a heat transport is still feasible, however; a detailed analysis is needed. (orange color)
- The value is lower than 0.5, which means a heat transport is not feasible. (red color)

Connection density in MWh/m
>2
0.5-2
<0.5

The case study site Schönerline showed a connection density of about 4 MWh/m, which is in green range. Therefore, a district heating network is a viable option connceting the WWTP and the adjacent residential area. In the further course of the analysis, in order to determine a final statement on feasibility, an economic evaluation is important.

6. Application of renewable energies and associated energy output improvements

From the REEF 2W technologies the following are considered:

- Renewable energy technologies such as photovoltaic power plant, solar thermal power plant, hydropower plant and hybrid collectors
- Thermal hydrolysis
- Power-to-gas
- Biogas upgrading
- Co-fermentation
- Heat pump

The criteria for selecting these technologies are their technological feasibility and their ability to increas EE and/or the share of RE. The integration of these technologies enables WWTPs to generate substantial amounts of energy which they can use on site, to the extent that they become self-sufficient and feed surplus energy into the grid. In general, from a technical perspective, it is possible to integrate all considered RE at the Schönerlinde WWTP. However, some of these technologies are not suitable due to following reasons:

- **Hydroelectric plant:** The installation of a hydroelectric plant is of no energetic interest to the WWTP Schönerlinde, as the topographical gradient of the effluent channel of the plant is too small, resulting in a low energy yield.
- **Heat pump and solar thermal plant:** As explained in the previous chapter, the WWTP Schönerlinde can already cover its heat demand with a CHP system and also has surplus thermal energy that is emitted into the environment, as there are no further possibilities for use on site and in the immediate vicinity for these surpluses (e.g. district heating). Therefore, a heat pump or a solar thermal plant for the availability of further thermal energy is not an energetically sensible option for the selected WWTP.
- **Co-fermentation:** The enrichment of sludge with bio-waste has been already tested at the Waßmannsdorf WWTP in Berlin. Due to several problems regarding economic efficiency of this technological solution and foam formation in the digester, BWB decided against the integration of this technology in the 6 WWTPs in Berlin. For this reason this REEF 2W solution is not considered in the present study.

The remaining REEF 2W technology solutions are biogas upgrading, power-to-gas and thermal hydrolysis, for which the application at the Schönderline WWTP will be evaluated in this section. In the following, the selected technologies are briefly described.

6.1. Selected technologies

6.1.1. Thermal hydrolysis

Anaerobic sludge stabilization at the WWTP Schönerlinde is performed by means of a digester. A major advantage of anaerobic digestion is that methane results as a byproduct of the process, which can be used as biofuel. In many cases, a WWTP can generate enough biogas to meet part of its energy needs. Biogas is a renewable resource that can usefully be increased in view of the growing need for RE and sustainability. Thermal hydrolysis is a technology that can increase the digestion performance by disintegration of sludge. The disintegration of sludge acts as a pre-treatment before anaerobic digestion. The objective is to destroy the floc structure of the sludge and with high energy input to dissolve cell walls. This disintegration achieves the transformation of non-biodegradable organic substances into bioavailable ones resulting in higher degradation rates of the volatile substances. The result is an increased biogas yield.

6.1.2. Biogas upgrading

Using the energy in wastewater by burning biogas from anaerobic digesters in a CHP unit allows wastewater facilities to generate some or all of their own electricity and heat demand. However, there is an excess of heat energy, especially in summer due to a lower heat demand of the WWTP resulting from weather conditions. Heat is usually produced in excess at a WWTP, but most of the time, the excess is lost due to the location of WWTPs which are too far away from potential external consumers. Therefore, a complete upgrading of the digester gas and feeding into natural gas pipelines make it possible to use the biomethane regardless of location and time. The produced biomethane during biogas upgrading is a gas from renewable resources with the same quality as natural gas and thus can replace it by providing a carbon-neutral form of energy. It is possible to produce fuel quality biomethane for an existing CNG fleet. Producing the biomethane and biofuel can enhance the image of the operator and may set trends for a main biogas utilization with higher technology standard than simply burn biogas in CHPs.

