D.T 3.3.3 – PA3: FEASIBILITY STUDY AUSTRIA

Project Title: REEF 2W Increased renewable energy and energy efficiency by integrating, combining and empowering urban wastewater and organic waste management systems

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Content

1. Introduction

The purpose of the deliverable is to finalize the feasibility study by combining D.T2.3.3 Feasibility Study (step 1&2)_Austria and D.T3.1.2 Feasibility Study (step 3&4)_Austria.

The aim of D.T2.3.3 was to analyse the energy efficiency and the potential to produce renewable energy in the project's pilots. This was done using the REEF 2W tool. Implementing the first part of the feasibility study allows to understand how much energy the WWTP is currently using, and at what level of efficiency.

In D.T 3.1.2. the developed Integrated Sustainability Assessment (ISA) was applied to compare the status quo and the proposed REEF 2W solution. Based on the ISA evaluation, decision makers can evaluate strengths and weaknesses of the proposed innovative solutions in the following contexts: Environmental, economic, social and technical.

Essential parts of this deliverable (D.T3.3.3) are based on previous REEF 2W deliverables such as D.T2.3.3 or D.T3.1.2. Revised data and information, concerning the energetic and spatial context of the feasibility study, are partly derived from Zach et al. (2019).

The following deliverable is split into seven essential chapters. In chapter 2, the background and the methodology are generically described and followed by a brief presentation of the expected benefits. Chapter 3 contains a pilot site description as well as a detailed evaluation of the WWTPs energetic context. The optimisation of the energy balance is the focus of chapter 4. In this context a differentiation between heat and electricity is followed. Chapter 5 evaluates the available renewable energy potentials at the pilot site with emphasis on heat recovery from wastewater. Chapter 6 contains a comprehensive spatial analysis, including district heating planning and a re-evaluation of the energy demand in the vicinity of the WWTP. The second last chapter presents the adapted and improved ISA, including evaluations of generic and specific indicators, which is finally followed by the last chapter consisting of a brief conclusion.

2. Background

2.1. Methodology of the feasibility study

The REEF 2W tool is used to systematically assess technical innovations for energy optimisation of wastewater treatment plants (WWTPs) based on different sustainability criteria. The instrument allows predictions concerning potentials to improve the energy performance, the technical feasibility or the environmental sustainability of the REEF 2W solutions. For more detailed information, see D.T1.4.1-3.

The REEF 2W tool, which was developed as an Excel spreadsheet, comprises five core steps (as illustrated in Figure 1):

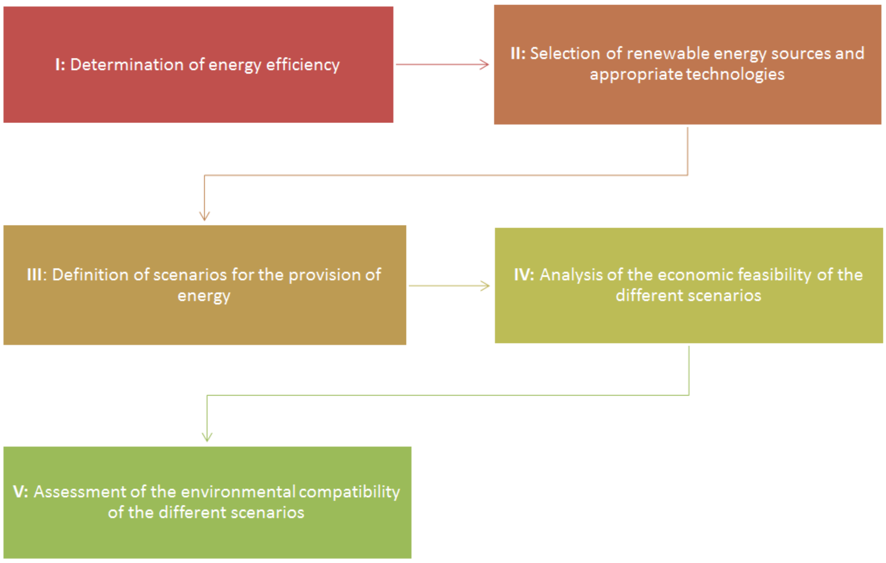

Figure 1: The five steps of the ISA method

I: Energy efficiency 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.

II: Suitable technologies are selected through a potential analysis that compares different renewable energy sources. Emphasis in the project is set on improving heat, electricity 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 as well as 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. Expected Benefits

The implementation of REEF 2W technologies entails several advantages from an energetic, economic and environmental point of view. A brief overview of these advantages is given in Table 1.

Table 1: Overview of benefits regarding REEF 2W 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 cost**s, especially where cost-intensive waste incineration is the only option. Optimising the economic situation of wastewater treatment plants leads to **financial savings for municipalities.**	Energy savings and reduced use of fossil fuels result in a **lower CO_2-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 CO_2-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

The wastewater treatment plant, serving as the Austrian pilot site, is the plant of RHV Trattnachtal, located in Upper Austria (15 km north of Wels) with a capacity of 74.000 population equivalents (PE).

Since 2008 the Biogas Trattnachtal GmbH has been running a waste co-fermentation on the site of the WWTP. The Biogas Trattnachtal GmbH is 100 % owned by the RHV- Trattnachtal. The Biogas Trattnachtal GmbH is the holder of the permit for waste processing (marked green in Figure 1) and the RHV Trattnachtal holds the permit for the wastewater treatment (marked blue and red). Both permits have to be obtained from the local government but from different departments, which leads to different permits concerning the involved topics and technical experts.

The waste co-fermentation changed the energy need and output of the WWTP drastically.

WWTPs with digesters have a considerable heat demand. On the one hand, they have to heat the sludge, on the other hand, the digesters lose heat due to their surface. Figure 1 shows the map of the WWTP of RHV Trattnachtal.

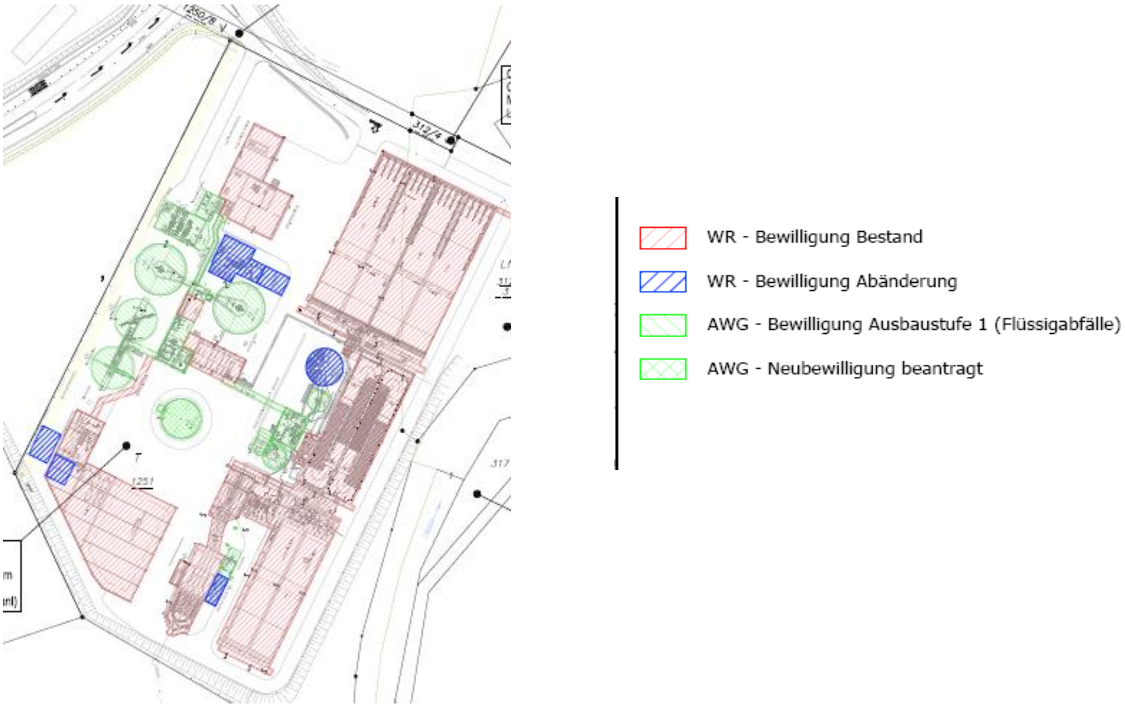

Figure 1: Map of the wastewater treatment plant RHV Trattnachtal (Austrian pilot plant), (RHV Trattnachtal, s. a.)

As for electricity, any surplus generated with the combined heat and power plant (CHP) can be easily fed into the electricity grid. However, from an economic point of view and due to comparably low feed-in tariffs, selling electricity is currently a rather unattractive option.

Selling surplus thermal energy from the CHP is a challenging task. In order to transport thermal energy, heat losses have to be considered and a district heating network (DHN) has to be realised. However, approximately 153,000 kWh of surplus heat is currently used to supply a nearby farm.

Feeding biogas into the natural gas grid is not followed in this case study. The reason for this are comparably high costs for purification. The following chapter addresses the energetic context of the WWTP reflecting energy consumption and production in more detail. Additionally, an evaluation of the energy efficiency of the WWTP is conducted.

