D.T. 4.3.3 PRE-ASSESMENT FOR EVALUATING THE SUITABILITY OF 15 2W PLANTS TO BECOME REEF 2W

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 Contents

1. Introduction and General Information 3

1.1. The REEF2W Project 3

1.2. Scope of the deliverable 3

2. PRE-ASSESSMENT APPROACH (METHODOLOGY) 4

3. Description of first pilot site 4

3.1. Characteristics of the WWTP Braunschweig 4

3.2. Energy performance 5

3.3. Analysis of the WWTP spatial context 6

3.4. Result and disscussion 6

4. Description of second pilot site 6

4.1. Characteristics of the WWTP Waßmannsdorf 6

4.2. Evaluation of energy efficiency 7

4.3. Analysis of the WWTP spatial context 8

4.4. Result and disscussion 9

5. Description of third pilot site 9

5.1. Characteristics of the WWTP 9

5.2. Evaluation of energy efficiency 10

5.3. Analysis of the WWTP spatial context 11

5.4. Result and disscussion 12

6. Conclusion 12

Sources 13

1. Introduction and General Information

1.1. The REEF2W Project

In the wake of the energy transition (“Energiewende”), an increased focus is concentrating on the yet unexploited energy-saving potential of the wastewater sector. Wastewater treatment plants 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 that 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 REEF2 Water 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 make economic viable, project partners will develop a comprehensive assessment tool in close collaboration with utility operators in-a series of workshops. Another key task of Reef2 Water 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

The purpose of this deliverable is to analyse and carry out a pre-assessment for further WWTPs to become REEF 2W. These form the first two steps of the Integrated Sustainability Assessment (ISA). Implementing the first part of the feasibility 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.

<u>How is it relating to previous deliverables?</u>

The ISA methodology was developed in the REEF 2W project and has been tested during the training courses. While the feedback gathered from the participants is being integrated, this is the first organized attempt to test the ISA tool. The results for applying these first two tools will provide the data required to conduct the second part of the Feasibility Study (in Work Package 3). 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).

2. PRE-ASSESSMENT APPROACH (METHODOLOGY)

During the workshop in Berlin, PAs were informed about the possibility of participating in the second feasibility study. The operator of the WWTP Waßmannsdorf was interested in a pre-assessment. Further WWTP operators were contacted via email and telephone and were informed about the REEF 2W project and the pre-assessment. As a result, two operators accepted the participation of their WWTPs on the pre-assessment. An excel data sheet with requested information for the REEF 2W tool was sent to all three operators. This data was used in the REEF 2W tool to assume the energy efficiency of the WWTPs as well as the potential thermal energy consumers in the vicinity of the plant (UCA tool).

There is a report for each WWTP with the following approach: First, the characteristics of the WWTP such as location, size and inflow of the plant will be introduced. The second part describes energy performance of the WTTP and evaluates the current level of energy efficiency. The third part analyses the potentials for an efficient integration of surplus heat into local energy supply concepts (spatial analysis). The final part provides a conclusion of the pre-assessments based on the comparison of three WWTPs and chooses the most promising site for a more detailed feasibility study.

3. Description of first pilot site

3.1. Characteristics of the WWTP Braunschweig

The wastewater of the city of Braunschweig and surrounding communities is delivered by pumping stations to the WWTP Steinhof (figure 1). Here, the wastewater is treated for the removal of suspended solids, organic matter, and nutrients N and P in a conventional activated sludge process with nutrient removal. The status quo of wastewater treatment consists of mechanical treatment, primary sedimentation, activated sludge process and final clarifier, infiltration fields, and a water reuse system for agricultural irrigation with effluent and sludge (in summer). Sludge treatment consists of anaerobic sludge stabilisation in digestors, biogas electrification in combined heat and power (CHP) plants and seasonal sludge dewatering and storage on-site. In addition to the wastewater-derived sludge, a small amount of external co-substrate (grease) is converted to biogas, using free digestor capacity for the disposal of food waste to improve biogas production. Part of the purified effluent from the process is then spread on historic infiltration fields (220 ha, in operation for more than 100a) for polishing prior to its discharge to surface waters via the Aue-Oker canal. The remaining part of the effluent is pumped to a dedicated agricultural area where it is spread on agricultural fields. (Remy, 2012)

On average, it is calculated that the WWTP Braunschweig receives a wastewater load of 350000 PECOD per year (SE/BS 2010).