6.1.3. Power to Gas

With the Urban Development Plan for the Climate (StEP) approved on 31 May 2011, Berlin started to fit the city for the future. The following main goals were defined for Berlin:

- Reduction of carbon dioxide emissions by 85 percent by 2050 (reference year 1990)
- The city of Berlin becomes climate-neutral by 2050 (EWG Bln)

Berlin’s climate policy demands for not only electricity generated from RE, but also other climate-neutral energy sources such as biomethane for the mobility, heating and industrial sectors.

Power-to-gas technology is a promising option for Berlin as the city is an urban area that lacks many possibilities for biogas production.

As mentioned above, the WWTP Schönerlinde has already three wind turbines. A power-to-gas module could capture and store electricity from these turbines. The storage of generated hydrogen from the Power-to-Gas unit would take place in the natural gas grid so that generation and consumption of RE can be decoupled. However, the injection of hydrogen into the natrual gas grid is limited up to maximum of 9 % of hydrogen share (DVGW 260). Therefore, a subsequent methanation of the hydrogen would be an appropriate measure. For this, carbon dioxide and the produced hydrogen are converted into CH_4 via biological reaction. The carbon dioxide for this process can be taken from various sources at a WWTP e.g. from biogas upgrading. Furthermore, the very pure oxygen stream, which is generated as a side product during electrolysis, can be used to save on aeration costs during the aerobic biological treatment stage. Due to the higher oxygen content than ambient air, less electrical energy is required for the blowers to achieve the same oxygen content in the water.

6.1.4. Renewable Energies

The installation of a photovoltaic (PV) power plant and/or hybrid collectors is particularly suitable for this WWTP to become energy self-ufficient. As already mentioned, there are three wind turbines, each with an output of two megawatts at the WWTP plant Schönerlinde. In order to conduct a comparative analysis of RE consumption in the tool, the area needed for one wind turbine (approximately 350 m^2) is used to evaluate the energy performance of other renewable energies (photovoltaic and hybrid collectors) (Fören e.V. , 2018). Using the same area makes it possible to compare these renewable technologies with each other.

6.2. Evaluation of techologies using REEF 2W tool

6.2.1. Photovoltaic power plant vs. hybrid collectors

This section provides a brief analysis of the comparison of the use of RE in the tool. To compare the results, the area of 350 m^2 was used for both technologies (photovoltaic and hybrid collector). In the first part, the technologies are compared with the status quo. The changes in energy generation are shown in the following figures.