3.2. Analysis of the WWTPs energetic context

3.2.1. Current energy consumption and production

On a daily basis, the RHV Trattnachtal produces approximately 100 m^3 preliminary sludge with a dry matter content of 3-6 % and 20 m^3 excess sludge with 2-3 % dry matter. The digestion needs heat energy, because the sludge is approximately 20 °C colder than the digester, which should have around 40 °C.

In 2006, before the co-fermentation plant was put into operation, the combined heat and power unit generated 933,300 kWh, which was 65 % of the total needed electricity (1,435,000 kWh).

Table 2 shows values of 2016 on a monthly basis, in which more electricity is produced than consumed. However, there are days (hours/minutes) when additional electricity is needed and the consumption surpasses the production. In total this amount is estimated to be below 1 % of total electricity consumption.

Table 2: Monthly electric energy balance in kWh for 2016 (RHV Trattnachtal, s. a.)

in kWh (2016)	production	consumption	sold	bought
Jan	212,741	168,899	58,211	15,363
Feb	181,081	149,077	53,869	21,865
Mar	383,497	173,502	211,333	1,338
Apr	268,447	148,559	122,211	2,323
May	306,903	160,642	147,813	1,552
Jun	307,335	161,110	147,629	1,404
Jul	316,455	174,095	144,555	2,195
Aug	283,867	169,399	117,463	2,995
Sep	338,089	177,051	161,318	280
Oct	345,993	178,516	168,552	1,075
Nov	379,889	179,390	200,978	479
Dec	421,157	200,731	220,799	373
total	**3,744,000**	**2,041,000**	**1,755,000**	**51,000**

After the introduction of co-fermentation in 2008, the energy consumption rose significantly by 40 % (from 1,435,000 kWh in 2006 to 2,041,000 kWh in 2016). This is mainly due to the fact that the RHV set up additional, energy consuming technologies on-site (decanter press and a membrane filtration). However, they were using own electricity generated at the WWTP.

The energy production rose by nearly 400 % (from 933,300 kWh in 2006 to 3,744,000 kWh in 2016), so the biogas plant can now easily provide the needed electricity for the WWTP.

Currently, the biogas plant is selling the electricity for 12c/kWh to the RHV Trattnachtal and the surplus electricity is sold to the grid. The market price for electricity is quite low and has been fluctuating between 3-6c/kWh over the last 6 years. In 2016, nearly half of the produced electricity was sold, making it a much better option to get a subsidized tariff (usually around 8-10 c/kWh) from the state in case one exists. In the same year the total costs for natural gas were below 5,000 € (mainly measuring and net costs) and the price for electricity from the grid summed up to approximately 20,000 € (mostly measuring and net costs). One negative aspect is the massive increase of sewage sludge (it nearly doubled) due to waste fermentation.

The following overview shows the power consumption of the RHV Trattnachtal in the year 2016:

- total electricity need of around 2 mio. kWh from which
  - the screening and sand trap needed around 9 %
  - the aeration needed around 25 %
  - the return activated sludge cycle needed around 17 % of the digesters incl. sludge line needed around 11 %
  - diverse consumers needed around 38 %

The sewage plant has a maximum capacity of 74,000 population equivalents (PE) and an average load of 50,000 PE. This results in an electricity need of:

- 2,000,000 kWh/74,000 PE= 27 kWh per PE maximum performance
- 2,000,000 kWh/50,000 PE= 40 kWh per PE average performance

The electricity need can also be calculated in combination with the treated wastewater volume of 2016:

- 2,000,000 kWh electricity for 6,024,000 m^3 wastewater = 0.33 kWh per m^3 of wastewater

The following table (Table 3) shows the utilisation, the consumption and production of heat of the WWTP between 2006 and 2016. In 2016, 153 MWh were used to supply a nearby farm with thermal energy and 177 MWh are unused (chiller). Concerning the heat consumption, the lion's share is dedicated to the heating of digesters, followed by heating demand of the WWTP's buildings and sanitary facilities. Finally, thermal energy production more than doubled between 2006 and 2016.

Table 3: Overview of heat consumption and production at the WWTP (RHV Trattnachtal, s. a.)

		2006 [MWh/a]	2016 [MWh/a]
consumption	digester heat	1,500	2,020
	buildings	270	200
	sanitation	0	89
	total use	**1,770**	**2,309**
production	heat production by local sources	1,200	2,848
	natural gas	570	0

The WWTP has a maximum performance of 74,000 PE and an average performance of 50,000 PE, resulting in a heat consumption of:

- 2,309,000 kWh/74,000 PE= 31 kWh per PE maximum performance
- 2,309,000 kWh/50,000 PE= 46 kWh per PE average performance

The heat consumption can also be calculated in combination with the treated water volume of 2016:

- 2,309,000 kWh heat for 6,024,000 m3 waste water = 0.38 kWh per m^3 of wastewater

A monthly comparison between thermal energy production and consumption is highlighted in Table 4. According to the energy balance, most of the heat is used for heating the digestion towers. Currently, the towers are operating on comparably high temperature. Simultaneously a minimum amount of chemicals is used. However, the temperature to heat the towers could be reduced and thus the energy gained could be utilised for other purposes. Similar to the electricity balance, a thermal surplus is available each month. Unfortunately, 177 MWh were not used and discharged via a chiller in 2016.

Table 4: Monthly thermal energy balance in kWh (RHV Trattnachtal, s. a.)

in kWh (2016)	production	consumption	
		total	share of digestion tower
Jan	224,000	121,000	91,000
Feb	192,000	140,000	119,000
Mar	243,000	171,000	141,000
Apr	212,000	168,000	150,000
May	266,000	242,000	225,000
Jun	230,000	214,000	200,000
Jul	204,000	184,000	165,000
Aug	171,000	153,000	139,000
Sep	244,000	215,000	192,000
Oct	248,000	212,000	184,000
Nov	294,000	237,000	201,000
Dec	320,000	252,000	213,000
total	**2,848,000**	**2,309,000**	**2,020,000**

The amount of thermal energy currently unused and the realisation of energy efficiency measures shows the already available surplus of thermal energy at the pilot site. If in addition, heat recovery from the effluent of the WWTP is followed the plant can be realised as a vital thermal energy source for the surrounding municipalities.

3.2.2. Evaluation of energy efficiency (EE)

For electricity consumption/efficiency the Austrian benchmarking system can be taken as reference (as it is included in tool 1 and visualised in Table 5).

Table 5: Benchmarks of Austrian WWTPs with respect to electric energy consumption (after Lindtner, 2008)

Calculation results	Unit	Standard range	
WWTP total electricity consumption	$kWh/PE_{120}/a$	20	50
Inflow pumping station and mechanical pre-treatment	$kWh/PE_{120}/a$	2.5	5.5
Pumping station	$kWh/PE_{120}/a$	1.5	3.5
Screening	$kWh/PE_{120}/a$	0.5	1
Sand trap and primary clarifier	$kWh/PE_{120}/a$	0.5	1
Mechanical-biological treatment	$kWh/PE_{120}/a$	14.5	33
Aeration	$kWh/PE_{120}/a$	11.5	22
Stirrers	$kWh/PE_{120}/a$	1.5	4.5
Return sludge pumps	$kWh/PE_{120}/a$	1	4.5
Miscellaneous (sec. clarifier)	$kWh/PE_{120}/a$	0.5	2
Sludge treatment	$kWh/PE_{120}/a$	2	7
Thickening	$kWh/PE_{120}/a$	0.5	1
Digestion	$kWh/PE_{120}/a$	1	2.5
dewatering	$kWh/PE_{120}/a$	0.5	3.5
Infrastructure	$kWh/PE_{120}/a$	1	4.5
Heating	$kWh/PE_{120}/a$	0	2.5
Misc. infrastructure	$kWh/PE_{120}/a$	1	2

The total electric energy consumption (approx. 40 kWh/PE) lies within the standard range of 20 to 50 kWh/PE. The consumption for screening and sand trap (4 kWh/PE) lies above the standard range of 1-2 kWh/PE. The aeration (10 kWh/PE) needs less energy than the standard range (11.5 to 22 kWh/PE) indicates. The digesters including sludge line needed 4 kWh/PE, which is in the standard range of 2 to 7 kWh/PE.

For heat, the standard range is given in the following table (Table 6).

Table 6: Benchmarks of Austrian WWTPs with respect to thermal energy consumption (after Lindtner, 2008)

Calculation results	Unit	Standard range	
WWTP total thermal energy consumption	kWh/PE_{120}/a	0	30
Sludge heating	kWh/PE_{120}/a	8	12
Transmission loss, digester tower heating	kWh/PE_{120}/a	0	4
Generation, storage and distribution loss	kWh/PE_{120}/a	0	2
Heat for buildings	kWh/PE_{120}/a	0	2
Heat for supply air unit	kWh/PE_{120}/a	0	10

The heat consumption of 46 kWh/PE lies above the standard range of 0 to 30 kWh/PE, mainly due to a high consumption for the digester towers (around 80 % of the total amount).