The CHP system receives biogas from multiple sources: digester gas from the WWTP, biogas from ALBA Niedersachsen-Anhalt GmbH's bio-waste fermentation facility, landfill gas from the waste disposal site in Watenbüttel, and biogas from an agricultural biogas plant in Hillerse. In total, the biogas amounts to approx. 7.3 million m^3/a. Due to the multiple gas sources, the CHP unit generates electricity and heat in excess of the WWTP demand. The excess electricity is injected into the public grid. The waste heat from the engines and the exhaust heat are used for heating purposes in the WWTP itself (digestor, buildings). A part of the heat is sold to the ALBA Niedersachsen-Anhalt GmbH's bio-waste fermentation facility. (Abwasserverband Braunschweig, 2020)

Due to the high amount of external gas available at the site, the degree of energy self-sufficiency of this system is higher than 100% for both electricity and heat demand of the WWTP.

Figure 1: Braunschweig WWTP (source: google maps)

3.2. Energy performance

The evaluation of the energy performance in the tool can be divided into two categories: energy efficiency (EE) of WWTP and generation of renewable energy (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 WWTP consumes between 20 and 50 kWh of electrical energy per year and per PE120. PE120 is equivalent to the organic loading of the WWTP, 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 gross energy consumption and do not consider on-site generation of electricity and heat.

The plant consumes about 12.2 GWh of electricity and 7.9 GWh of heat per year. Due to the high amount of external gas available, the degree of energy self-sufficiency of this system is higher than 100%. After entering the data in the tool, the average electricity demand of the WWTP Braunschweig is 33 kWh/PE/a, which is within the standard range of energy efficiency. The result of this analysis was compared to the benchmark published by the German water association (DWA) 2015. Figure 2 shows the specific electricity demand in kWh/PE/a of size class 5 (GK5: > 100.000 PE) in Germany on the abscissa. The ordinate shows the percentage of WWTPs that have a certain electricity demand.

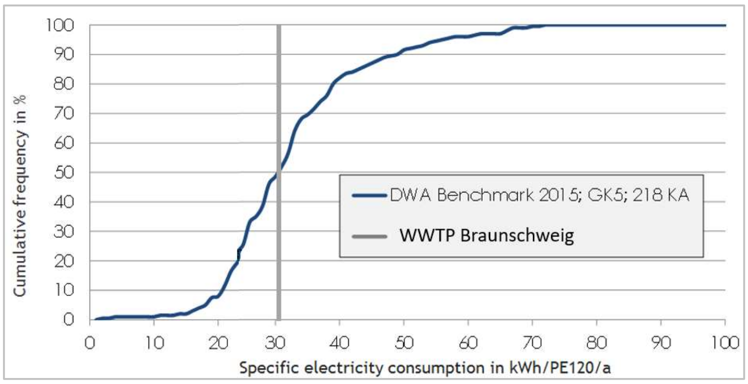

Figure 2: Specific electricity consumption of WWTP Braunschweig compared to DWA benchmark (DWA, 2015)

As shown in the figure above, the specific electricity consumption of WWTP Braunschweig is comparable to 50% of plants analysed in the DWA benchmark.

The result of thermal energy efficiency shows that the selected treatment plant is also within the standard range of thermal energy efficiency. This WWTP consumes 20 kWh/PE120/a of heat. As mentioned, heat is produced in excess at this WWTP, and the excess is sold to the ALBA Niedersachsen-Anhalt GmbH's bio-waste fermentation facility which is not far away from the WWTP.

Considering the EE results, the Braunschweig WWTP is energetically a well-performing WWTP. However, the energy costs of this plant can still be reduced by improving the energy efficiency of wastewater facilities' equipment and operations and by capturing more of the energy in wastewater to generate additional electricity and heat.

3.3. Analysis of the WWTP spatial context

As already mentioned, heat produced in the CHP plants is used on-site and sold to the nearby bio-waste plant. Therefore, there is no available excess heat on site, and a spatial analysis for nearby heat demand is not necessary.

3.4. Result and disscussion

The WWTP Braunschweig is a modern wastewater treatment plant with many implemented waste-to-energy solutions. Due to the changing legal regulations, the operator would like to investigate further options for the energy utilisation as alternative to the CHP units, such as biogas upgrading and feeding into the gas network or the potential for power-to-gas technology. Hence, this WWTP will continue with a more detailed feasibility study based on the REEF2W approach.