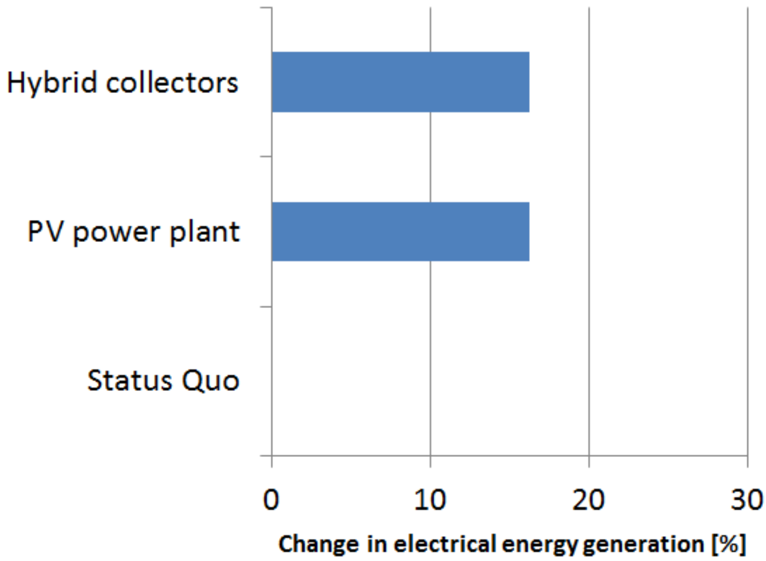

Figure 9: Comparison of electrical energy generation with status quo

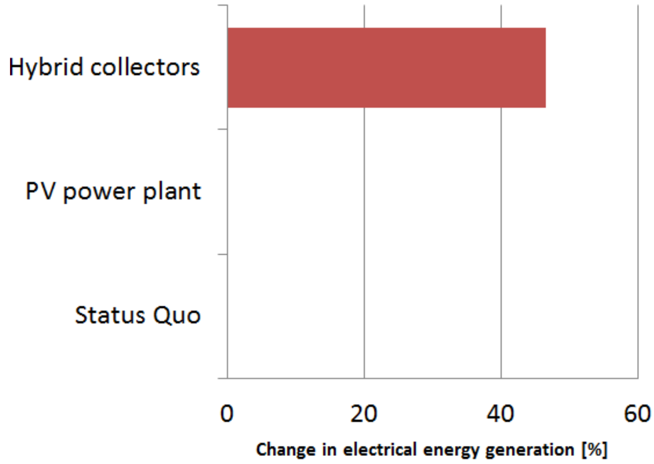

Figure 10: Comparison of thermal energy generation with status quo

As shown in Figure 9, using a photovoltaic power plant or hybrid collectors increases the electricity generation as well as electric self-sufficiency of the WWTP by 16 %. In addition, the hybrid plant increases the thermal energy generation by 45 % (see Figure 10), which, however, can not be used on site as explained in previous sections. The following Figure 11 shows the decrease in energy demand of the WWTP Schönerlinde using PV plant or hybrid collectors, which is 16 %. Therefore, the integration of a photovoltaic plant could be a good option from an energetic point of view. However, in order to make a final overall stantement on the integration of both technology solutions at the WWTP Schönerlinde, both technological solutions must be further analysed with regard to their economic and ecological advantages and disadvantages.

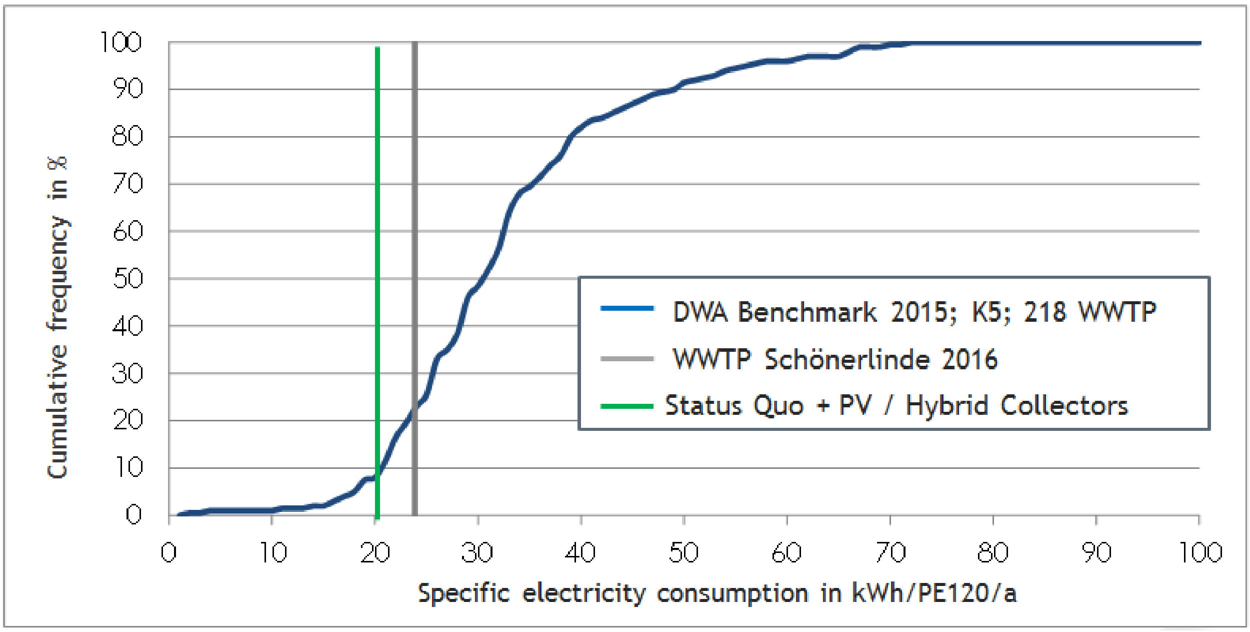

Figure 11: Specific electricity consumption of Schönerlinde WWTP

6.2.2. Thermal Hydrolysis

The hydrolysis step will enhance the biogas yield. The thermal hydrolysis stage is integrated into REEF 2W tool. The user can select between two options: Thermo-chemical (65 °C) and Thermo-pressure (165 °C). The following figure (Figure 13) shows how the gas generation of the WWTP could be changed if this technology is integrated into the selected plant.