4. Optimising the energy balance

The strategies to optimize the energy balance (electricity and heat) consist of three main fields of action:

- Reducing the energy demand of the WWTP
- Optimizing the energy output by using the resources that are available on-site
- Developing strategies to use the surplus (heat) energy at surrounding consumers' sites

Due to co-fermentation the wastewater treatment has already more than 100 % self-supply in electricity as well as in heat. In order to use this surplus heat and therefore making a heat grid profitable, it is desirable to increase this surplus (in this context, also electricity is relevant as it can be used for heat pumps). As a rule of thumb: 1 MW of heat power demand allows installing a heating grid of 1 km. Maximizing the surplus can provide environmental and economic benefits.

There are several options to reduce the demand of electricity and heat, which can be of interest for the RHV Trattnachtal.

4.1. Reducing the heat demand

In order to reduce the overall heat demand of the WWTP, it is essential to evaluate the performance of the largest heat consumers. At the pilot site under investigation, the operation of the digester towers proved to be the main heat sinks in 2016, comprising more than 87 % of the total thermal energy consumption. Accordingly, this section focuses on strategies to reduce this heat demand.

4.1.1. Insulation of the digester towers

An important option to reduce the heat demand is the insulation of the two digestion towers. Currently, heating up the sludge requires around 1,000,000 kWh/a; another about 1,000,000 kWh are subsequently needed for equalizing the heat losses via the surface of the digester towers. The average temperature within the digester towers in 2016 was 39.4 °C and the average ambient temperature at the pilot site was 11.4 °C. With the aid of the temperature difference of 28 °C and the total digester tower surface of 2,000 m^2 the average heat loss per m^2 can be calculated as follows:

$$1{,}000{,}000{,}000\ Wh/a/(8{,}760\ h/a*28\ K*2{,}000\ m^2) = 2\ W/m^2K$$

At the moment, the towers are insulated with a 10 cm glass wool layer. Under normal circumstances, this should lead to an insulation value of about 0.45 W/m^2K.

Glass wool is in principle quite resistant to humidity, provided that it is kept between two layers. If water enters, the thermal insulation quality of glass wool decreases rapidly. In addition to the sidewalls, the insulation of the roofs also has to be evaluated and if necessary, improved.

There are two options of enhancing the insulation quality:

(1) If the problem of humidity is relevant in this case, the glass wool layer should be kept dry by adequate/water proof insulation from outside water. This is a low-cost investment.

(2) In any case, an increase of the thickness of the insulation layer from 9 to 12 cm would result in better insulation values of about 0.18 W/m^2K (using PIR – Polyisocyanurat), However, realising this option requires a high investment. Using (2b) biological insulation materials could be another option to be considered.

4.1.2. Optimizing the temperature in the digester tower

One possibility is to optimize the temperature in the digester towers. Currently, there is no need to reduce the heat demand, as the surplus energy cannot be used. However, as soon as there is a heat grid installed, optimization of heat demand in the digester is a key issue. In this context, reducing the water content of the sludge is one option to reduce the energy demand and is evaluated in detail in section 4.1.3. Additionally, assessing the relation between the temperature in the digester towers and the amount of sewage gas recovery is crucial. It is assumed that temperatures below 35°C will decrease sewage gas recovery. However, at the pilot site an average temperature of 39.4°C was observed in 2016, whereas in 2017 the average temperature was at 44.9°C. Thus, an optimisation of the temperature is an option to reduce the total heat demand.

4.1.3. Minimizing water amount in the sludge

The higher the dry matter content in the sludge the less water needs to be warmed up. Therefore, the sludge should be as dry as possible (ensuring that its pumping ability can be maintained). Generally, doubling the dry matter content leads to a 50 % reduction of the required thermal energy for heating.

4.1.4. Changing to low temperature heating of the digester towers

Another option to improve the efficiency of heating the digester towers is to change to low temperature heating. A promising alternative would be to use the recovered low temperature heat from the effluent of the WWTP. The generated energy could be used to heat up the digester towers and simultaneously to provide low temperature heating to surrounding settlements of the WWTP via district heating. Thermal energy from digester gas could thus be used to temporally raise the temperature in the DHN for domestic warm water purposes. In order to realise this option, the heat exchanger in the digester towers needs to be exchanged, since the current one is designed for higher temperatures. If the shift to low temperature heating of the digester towers is followed, more biogas could be used to generate electricity. The newly available surplus electricity can further be used for heat pump operation (see chapter 5.1).

4.1.5. Optimizing aeration

Another possible strategy to reduce heat demand is the optimization of aeration. Either the amount of oxygen per time can be adjusted or time can be designated in which there shall be no aeration at all. Moreover, the amount of oxygen that has to be pumped into the wastewater basins depends on the actual quantity and quality of the wastewater. Other opportunities can be found by checking benchmark values of Austrian WWTPs.

4.2. Reducing the electricity demand

The lion’s share of the electricity consumption is usually associated with aeration. At the pilot site in Austria, only a share of about 25 % was measured for aeration. With a total of 40 kWh/(PE*a) the WWTP performs within the standard range of 20 to 50 kWh/(PE.a) (Lindtner 2008). Due to additional electricity measurements it was possible to calculate a savings potential of 2.5 kWh/(PE*a) for screening and sand trap. In order to obtain more detailed results, a technology specific acquisition of data is necessary.

4.3. Data availability and quality

As for energy consumption, monthly data from the last years has been taken as basis (electricity, heat and gas, partially split into different purposes). Older data is only estimated. Sub-monthly data was not available, but is not necessary for the scope of the analysis.

In light of energy optimization, wastewater flow and temperature data are available in good quality.

5. Application of renewable energies and associated energy output improvements

The two main energy sources at the WWTP are:

- The thermal energy of the treated wastewater – can be used for low temperature heat up to approximately 65 °C
- The energy in the sewage sludge (digester gas) – can be used for electricity and thermal energy provision

Other forms of locally available non-fossil energy sources are:

- Electricity:
  - Wind energy
  - Solar energy
  - Water power by using a height difference between the WWTP and the receiving water (i.e. river)
- Heat:
  - Solar energy

As requested by the WWTP operator, this pilot example will focus on wastewater heat recovery (thermal energy) and optimized use of the digester gas.

In order to be able to use the surplus heat energy a heating grid has to be installed. The first step is an analysis of the surrounding settlements and possible heat consumers regarding their energy consumption, temperature levels and willingness to participate in this energy concept. For the spatial context, see software tool N.2 and evaluations in chapter 6.

5.1. Heat recovery from wastewater

The mean wastewater flow through the WWTP is 688 m^3/h or 191 l/s on average in the years 2016 and 2017. Analysis of the wastewater effluent on an hourly basis shows that 120 l/s are permanently available. The aim of the operator is to use the annual electricity surplus from the CHP, of approximately 1,750,000 kWh, to operate heat pumps and consequently to recover thermal energy from wastewater. Depending on the temporal availability of surplus electricity, additional electricity will be required during certain time periods to exploit the full potentials of the heat pumps. Table 7 shows, that in 2016 and 2017 an annual mean wastewater flow of 6,000,000 m^3 was observed at the pilot plant of RHV. In the same period the average wastewater temperature was measured at 14.3 °C.

Table 7: Monthly WWTP wastewater flows, average wastewater temperatures and energy recovery potentials (RHV Trattnachtal, s. a.)

mean (2016-2017)	waste water [m³]	T effluent [°C]	cooling to [°C]	available thermal energy [kWh/month]	electrical energy for heat pump (50°C)
Jan	505,787	9.6	7.6	1,173,426	467,035
Feb	468,334	10.3	8.3	1,086,535	422,298
Mar	542,247	11.4	9.4	1,258,013	470,785
Apr	555,607	12.9	10.9	1,289,008	457,625
May	647,611	15.0	13.0	1,502,458	494,331
Jun	444,780	18.3	16.3	1,031,890	299,357
Jul	472,397	19.2	17.2	1,095,961	306,745
Aug	451,656	19.4	17.4	1,047,842	290,920
Sep	417,945	17.1	15.1	969,632	294,757
Oct	460,046	15.0	13.0	1,067,307	351,160
Nov	455,621	12.4	10.4	1,057,041	381,976
Dec	602,284	10.6	8.6	1,397,299	537,538
total	**6,024,315**	**14.3**	**12.3**	**13,976,411**	**4,774,528**

Considering a wastewater temperature decrease due to heat extraction (delta T) of 2K, an energy amount of 14,000,000 kWh/a could be extracted from the wastewater, resulting in an electric energy consumption of heat pumps of 4,800,000 kWh/a. Hence, a total of 18,800,000 kWh/a of thermal energy can be utilised. For this, additional off-site electricity demand of approximately 3,000,000 kWh/a is required. Taking this into account, strategies for reducing the electric energy demand and maximizing the electric energy efficiency are available and described in chapter 4, the provision of an even higher fraction of the electric energy for the heat pumps is possible.

In order to guarantee the heat recovery potentials, heat pumps with a capacity of 750 kW are necessary. Thus, the total thermal capacity is estimated to 2.75 MW.

Depending on the assumed delta T of the wastewater in the WWTP effluent, the available energy potential changes. Technically also a cooling of 4 K is possible. This would double the presented results accordingly: 28,000,000 kWh heat extraction from wastewater; 9,500,000 kWh electricity demand for the operation of heat pumps; 1.5 MW electric capacity and 5.5 MW thermal capacity.