4. Description of second pilot site

4.1. Characteristics of the WWTP Waßmannsdorf

The surveyed WWTP is one of the six treatment plants operated by the Berlin Water Utilities (Berliner Wasserbetriebe - BWB). It treats the wastewater of a large part of the city and additionally some smaller regions of Brandenburg. The connected population amounts to approx. 1.4 to 1.8 Mio. PE in terms of organic load of the influent. The plant uses a conventional approach for wastewater treatment with mechanical and biological treatment, nitrification and denitrification, enhanced biological phosphorus removal, mesophilic digestion and utilization of biogas in CHPs for heat and electrical power generation. Sludge from primary settlers and excess sludge from secondary settlers is collected, thickened and heated with heat exchangers prior to being pumped into mesophilic cascading digesters. The dewatered sludge is transported off-site to co-incineration or mono-incineration. The biogas utilization chain consists of 5 combined heat and power units with 1.2MWel each. Figure 3 gives an aerial overview of the WWTP.

Figure 3: Waßmannsdorf WWTP (source: google maps)

4.2. Evaluation of energy efficiency

In 2016, the WWTP Waßmannsdorf consumed 43 GWh electricity and 20 GWh thermal energy. In the same year, this plant produced approximately 35 GWh of electricity. After entering the data in the tool, the average electricity demand of the WWTP Waßmannsdorf is 24 kWh/PE/a, which is within the standard range of energy efficiency. The result of this analysis was compared to the benchmark published by the German water association (DWA) 2015. Figure 4 shows the specific electricity demand in kWh/PE/a of size class 5 (GK5: > 100.000 PE) in Germany.

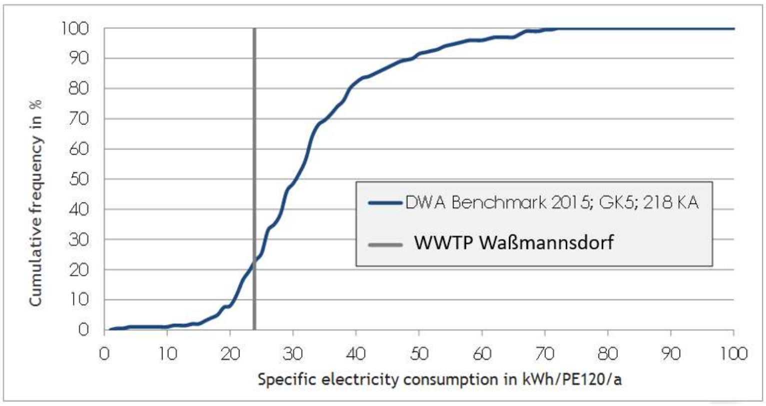

Figure 4: Specific electricity consumption of WWTP Waßmannsdorf compared to DWA benchmark (DWA, 2015)

As shown in Figure 4, the specific electricity consumption of the WWTP Waßmannsdorf is comparable to the 20 % of the best plants in the DWA benchmark. Only 43 WWTPs are more energy efficient. The result of thermal energy efficiency shows that the selected treatment plant is also within the standard range of thermal energy efficiency. This WWTP consumes 14 kWh/PE120/a of heat. Heat is produced in excess at this WWTP, and the excess is currently wasted due to the remote location of the WWTP. In addition to the specific electricity consumption, the DWA also published key figures for specific electricity generation from the combustion of biogas. As can be seen in Figure 5, the WWTP Waßmannsdorf produces more electricity than approx. 50% of the wastewater treatment plants in a performance comparison.

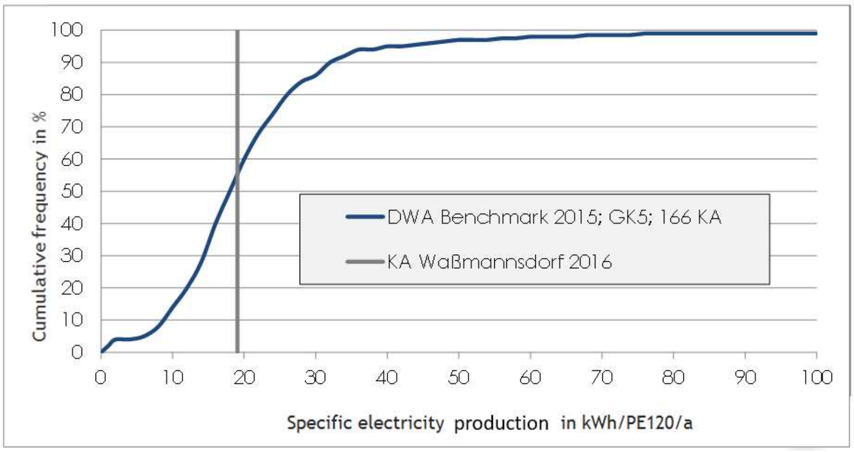

Figure 5: Comparison of the specific electrical power production at WWTP

Considering the EE results, the Waßmannsdorf WWTP is energetically a well-performing WWTP. However, the energy costs of this plant can still be reduced by improving the energy efficiency of wastewater facilities' equipment and operations and by capturing more of the energy in wastewater to generate electricity and heat.