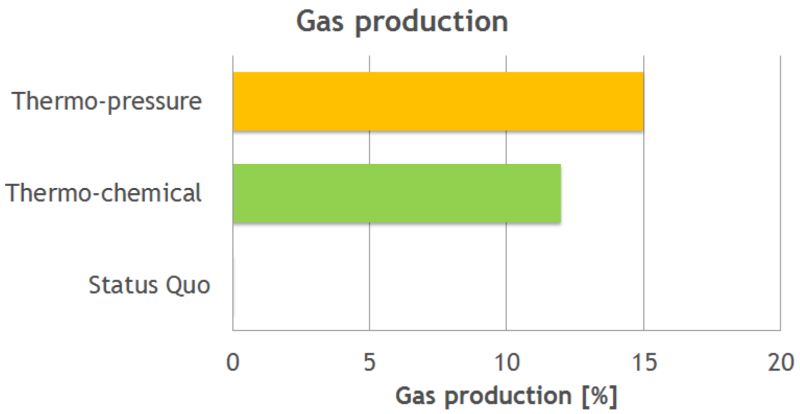

Figure 12: Comparison of biogas production using different thermal hydrolysis technologies

Figure 12 compares the biogas generation using thermal hydrolysis in the selected WWTP. Compared to the status quo, biogas generation in the digester is increased by up to 12 % through the use of thermo-chemical hydrolysis and up to 15 % through the use of thermo-pressure technology. Both technologies can be installed at the WWTP at the Schönerlinde WWTP.

From a energetic point of view, the thermo-pressure technology requires approximately 1.7 times more electrical and thermal energy than the thermo-chemical hydrolysis. However, the thermo-chemical hydrolysis requires on the other hand the addition of chemicals for disintegration of sludge. The next Figure 13 shows the improvement in the energy performance of the WWTP Schönerlinde by integrating a thermo-chemical process.

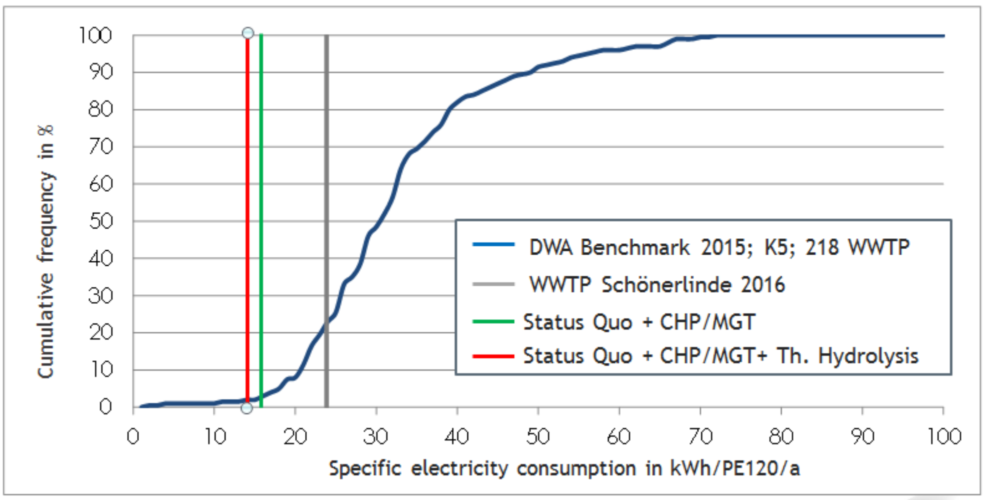

Figure 13: Change in specific electricity consumption (thermal hydrolysis)

The biogas produced at the WWTP Schönerlinde is already combusted in a CHP unit and MGTs and the generated energy is directly used on site. Thermal hydrolysis can increase the digestion performance by disintegration of sludge. The result is a higher biogas yield from sludge and an increase in EE and energy generation. Therefore, the generation of electrical energy can be increased up to 6 % (see Figure 13).

To sum up, the choice of the right hydrolysis options depends on the operator and specific condition of a WWTP.

6.2.3. Biogas Upgrading

As mentioned before, using the energy in wastewater by burning biogas from anaerobic digesters in a CHP unit and micro gas turbines allows wastewater facilities to generate some or all of their own electricity and heat demand. The following igure 14 shows the use of biogas in the Schönerlinde WWTP.