5.2. Digester gas utilization - CHP unit

Optimizing the energy output from digester gas (from sewage sludge and co-fermentation) is a vital aspect. In the development of energy supply strategies, the digester gas plays a completely different role compared to the energy recovery from wastewater explained before:

- It can be used for heat supply without using electric energy (e.g. for heat pumps),
- for heat at a high temperature level (contrary to low temperature wastewater heat)

- and it can additionally be used for electricity production.

Therefore, these two types of energetic (thermal) resources serve for different heat demands (which are: low temperature domestic heat, high temperature domestic heat, domestic warm water, digester heat, etc.). Stratified storage tanks can store thermal energy from both sources. An optimized storage strategy will help to cover all different heat energy needs. Currently, the WWTP delivers 2.85 GWh/a heat and 3.74 GWh/a electricity generated from digester gas.

In the energy concept, a second energy source will be taken into account: A thermal energy source in app. 4 km distance is able to deliver heat energy. There are also several thermal baths in this area, proving the availability of potential of geothermal heat. At this stage the exact energy potential of the geothermal source is unknown.

5.3. Other technologies

Other technologies/approaches considered in REEF 2W (as for instance solar energy, biogas upgrading, power to gas) are not relevant for the specific context of the investigated case study. Consequently, these technologies are not being considered here either.

6. Spatial analysis and potentials to utilise surplus energy from the WWTP

Before the spatial analysis is carried out, the magnitude of available surplus energy from the WWTP is estimated. Surplus electricity from the CHP is currently fed into the electricity grid. As indicated in chapter 5.1 surplus electricity provided by the CHP, will be partly used for the operation of heat pumps to recover thermal energy from wastewater. In total, 18.8 GWh/a (taking into consideration a cooling of 2K) of thermal energy can be recovered and sold, increasing the economic benefits of the operator. As suggested in D.T2.3.3 a more detailed spatial analysis was carried out in this deliverable, including comprehensive district heating planning and a revision of the energy demand in the vicinity of the WWTP. The following chapters are divided accordingly. After specifying characteristics of the study area, potential supply areas are evaluated followed by a specification of a district heating network and a final determination of supply areas, the so-called “energy zones”.

6.1. Characteristics of the study area

The pilot site is situated in the *Trattnachtal*, a valley along the river *Trattnach*, in Upper Austria (approx. 15 km north of Wels and 35 km southwest of Linz). Figure 2 shows the municipalities *Wallern an der Trattnach*, where the pilot site is located, and the neighbouring municipality *Bad Schallerbach*.

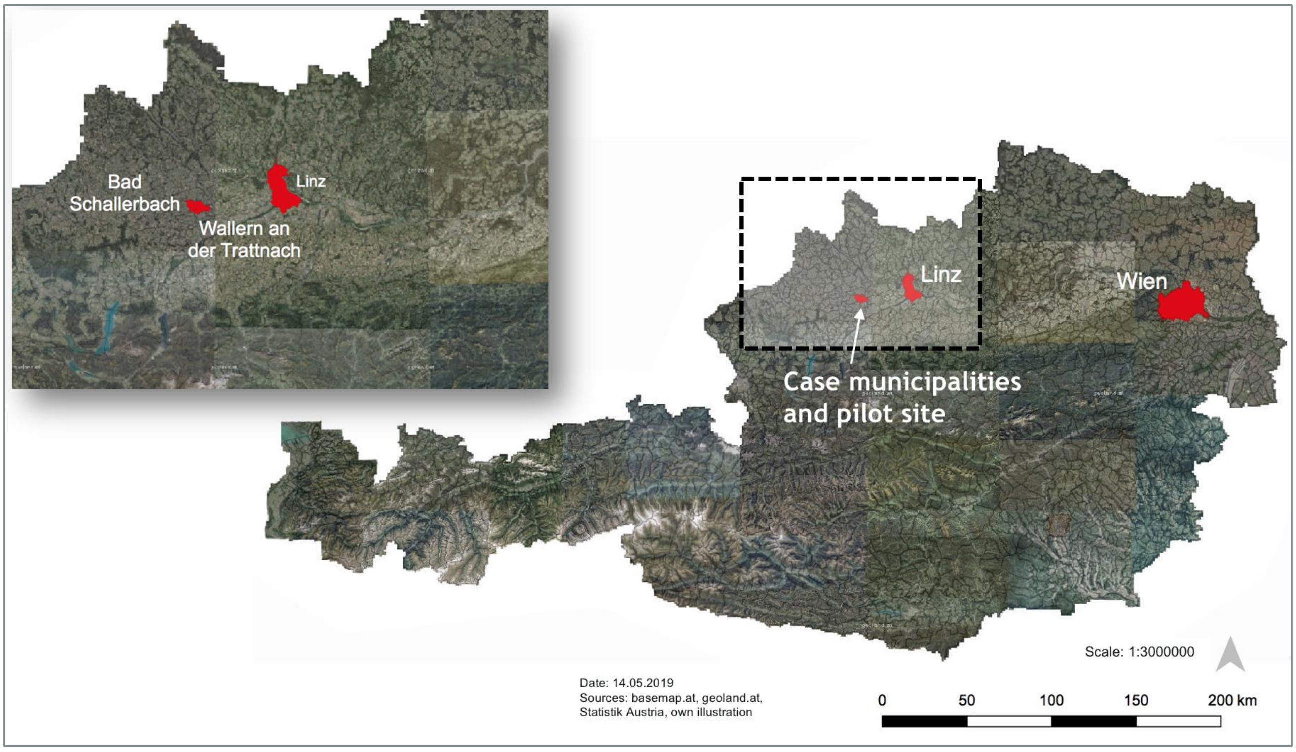

Figure 2: Location of case municipalities and pilot site (own illustration)

Both municipalities are assigned to the political district of *Grieskirchen* in the NUTS 3 Region *Innviertel* AT311. In 2017, *Wallern an der Trattnach* had a total population of 3,039 and *Bad Schallerbach* 4,169 inhabitants (Statisik Austria, s. a.).

The exact address of the *RHV-Trattnachtal* and the *Biogas Trattnachtal GmbH* is *Parzham 3, A-4702 Wallern an der Trattnach*. As Figure 3 shows, the pilot site is situated approximately 1.8 km from the village centre of *Wallern an der Trattnach*.

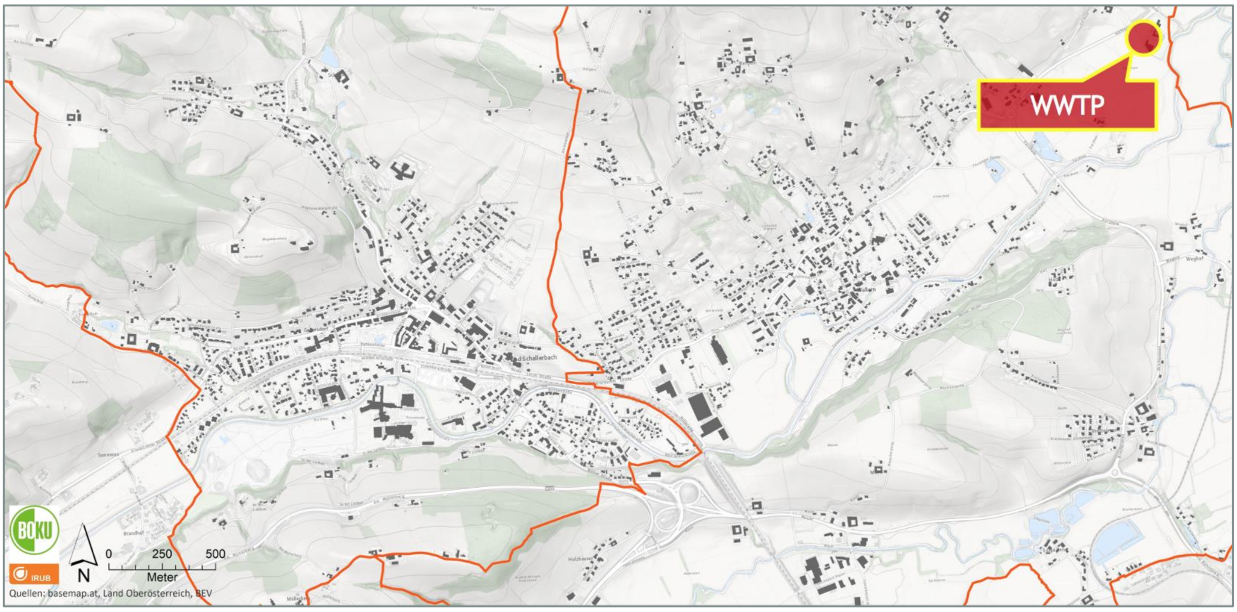

Figure 3: Overview of the Trattnachtal including the location of the WWTP (own illustration)

6.2. Initial evaluation of suitable zones for heat supply

After a first impression of the aerial photograph, potential hotspots of thermal energy consumption were identified. The starting point for the visual analysis were the village centres of *Wallern an der Trattnach* and *Bad Schallerbach*, respectively. As indicated in software tool N.2, areas with potentially high heat demand are village/town centres as well as areas with multi-storey buildings and commercial/industrial areas. These relevant areas/zones of interest were used to get a first impression about the spatial context of the considered WWTP.