4.3. Analysis of the WWTP spatial context

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

The urban compatibility assessment (UCA) can show the possibilities whether potential surplus/excess energy generated at the WWTP like excess heat can be utilized in the surroundings of the WWTP.

Figure 6: WWTP Waßmannsdorf and airport BER (source: google maps)

After the analysis with the UCA tool, the newly constructed major airport BER was selected as a potential thermal energy consumer (Figure 6). The airport is approximately 3.5 kilometres away from the WWTP and has an area of approx. 166000 m2, which is equal to 16.6 hectare.

In order to calculate the urban compatibility in the REEF 2W, the external distance between consumers and WWTP should be assumed and entered into the tool. The next figure (figure 7) shows the estimated distance between both areas.

Figure 7: Visualization of distance between WWTP and heat costumer (google maps)

The case study site showed a connection density of about 2.2 MWh/m, which is in green range. Therefore, a district heating network is a viable option connecting the WWTP and the adjacent area of the airport. In the further course of the analysis, in order to determine a final statement on feasibility, an economic evaluation of this option would be important.

4.4. Result and disscussion

The Waßmannsdorf WWTP is energetically a well-performing WWTP. The result of the pre-assessment was presented to the operator of this plant. The operator informed us that the plant will be extended with a large sludge incineration facility on-site in 2025 that will produce even more heat on-site. They also informed us that this additional heat would be sold to the district heating network via a planned connection, which is now economical due to the additional heat produced at the incineration facility. Therefore, all available excess heat will be sold in the future. Finally, the operator currently sees no further potential for energy improvements with the REEF2W technological implementation at this WWTP, and declined to continue with a detailed feasibility study.

5. Description of third pilot site

5.1. Characteristics of the WWTP

The operator of third WWTP would like to participate in the assessment anonymously. Therefore, the name of the wastewater treatment plant is not mentioned in this part. The selected wastewater treatment plant is situated in south of Germany and was built in 1963. At that time, the inlet pumping stations, the mechanical pre-cleaning, the pre-clarification and sludge digestion were built. Later, the sewage treatment plant was expanded to include the biological purification stage (see Figure 8). The size of the wastewater treatment plant is 87,500 PE. However, the connected population was about 59,500 PE in 2017. The plant uses a conventional approach for wastewater treatment with mechanical and biological treatment, nitrification and denitrification, mesophilic digestion in two stages and utilization of biogas in CHPs for heat and electrical power generation.

Figure 8: third WWTP (anonymous participation) (source: google maps)

5.2. Evaluation of energy efficiency

In 2017, this WWTP had an electricity demand of 3 GWh and produced approximately 1.5 GWh of electricity by combustion of biogas in the CHP unit. The specific electrical power consumption is calculated from the annual electricity consumption (3 GWh/a) and the connected population based on the COD daily load (120 g COD/ (PE · d)). The tool shows that the average electricity demand of the WWTP is 51 kWh/PE/a, which is above the standard range of energy efficiency. The result of this analysis was compared to the benchmark published by the German water association (DWA) 2015. Figure 9 shows the specific electricity demand in kWh/PE/a of size class 4 (GK4: 10,000 to 100,000 PE) in Germany.

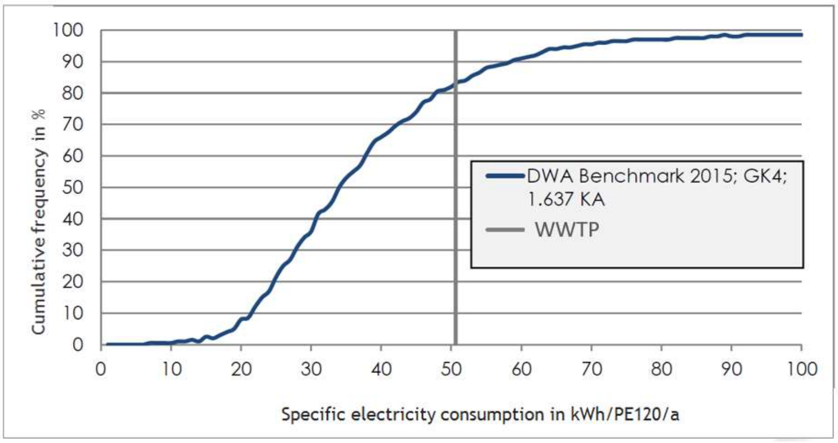

Figure 9: Specific electricity consumption of WWTP compared to DWA benchmark (DWA, 2015)