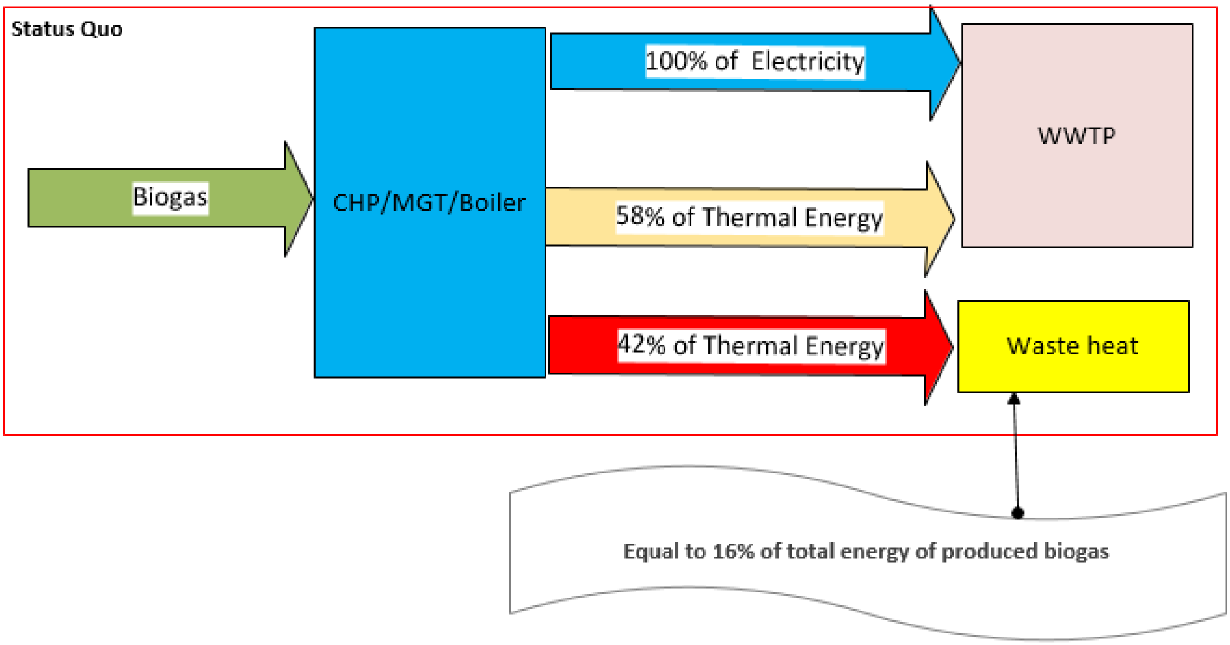

Figure 14: Biogas utilisation at the WWTP Schönerlinde

As shown in the Figure 14, there is an excess of heat energy, especially in summer, due to a lower heat demand of the WWTP resulting from weather conditions. To avoid this energy loss, biogas can be upgraded to biomethane, which enhances its quality through a separation process. Upgrading unit separates the raw biogas into a methane-rich product stream and a CO_2-rich offgas. Three main separation technologies are considered in the tool and can be selected: pressure water scrubbing (PWS), pressure swing adsorption (PSA) and membrane. The energy consumption of these three technologies is calculated. The results are shown in Figure 15.

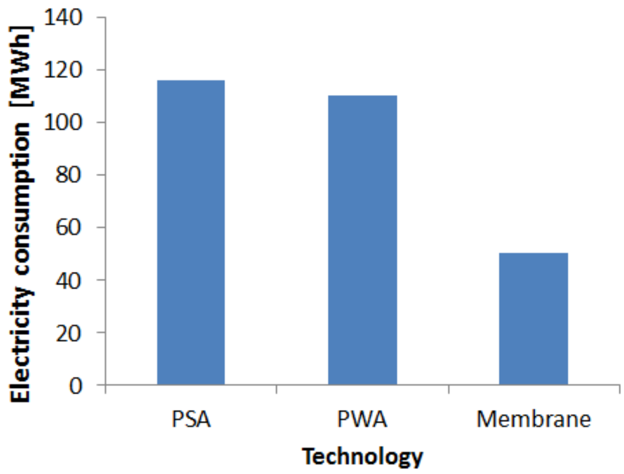

Figure 15: Comparison of electricity consumption of all three technologies

As shown in Figure 15, both PSA and PWA technologies require approximately 0.11 GWh electricity per year to upgrade the entire amount of generated biogas at the WWTP Schönerlinde. The membrane technology consumes 0.05 GWh less electricity for generating the same amount of biomethane. In general, the choice of a suitable technology depends on various factors such as the mode of operation, amount of biogas and legal requirements as well as investment costs.