6.3. District heating planning

Based on the initial visual analysis, relevant areas - so called "energy zones" – were delimited. In parallel, a potential district heating network connecting the single areas was also taken into consideration. For the final delimitation of the areas and the potential district heating network certain natural and anthropogenic barriers in the *Trattnachtal* were identified. In the pilot region, there are a couple of barriers like the river *Trattnach* or the railway tracks through *Bad Schallerbach*. Another vital aspect for drafting a district heating network is the height level difference, which is an indicator for the gradient of the slope. In the northern part of both municipalities, the slopes are quite steep, resulting in a natural barrier for a potential district heating network.

In summary, the essential criteria for delimitating relevant supply areas and the district heating network are:

(1) Identification of areas (and buildings) with potentially high energy demand like village and town centres, areas with multi-storey buildings or commercial/industrial areas.

(2) Identification of municipal buildings, as municipalities act as “initial seedbeds in transition” (Geels 2010) and are often interested in supplying their “own” buildings with renewable energy

(3) Planning documents like local development concepts or zoning plans to further identify potential areas for heat supply (also in the context of future developments).

(4) Identification of natural and anthropogenic barriers that might pose an impact on the realization of a district heating network (e. g. railway tracks, rivers, slopes, protected areas etc.).

(5) Already existing infrastructure like the road network. Existing road networks can be used as vectors for planning district heating networks (see Figure 4).

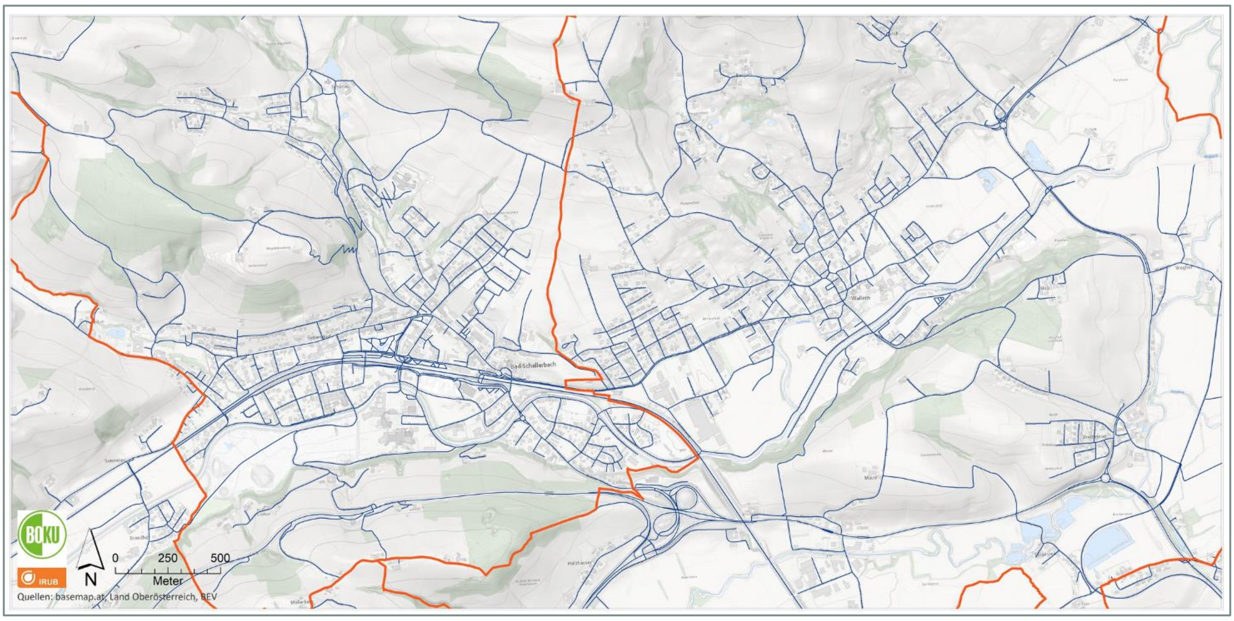

Figure 4: Illustration of existing road network in the Trattnachtal (own illustration)

6.4. Final determination of energy zones and district heating network

The following illustration (Figure 5) shows a differentiation of relevant areas in the Trattnachtal that can consequently be used for an analysis with software tool N.2. In contrast to D.T2.3.3 also specific GIS analysis were carried out in addition to the application of software tool N.2. The first relevant areas (Area_ID: W2 and W1) represent the village centre of *Wallern an der Trattnach* and B2_1 and B2_2 delimit the centre of *Bad Schallerbach*.

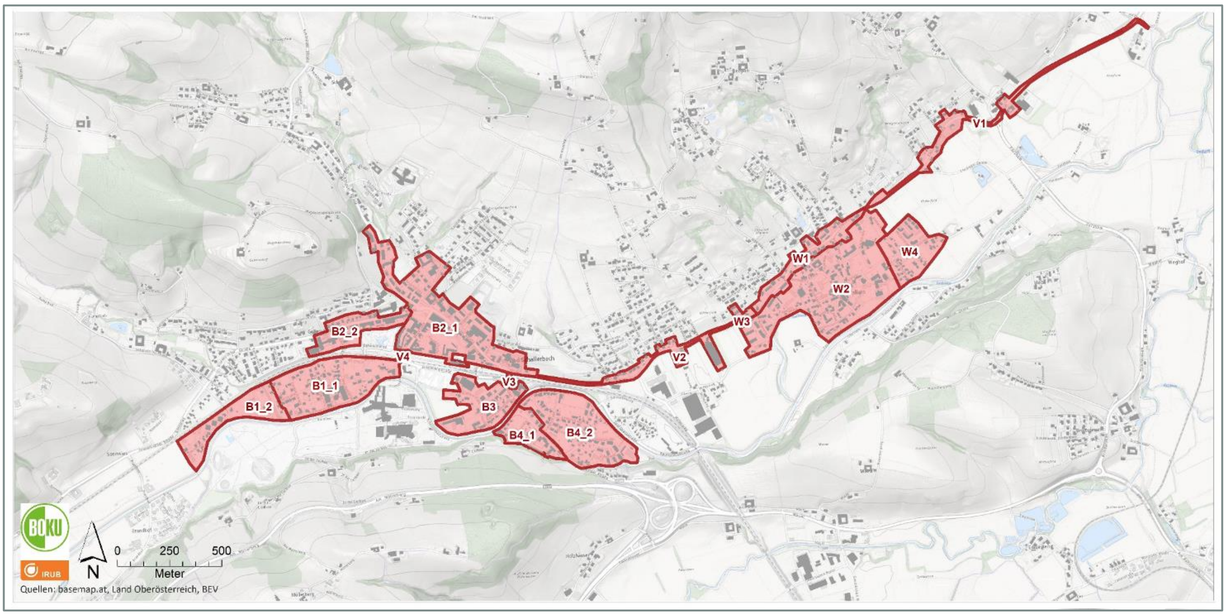

Figure 5: Illustration of relevant areas (energy zones) representing a mix of different energy consumers and hotspots of energy demand (own illustration)

Both village centres are highlighted in more detail in Figure 6, including the generated district heating network. The overall goal is to generate an efficient district heating network, divided into main segments and building links, which are both oriented to the existing road network. Hence, the main segments were generated using the GIP geo-dataset (https://www.gip.gv.at/). The GIP dataset includes all relevant road networks. Building links were consequently generated right-angled, starting from the main segment to the potentially supplied building. Results are presented in Figure 6, from which the total lengths of the district heating network can be derived and used to calculate the connection density in MWh/m.a.

Figure 6: Illustration of village centres and the generated district heating network (own illustration)

For every energy zone a calculation of the total heat demand and the total district heating network lengths is followed. This way, the connection densities can be calculated, which serve as indicators to evaluate the feasibility of the zones for heat supply. After the connection densities in MWh/m.a of the single energy zones were evaluated, a final combination (total supply area) of energy zones was defined. Energy zones with comparably low connection densities were no longer considered. The final supply area is illustrated in Figure 7. In total there are seven energy zones (W2, W3, B2_1, B2_2, B1_1, B3 and B4_1) and four subzones connecting the energy zones (V1, V2, V3 and V4).