It can be seen that around 83% of the wastewater treatment plants of this size have a lower specific power consumption than the reference WWTP. The result of thermal energy efficiency shows that the selected treatment plant is within the standard range of thermal energy efficiency. This WWTP consumes 22 kWh/PE120/a of heat. Heat is produced in excess at this WWTP, however in low amounts.

The next figure (Figure 10) compares the specific electrical power production of the selected WWTP with the data from DWA benchmarking.

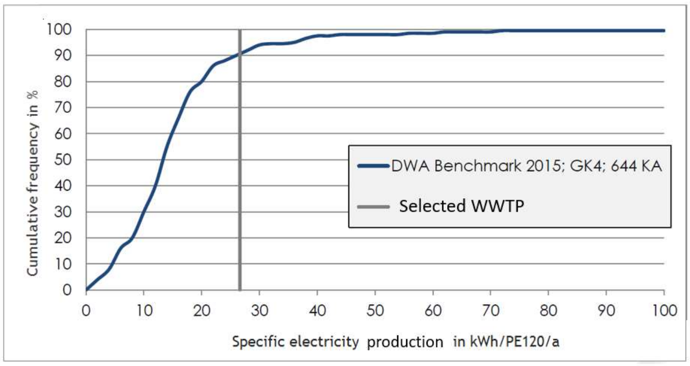

Figure 10: Comparison of the specific electrical power production at WWTP

As can be seen in Figure 10, this WWTP produces more electricity than approx. 90% of the wastewater treatment plants in a performance comparison. According to the operator, this comparatively high value is partly due to the dosage of enzymes in the digester, and partly due to the two-stage digestion.

The comparatively high specific power consumption at WWTP is partly due to the configuration of plant. The energy consumption of this plant can be reduced by improving the energy efficiency of wastewater facilities' equipment and operations and by capturing the energy in wastewater to generate electricity and heat.

5.3. Analysis of the WWTP spatial context

The selected WWTP has approximately 16 MWh excess heat (especially in summer). The UCA tool was used to determine the possibilities whether potential this excess energy can be utilized in the surroundings of the WWTP. After the rough spatial analysis, the illustrated area was selected as a potential thermal energy consumer (figure 11).

Figure 11: the WWTP and the selected area (source: google maps)

The selected area is about 8300 m2 and approximately 200 metres away from the WWTP. The case study site showed a connection density of about 1.6 MWh/m, which is in yellow range of the tool. A connection density above 2 MWh/m would be the best achievable result for the feasibility of a district heating network. With a connection density of 1.6 MWh/m, a detailed analysis of the heat demand and further investigation is suggested and should be followed.

5.4. Result and disscussion

The result of the pre-assessment was presented to the operator of this plant. The operator informed us that finances are the key barrier to implement further wastewater-to-energy technologies. They also informed us that they currently do not have financial possibilities to implement the analysed wastewater-to-energy technologies. Hence, they decided to no continue with a detailed feasibility study, but that they will consider the REEF2W tool in the future if a plant upgrading is planned.

6. Conclusion

After presenting and discussing the results with the operators, the WWTP Braunschweig was the most promising plant among all the WWTPs involved in the preliminary assessment. The further reasons for selecting this WWTP are as follows:

- Innovation: The WWTP Braunschweig has already implemented two REEF 2W technologies (co-fermentation and thermal hydrolysis) and shows a high potential for taking up innovations.
- Investments: The operator is ready to invest in REEF 2W technologies such as biogas upgrading or Power-to-gas
- Energy: The possibility of selling the excess energy (electricity and heat) is currently being practiced.
- Business plan: The operator is looking for new and innovative business plans for biogas.

In the next step, the selected WWTP is analysed in more detail. In this context, different scenarios are selected and compared in order to demonstrate how excess energy can be used for self-supply of the WWTP and feed-in into the gas, electricity and heat grid. These options consider the amount of available surplus energy, energy consumption and energy demand of neighbouring settlements as well as existing grid infrastructures. 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.

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