Biogas upgrading and feeding into the gas grid enable biomethane to be used independently of time and place. Biogas upgrading is an energetically efficient way of using digester gas, as no excess thermal energy is released compared to the current situation at the WWTP Schönerlinde. Moreover, the biogas upgrading technology can compete with the gas engines in a WWTP due to legal changes (Renewable Energy Act, Combined Heat and Power Act). This technology is more economical for new investment projects due to its low investment and operating costs. However, when upgrading the entire biogas stream, the plant operator must cover the total energy demand by external suppliers.

Therefore, a combination of a CHP plant and a biogas upgrading technology is an energetically efficient way to utilise digester gas, to cover part of the electrical energy demand and to reduce the excess heat from CHP unit.

6.2.4. Power-to-Gas

As described above, the energy surplus from renewable energies can be used in a Power-to-Gas unit to split water into hydrogen and oxygen. This technology is when the user selects biogas upgrading for the future scenario in the second step of the tool.

The capacity of the Power-to-Gas unit depends on the electricity generated from the Schönerlinde wind power plant. With a 2 MW electrolyser and 6 MW wind turbine, about 2,300,000 cubic meter of hydrogen can be produced per year. The hydrogen generated can be used in a subsequent methanation process to produce biomethane. With this amount of hydrogen, about 600,000 cubic meter CO_2 can be captured and converted into biomethane.

At the moment, the investment and operating costs of the power-to-gas are extremely high. Obtaining this investment cost poses a major challenge for an operator. Nevertheless, the economy of power-to-gas also depends on the available electricity and its price. Government incentives such as direct and indirect subsidies could make this technology interesting in the future.

6.3. Discussion & Conclusion

The first part of the tool (EE) can provide an easy and rapid performance analysis. For the evaluation of this part, it is important to use high-quality and real data from a WWTP. However, detailed information regarding individual process steps and equipment such as pumps, motors and screens from the WWTP Schönerlinde were not available for comparison. The evaluation of the energy performance of the case study site as well as the gas production and consumption was simplified. The results of the first part of this Feasibility Study show that the Schönerlinde WWTP is energetically within the defined energy efficiency range. However, the energy costs can still be reduced by improving the EE of wastewater facilities' equipment and operations and by capturing the energy in wastewater to generate electricity and heat. Furthermore, it could be shown, that the calculated amounts of biogas in the tool correspond the real production at the case study site, which proves that the tool works correctly. The the results of the first part are acceptable and sufficient for the first analysis. However, the outcomes are not adequate for precise planning, as all calculations are based on monthly and annual averages. In order to be able to calculate precise energy production of renewable sources, at least the daily weather data are necessary. In addition, the weather-related availability of renewable energies (intermittent availability of sun and wind) is neglected on monthly and annual averages.The second part of the tool compares and evaluates the combination of different renewable energy technologies in the selected WWTP. The result shows that a solar plant could improve electrical energy self-sufficiency. Two other technologies (solar thermal plant and heat pump) increase the thermal energy generation, however; the selected WWTP has already enough heat from the CHP system. These two technologies would be interesting if customer for the heat surpluses exist. The use of renewable energy technologies in the Schönerlinde WWTP can improve the energy self-sufficiency and increase the potential to become energy-neutral. However, the integration of these technologies is highly dependent on various factors such as available space, investment costs, and energy demand. Due to the results, thermal hydrolysis can boost the biogas generation and hence energy generation. Upgrading of biogas to biomethane and its injection into natural gas grid allow the highest efficiency levels to be achieved, both in the generation of electricity and in direct heat utilisation. This practice is mature enough and commercially available. The last technology evaluated in this analysis was power-to-gas. This technology can be used to enhance the biomethane production and to use the excess power from RE technologies.

Comparing the result of both parts of the tool indicates that the integration of RE and REEF 2W solution cncepts such as thermal hydrolysis has the potential to lead the case study site to energy neutrality.

7. Sources

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