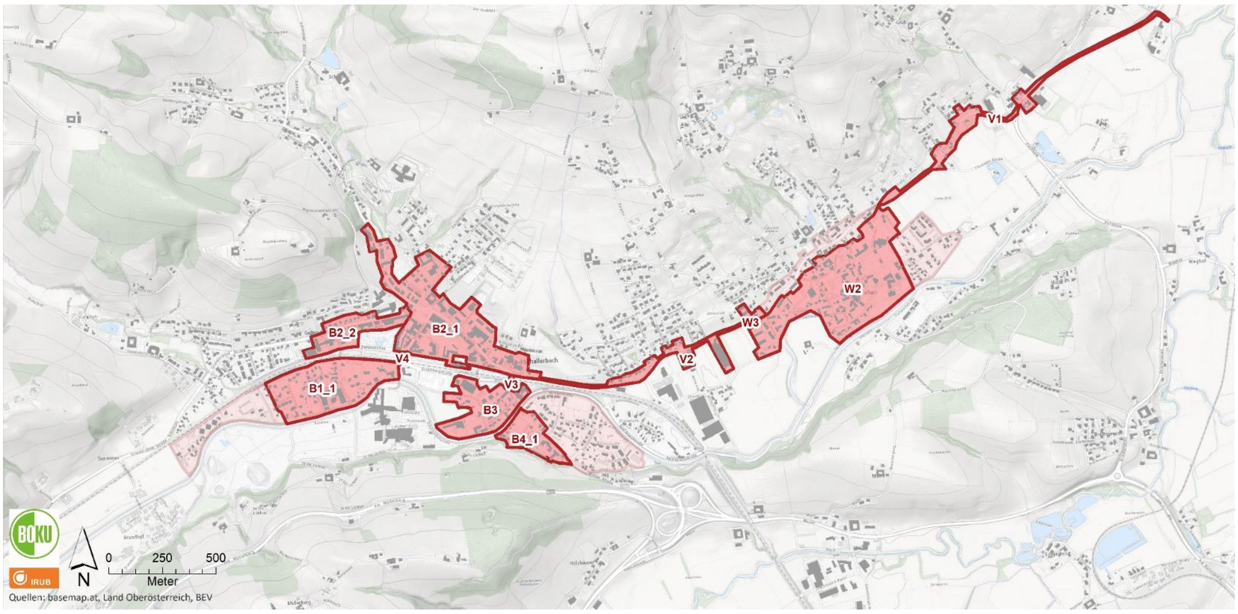

Figure 7: Final combination of energy zones representing the supply area (own illustration)

The following results are based on the combination of energy zones, as illustrated in Figure 7. Basis for the calculation is the total heat demand in the settlements under investigation, including residential buildings, municipal buildings and heat demand of services or industries. Generally, district heating planning should not only focus on the current status of the settlements. Hence, it is essential to take future developments like renovation activities into consideration. Another vital part is to imply a certain connection rate of supplied consumers, because in most cases it is not possible to connect every building to the district heating network. In that sense, residential buildings with a building period after the year 2001 were not included in the calculations (adapted connection rate). Additionally, the space heating demand was reduced by 20 % for all residential buildings. This way it was possible to consider a certain connection rate and renovation activities in the calculations.

Data on energy consumption of municipal buildings was provided by the authorities of the case municipalities. Additionally, the heat demand of the sectors services and industry were also considered. Relevant energy consumption data, concerning residential buildings as well as service and industrial buildings were calculated based on the methodology presented in Abart-Heriszt et al. (2019). The exact locations of individual buildings are based on the national register of buildings and dwellings (AGWR).

As Table 8 shows, the total area of energy zones comprises 78 hectares, corresponding to around 20,300 MWh/a of thermal energy demand. In total, 369 individual buildings are connected to the evaluated district heating network. The required district heating network stretches over 17,400 m and can be subdivided into 13,000 m main segments and 4,400 m building links.

As a result of the more detailed spatial analysis (in comparison to D.T2.3.3) the connection density was calculated to be 1.17 MWh/m.a. A connection density between 0.7 and 1.4 is considered suitable for more detailed evaluations (Nussbaumer et al. 2017).

Table 8: Evaluation results of energy zones as illustrated in Figure 8

Scenario I		
Area of energy zones	78	ha
Heat demand	20,300	MWh/a
Number of connected buildings	369	
Total grid length	17,400	m
Main segment	13,000	m
Building links	4,400	m
Connection density	1.17	MWh/m.a

The spatial analyses showed, that there is considerable heat demand in the vicinity of the WWTP. A potential next step would be to include spatiotemporal modelling in the evaluations (e.g. Ramirez Camargo and Stoeglehner 2018). With the help of spatiotemporal modelling it is possible to evaluate the energy demand on high temporal resolution like months, days or hours. From a technical point of view this would be helpful, in order to match energy generation from the WWTP and energy demand in the WWTPs surrounding settlements. For instance, during summer periods a lot of heat can be recovered from the WWTP, whereas during the same time hardly any space heating is required. Due to spatiotemporal modelling, the match as well as the mismatch of demand and supply can be identified and the operation of heat supply can be optimized, resulting in economic benefits for the energy provider.

The evaluations presented in this spatial analysis can be further used to supply policymakers with information on how to recover and use local renewable energy from the WWTP. Due to the local character of thermal energy, it is not possible to supply all relevant areas of both municipalities. However, the heat recovery from the WWTP would increase the share of renewable energy supply in the case municipalities. Hence, this utilisation of local renewable energy can contribute to the energy turn, which is a fundamental pillar to tackle climate change. Based on the energetic and spatial evaluations, the following chapters are dedicated to the revised Integrated Sustainability Assessment (ISA).

7. ISA of pilot in Austria

7.1. Pilot and applied REEF 2W technology specification

The REEF 2W pilot site in Austria is located approximately 200 km west of Vienna and 40 km south-west of Linz, comprising the municipalities of "Wallern an der Trattnach" and "Bad Schallerbach". North-east of the village centre of Wallern an der Trattnach the wastewater treatment plant (WWTP with 74,000/50,000 PE) "RHV Trattnachtal" is located. The pilot site, including the WWTP and its surroundings, serves as an example to realize the REEF 2W solution of recovering thermal energy from wastewater.

In this context, Figure 8 illustrates a simplified scheme of the REEF 2W solution. Currently there are two digester towers in operation, providing biogas to a CHP unit. Considering the annual energy balance, the WWTP provides surplus electricity as well as thermal energy. Due to this fact, surplus electricity (provided by the CHP unit) could be used to operate (a) heat pump(s), thus recovering thermal energy from the effluent of the WWTP. Since an initial evaluation of the energy demand in the two municipalities already showed that there is sufficient heat demand in the surroundings, the REEF 2W solution of installing a heat pump in the effluent of the WWTP was followed and is evaluated in more detail in the subsequent ISA.

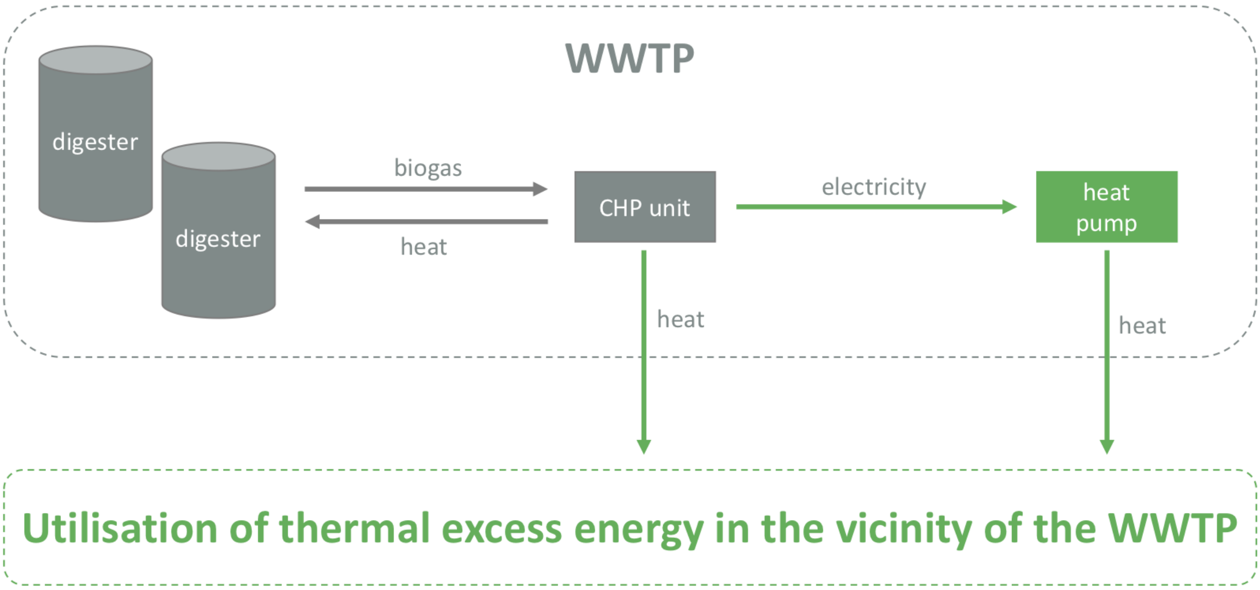

Figure 8: Simplified scheme for the REEF 2W solution at the pilot site in Austria

The following subchapters start with a pre-assessment, evaluating general indicators presented and described in Deliverable 3.1.1. and initially evaluated in Deliverable 3.1.2. The general indicator evaluation is followed by the calculation of specific indicators and a corresponding multi-criteria analysis. Data for the evaluation can be found in this deliverable, in previous REEF 2W deliverables and in the recent publications by Neugebauer et al. (2019) and Zach et al. (2019).

7.2. General indicator evaluation

As described in D.T3.1.1 the "indicator pyramid" serves as a basis for the hierarchical approach of the ISA. On the pre-assessment level general indicators are evaluated which are presented in the following table (see Table 9). Further, the results are differentiated between the Status Quo (current situation) and the applied REEF 2W solution at the pilot site.

Table 9: General indicators used for the pre-assessment at the pilot site in Austria

Sustainability criteria	General indicator	Measurement	Categories	Graduation	Status Quo	REEF 2W solution	Explanations on classification
Availability of excess energy (Software tool N.1)	Electric excess energy provision	Difference between electric energy production and consumption in kWh	> 0 ≤ 0	A B	A	B	Staus Quo: 3.7 GWh/a - 2 GWh/a = 1,700,000 kWh/a surplus REEF 2W solution: 1.7 GWh/a - 4.8 GWh/a = 3,100,000 kWh/a additional external electricity demand due to heat pump application
	Thermal excess energy provision	Difference between thermal energy production and consumption in kWh	> 0 ≤ 0	A B	A	A	Staus Quo: 2.8 GWh/a - 2.3 GWh/a = 500 kWh/a thermal surplus REEF 2W solution: 0.5 GWh/a + 14 GWh/a + 4.8 GWh/a = 19,300,000 kWh/a
	Excess digester gas provision	Difference between digester gas production and consumption in m^3	> 0 ≤ 0	A B	B	B	In both scenarios surplus is not available, due to the utilisation of gas for thermal energy
Availability of energy consumers (Software tool N.2)	Excess electricity demand	Electricity demand in the vicinity of the WWTP and in kWh	> 0 = 0	A B	A	A	The WWTP is connected to the electricity grid and electricity demand is given in the municipalities and settlements nearby.
	Excess heat demand	Heat demand in the vicinity of the WWTP and in kWh	> 0 = 0	A B	A	A	Heat demand is already given within a radius of 1 km from the WWTP. First spatial assessments indicate more than 20 GWh/a heat demand in selected zones in the neighbouring municipalities.
	Excess digester gas demand	Digester gas demand in the vicinity of the WWTP and in kWh	> 0 = 0	A B	A	A	Gas demand in the vicinity of the WWTP is given. Additionally, gas networks stretch across the two pilot municipalities.

It can be seen that in the status-quo a surplus of electricity is given (“A” rating). If a heat pump is applied, additional electricity is required, resulting in a “B” rating for the REEF 2W solution. However, due to the heat pump application, even more thermal excess energy can be provided in the future. The produced digester gas by the CHP unit is entirely used for thermal energy provision, therefore there is no excess digester gas available. Electricity, heat as well as gas demand is above zero in all scenarios. More specific spatial analyses, as shown in chapter 6, indicate more than 20 GWh/a heat demand in relevant energy zones, resulting in an “A” rating.

7.3. Specific indicator evaluation

Based on the pre-assessment level, the actual assessment using specific indicators is followed. Results of the general assessment indicates that a further evaluation of the specific criteria can be followed. Table 10 shows the evaluated sustainability criteria that are split into: Environmental, social, economic and technical criteria. Unfortunately, it was not possible to assess each indicator in the “Status Quo” due to the character of some indicators that imply a “change” in order to be evaluated. Problems and suitability regarding indicator applications are specified in chapter 7.4.

Table 10: Results of specific sustainability indicators for the pilot in Austria

Sustainability criteria	Indicator	Measurement	Categories	Grad-uation	Status Quo	REEF 2W solution	Explanations on classification
Environmental context	CO_2 emissions reduction for consumed electric energy (internal and external)	%	> 0 = 0	A B	A	A	Status-Quo: Total consumption (including electricity sold) equals to 979,300 kg CO_2, whereas the electricity externally bought is calculated at 13,200 kg CO_2. Hence, a reduction of 99 % is derived. REEF 2W solution: Additional external electricity is required, due to heat pump operation. Therefore, the total consumption equals to 1,772,000 kg CO_2, whereas the additionally required energy from the grid is calculated at 806,000 kg CO_2. Hence a reduction of 55 % is derived.
	CO_2 emissions reduction for consumed thermal energy (internal and external)	%	> 0 = 0	A B	A	A	Status-Quo: Since a thermal surplus is available via the CHP unit, the reduction is >100 % REEF 2W solution: Surplus increases even more after recovering heat from the wastewater.
	Share of renewable electricity (internal and external)	%	> 100 100-0 0	A B C	B	B	Status-Quo: Approximately 99 % of electricity is produced renewable on site (3.74 GWh/3.8 GWh) REEF 2W solution: Due to the additional electricity demand caused by the heat pump, the share of renewable electricity is estimated at 55 % (3.7 GWh/6.8 GWh)
	Share of renewable thermal energy (internal and external)	%	> 100 100-0 0	A B C	A	A	Status-Quo: More than 100%, due to the surplus of heat provided by the CHP unit REEF 2W solution: After applying the heat pump, even more surplus heat can be provided resulting in more than 100 % renewable thermal energy
	Share of renewable gas (external)	%	> 100 100-0 0	A B C	N/A	N/A	Gas is used exclusively for heat generation
	Sludge production change	Delta t DM / year	<0 0 >0	A B C	B	B	Due to heat pump application there is no change in sludge production.

Sustain ability criteria	Indicator	Measurement	Categories	Grad-uation	Status Quo	REEF 2W solution	Explanations on classification
Social context	Affordable energy	%	Lower Same (+-10 %) Higher	A B C	B	B	Status Quo: Surplus electricity is offered at market prices REEF 2W solution: It is assumed, that surplus heat via district heating will be within the range of +-10 %
	Number of applied technologies for electric energy provision (*Resilience*)	Quantity	3 1-2 0	A B C	B	B	Status Quo: Currently only CHP unit at the WWTP REEF 2W solution: Also, in the future only CHP unit at the WWTP
	Number of applied technologies for thermal energy provision (*Resilience*)	Quantity	3 1-2 0	A B C	B	B	Status Quo: Currently only the CHP unit at the WWTP REEF 2W solution: Besides the CHP unit also heat pump application to recover heat from the effluent
	Additional employment	Change of employment, job creation or loss	>0 0 <0	A B C	B	B	Status Quo: No change of employment REEF 2W solution: Based on cautious considerations it is assumed that there will be no additional employment
	Local environmental welfare	Indication of local welfare change	Positive Neutral Negative	A B C	B	A	Status Quo: No change of local welfare REEF 2W solution: Due to central heat supply via district heating no additional emissions at consumer site, resulting in a positive rating.
Economic context	Return of Investment (ROI)	Years	<3 3-10 >10	A B C	N/A	C	Status Quo: Since no investments are made in the Status Quo, this indicator is not applicable REEF 2W solution: Based on experience from previous heat recovery applications (e.g. Amstetten, Austria) the ROI is estimated to be slightly above 10 years.
	Additional income	€	>0	A	A	A	Status Quo: Additional income is above 0 due to selling electricity from the CHP unit

Sustain ability criteria	Indicator	Measurement	Categories	Grad-uation	Status Quo	REEF 2W solution	Explanations on classification
			0 <0	B C			REEF 2W solution: Similarly to the status quo, it is assumed that if heat is recovered that there will be additional income due to selling the heat to heat consumers in the vicinity of the WWTP.
	Energy costs saving	€	>0 0 <0	A B C	A	A	Status Quo: Electricity is currently sold, resulting in energy costs savings, due to reduced external demand. REEF 2W solution: Currently the digester towers are refurbished (insulation). Hence, energy costs will be saved in the future. Also, excess energy from heat recovery will be sold after applying the REEF 2W solution. Therefore, it will not be necessary to purchase external thermal energy.
Technical context (energetic & spatial)	Degree of electric self-sufficiency	Ratio between electric energy production and consumption in %	>75 25-75 <25	A B C	A	B	Status Quo: More than 75 %, since more electricity is currently produced than consumed REEF 2W solution: Considering the future electricity consumption of the heat pump, additional electricity is required and the self-sufficiency will be decreased to approximately 55 %
	Degree of thermal self-sufficiency	Ratio between thermal energy production and consumption in %	>100 20-100 <20	A B C	A	A	Status Quo: 0.5 GWh surplus, resulting in more than 100 % REEF 2W solution: Even more surplus is generated (approx. 19 GWh)
	Degree of externally usable excess heat	Ratio between heat production and consumption in %	> 0 0	A B	B	A	Status Quo: Currently the excess heat is not sufficiently used. REEF 2W solution: After applying a district heating network and supplying external consumers the degree of usable excess heat will be >0
	Degree of usable excess gas	Ratio between gas production and consumption in %	> 0 0	A B	B	B	Status Quo: No biogas upgrading or feed-in station REEF 2W solution: No biogas upgrading or feed-in station planned

Sustain ability criteria	Indicator	Measurement	Categories	Grad-uation	Status Quo	REEF 2W solution	Explanations on classification
	Electric energy consumption at WWTP	$kWh/PE_{120}.a$	< 20 20 - 50 > 50	A B C	B	N/A	Status Quo: 40 $kWh/PE_{120}.a$ REEF 2W solution: The benchmarks according to Lindtner are values for conventional WWTPs, not including technologies like co-fermentation or heat pump applications. Therefore we specified N/A for the REEF 2W solution.
	Thermal energy consumption at WWTP	$kWh/PE_{120}.a$	<30 > 30	A B	B	N/A	Status Quo: 46 $kWh/PE_{120}.a$ REEF 2W solution: The benchmarks according to Lindtner are values for conventional WWTPs, not including technologies like co-fermentation or heat pump applications. Therefore we specified N/A for the REEF 2W solution.
	Electric energy generation at WWTP (with anaerobic stabilisation)	$kWh/PE_{120}.a$	>20 10-20 <10	A B C	A	N/A	Status Quo: 75 $kWh/PE_{120}.a$ REEF 2W solution: The benchmarks according to Lindtner are values for conventional WWTPs, not including technologies like co-fermentation or heat pump applications. Therefore we specified N/A for the REEF 2W solution.
	Thermal energy generation at WWTP (with anaerobic stabilisation)	$kWh/PE_{120}.a$	>40 20-40 <20	A B C	A	N/A	Status Quo: 57 $kWh/PE_{120}.a$ REEF 2W solution: The benchmarks according to Lindtner are values for conventional WWTPs, not including technologies like co-fermentation or heat pump applications. Therefore we specified N/A for the REEF 2W solution.

From an environmental point of view, additional electricity is required for the operation of the heat pump. However, the amount of excess heat of 19 GWh/a (mainly from heat recovery) can be interpreted as the main environmental benefit of the REEF 2W solution. Simultaneously the social benefits of the REEF 2W scenario outweigh the current situation. For example, the number of applied technologies for thermal energy provision increases and the local environmental welfare is positively influenced. Although additional income, due to the disposal of surplus heat in the REEF 2W scenario, will be generated, the Return on Investment (ROI) of the heat pump application shows a rather poor rating “C”.

7.4. Suitability of indicators

In Austria, the majority of indicators were used, except indicators related to biogas (e.g. "Share of renewable gas (external)". This is due to the utilisation of biogas for thermal energy on-site. Additionally, some indicators could not be calculated because of their character of implying a "change". If the requirements for a change were not applicable, the indicators could not be calculated. This is especially relevant for indicators in the Status quo, like the ROI. Whenever it was not possible to apply an indicator the specification of "N/A" (not applicable) was used. Further, the benchmarks according to Lindtner are values for conventional WWTPs, not including technologies like co-fermentation or heat pump applications. Therefore, a specification of N/A for the REEF 2W solution was followed.

The calculation of values for the final indicator evaluations was done partly by using of REEF 2W tools and partly by own calculations, using more detailed data from the WWTP. It is also important to mention, that the methodology used for the holistic spatial analysis goes beyond the capability of the REEF 2W tool.

7.5. Multi-criteria decision analysis (MCDA)

The following table (Table 11) shows the results of the first ISA application for both "Status Quo" and the "REEF 2W solution". The assigned colours were used to underline the alphabetical graduation in order for decision makers to easily identify where improvements are required or on the contrary where the WWTP is performing comparably well. The results indicate that the performance of the WWTP is already promising. For instance, the heat pump application of the REEF 2W solution only affects the electric excess energy provision.

Table 11: Overview and visualisation of general indicator results for the pilot in Austria

General indicator	Categories	Graduation	Status Quo	REEF 2W solution
Electric excess energy provision	> 0 ≤ 0	A B	A	B
Thermal excess energy provision	> 0 ≤ 0	A B	A	A
Excess digester gas provision	> 0 ≤ 0	A B	B	B
Excess electricity demand	> 0 = 0	A B	A	A
Excess heat demand	> 0 = 0	A B	A	A
Excess digester gas demand	> 0 = 0	A B	A	A

Table 12 shows the results of the specific indicators. Some cells are indicated with "N/A", because some indicators were not suitable to be applied. For further information on the suitability of indicators see Chapter 7.4.

Table 12: Overview and visualisation of indicator results for the pilot in Austria

Indicator	Categories	Graduation	Status Quo	REEF 2W solution
CO_2 emissions reduction for consumed electric energy (internal and external)	> 0 = 0	A B	A	A
CO_2 emissions reduction for consumed thermal energy (internal and external)	> 0 = 0	A B	A	A
Share of renewable electricity (internal and external)	> 100 100-0 0	A B C	B	B
Share of renewable thermal energy (internal and external)	> 100 100-0 0	A B C	A	A
Share of renewable gas (external)	> 100 100-0 0	A B C	N/A	N/A
Sludge production change	<0 0 >0	A B C	B	B
Affordable energy	Lower Same (+-10 %) Higher	A B C	B	B
Number of applied technologies for electric energy provision (*Resilience*)	3 1-2 0	A B C	B	B
Number of applied technologies for thermal energy provision (*Resilience*)	3 1-2 0	A B C	B	B
Additional employment	>0 0 <0	A B C	B	B
Local environmental welfare	Positive Neutral Negative	A B C	B	A
Return of Investment (ROI)	<3 3-10 >10	A B C	N/A	C
Additional income	>0	A	A	A

Indicator	Categories	Graduation	Status Quo	REEF 2W solution
	0 <0	B C		
Energy costs saving	>0 0 <0	A B C	A	A
Degree of electric self-sufficiency	>75 25-75 <25	A B C	A	B
Degree of thermal self-sufficiency	>100 20-100 <20	A B C	A	A
Degree of externally usable excess heat	> 0 0	A B	B	A
Degree of usable excess gas	> 0 0	A B	B	B
Electric energy consumption at WWTP	< 20 20 - 50 > 50	A B C	B	N/A
Thermal energy consumption at WWTP	<30 > 30	A C	B	N/A
Electric energy generation at WWTP (with anaerobic stabilisation)	>20 10-20 <10	A B C	A	N/A
Thermal energy generation at WWTP (with anaerobic stabilisation)	>40 20-40 <20	A B C	A	N/A

A weighing of each indicator and an aggregation to a single resultant value is not followed for the Austrian case study. Considering one final resultant value implies that an inferior rating can be compensated by a better rating. For instance, a good rating in the “sludge production change” could overrule a bad performance in “share of renewable thermal energy”. Therefore, the decision maker should consider all individual results of the indicators. In this context it is possible to consign the decision entirely to the decision maker.

8. Conclusion

This deliverable further deepens the analysis of the energetic (i.e. energy optimisation and generation) and spatial context of the feasibility study in Austria. The focus of the former was laid on the evaluation of the electric and thermal efficiency as well as the possibilities of renewable energy generation based on digester gas and wastewater heat recovery. The focus of the latter was to identify possible energy (heat) consumers in the settlement structures surrounding the investigated WWTP. By dealing with the spatial context, the actually realisable potential of renewable energy supply can be derived from natural, technical and economic potentials.

Although the investigations revealed a certain potential for increasing energy efficiency (e.g. high thermal energy consumption of the digestion towers), generation of electric and thermal energy based on digester gas already exceeds internal demands by far (due to co-digestion). The available surplus heat will be even increased, if wastewater heat recovery from the effluent is considered.

The spatial analysis showed, that there is also potential heat demand available in the vicinity of the WWTP. Further, the economic feasibility of a district heating network can be taken for granted due to the comparably high connection densities.

Consequently, the findings give clear evidence that a wastewater-based heat supply is an option that is more than worth for further investigation. From an environmental point of view, a heat pump-based heat supply (wastewater heat recovery) can certainly be considered beneficial, as the heat pump can be partly operated by the “green” electricity produced at the WWTP (from digester gas application). Additionally, the Integrated Sustainability Assessment further revealed promising results. After a closer look at the scales of energy provision it is possible to utilise more than 18 GWh/a of thermal energy via heat recovery to the surroundings of the WWTP. Compared to electricity, thermal energy supply is largely based on fossil energy sources like natural gas or oil. Therefore, the substitution of these fossil sources with renewables, like heat recovery from wastewater, is a significant contribution towards energy transition.

References

Abart-Heriszt, L., Erker, S., Stoeglehner, G. (2019): The Energy Mosaic Austria—A Nationwide Energy and Greenhouse Gas Inventory on Municipal Level as Action Field of Integrated Spatial and Energy Planning. Energies 12:3065. https://doi.org/10.3390/en12163065

Geels, F. (2010): The role of the cities in technological transitions: analytical clarifications and historical examples. In H. Bulkeley, V. Castán Broto, M. Hodson, & S. Marvin (Hrsg.), Cities and low carbon transitions (S. 13–28). London, Routledge.

Lindtner S. (2008): Leitfaden fuer die Erstellung eines Energiekonzeptes kommunaler Klaeranlagen (Guideline for the Development of an energy concept for municipal wastewater treatment plants). Austrian Federal Ministry of Agriculture and Forestry, Environment and Water Management (BMLFUW), Vienna.

Neugebauer, G., Lichtenwöhrer, P., Kretschmer, F., Stöglehner, G., Langergraber, G. (2019): Integrale Bewertung von Kläranlagen als lokale Energiezellen. Wiener Mitteilungen 251, I1-I12.

Nussbaumer, T., Thalmann, S., Jenni, A., Ködel, J. (2017): Planungshandbuch Fernwärme. Bundesamt für Energie, Ittigen.

Ramirez Camargo, L., Stoeglehner, G. (2018): Spatiotemporal modelling for integrated spatial and energy planning. Energy, Sustainability and Society 8. https://doi.org/10.1186/s13705-018-0174-z

RHV Trattnachtal. (s. a.): Written and oral provision of operational information and data by the WWTP.

Statistik Austria. (s. a.): Einwohnerzahl und Komponenten der Bevölkerungsentwicklung (number of inhabitants and components of population development). Available online: http://www.statistik.at/blickgem/pr1/g40832.pdf and http://www.statistik.at/blickgem/pr1/g40802.pdf.

Zach, F., Lichtenwöhrer, P., Neugebauer, G., Kretschmer, F. (2019): REEF 2W Machbarkeitsstudie - Fallbeispiel RHV Trattnachtal. Wiener Mitteilungen 251, K1-K11.