D.T.2.3.3 FIRST PART OF THE FEASIBILITY STUDY (STEP 1 + 2) FOR THE PILOT PROPOSED - AUSTRIA

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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Submission Date: 01/2020

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1. Introduction

1.1. The REEF 2W Project

In the wake of the energy turn/transition, 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 also a potential source of electricity and particularly heat, apart from WWTP internal (digester gas) use energy generation from wastewater has often been overlooked so far. Today, 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 in several cases utilities are not only capable of becoming energy self-sufficient, but also suppliers of energy thereby diversifying the local energy mix.

The project REEF 2W recognizes that wastewater (and to a certain extend also urban waste) 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 project's main objective is to drive up energy efficiency and renewable energy production of WWTPs. To prove that the new technologies and approaches can be technically feasible and make 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

The purpose of this deliverable is twofold: (1) To analyse the energy efficiency and the potential to produce renewable energy in the project's five pilots (energy efficiency/renewable energy sources – EE/RES). (2) To assess WWTP external energy supply options (urban compatibility assessment - UCA). This will be done, using the REEF 2W tools 1 (EE/RES) and 2 (UCA). Implementing the first part of the feasibility study will allow to better understand current (electric and thermal) energy consumption and optimisation as well as (electric and thermal) energy generation potentials. Furthermore, it gives an impression on the suitability of the WWTP adjacent infrastructure (settlements) for wastewater based energy supply.

2. Description of pilot site (status quo)

2.1. Characteristics of the WWTP

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.)

2.2. Technology upgrade of the pilot

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 a more than 100 % self-supply in electricity as well as in heat. In order to use this surplus heat and therefore make a heat grid profitable, it is desirable to increase this surplus (in this respect also electricity is relevant as it can be used for heat pumps). As a rough rule: 1 MW of heat power demand allows to install a heating grid of 1 km. For electricity generation, already smaller amounts might be lucrative, provided this amount can be fed into/sold to the grid for reasonable a price. 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 RHV Trattnachtal.

2.2.1. Reducing heat and electricity demand

Insulation of the digester towers

An important option to reduce the heat demand is the insulation of the two digestion towers. At the moment, they are insulated with a 9 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.

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.

(2a) 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.

Optimizing the temperature in the digester tower

Another 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.

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).

Optimizing aeration

One 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.

2.2.2. Optimizing the energy output

The two main energy sources on a 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
- 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.

2.2.3. Strategies to use the surplus (heat) energy at surrounding infrastructure

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.

2.3. 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.

3. Analysis of the WWTPs energetic context – Application of Software tool N.1

3.1. 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 (that equals ap. 100 kW_{el} and 120 kW_{th}), which was 65 % of the total needed electricity (1.435.000 kWh).

Table 1: Monthly electric energy balance in kWh (RHV Trattnachtal, s. a.)

in kWh 2016	production	consumption	sold	bought
Jan	211.747	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 2016	**3.744.460**	**2.040.971**	**1.754.731**	**51.242**

After the introduction of co-fermentation in 2008, the energy consumption rose significantly by 40 % (from 1.435.000 in 2006 to 2.040.971 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 the own electricity.

The energy production rose by nearly 400 % (from 933.300 in 2006 to 3.744.460 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 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 app. 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 %
  - 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 PT= **27 kWh per PE maximum performance**
- 2.000.000 kWh/50.000 PT= **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 5.900.000 m^3 wastewater = **0.34 kWh per m^3 of wastewater**

The following table 2 shows the heat consumption (and production) of the WWTP.

Table 2: Overview of heat consumption and heat production at the WWTP (RHV Trattnachtal, s. a.)

	2006*	2016
district heating	0	153
chiller	40	177
digester heat	1500	1890
buildings	270	342
sanitation	0	153
total use	1770	2385
production	1200	2684
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:

- 2.385.000 kWh/74.000 PT= **32 kWh per PE maximum performance**
- 2.385.000 kWh/50.000 PT= **48 kWh per PE average performance**

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

- 2.385.000 kWh heat for 5.900.000 m^3 waste water = **0.40 kWh per m^3 of wastewater**

3.2. 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).

Table 3: 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 (40 kWh/PE) lies within the standard range of 20 to 50 kWh/PE.

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 incl. 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 4: 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 48 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).

3.3. On-site renewable energy generation (RES)

Thermal energy content of wastewater – 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.

With a wastewater temperature decrease due to heat extraction (delta T) of 2K an energy amount of 120 l/s*4,18 kJ/kgK*2K = 1 MW (1 kg corresponds to 1 liter of water) could be extracted from the wastewater permanently, resulting in an electric energy consumption for heat pumps (using a COP of 4) of 250 kW. On an annual average, the WWTP has an electric energy surplus of 200 kW (the seasonal variations will be of importance as as the lowest excess is achieved in January and February). This means that – using heat storages with an appropriate volume – most of the energy used for the heat pumps can be covered by the surplus energy generated at the WWTP. Taking into account that strategies for reducing the electric energy demand and maximizing the electric energy efficiency are available and will be investigated regarding their practicability for this pilot plant, the provision of an even higher fraction of the electric energy for the heat pumps is realistic. Table 5 shows the detailed data for wastewater flow and temperature.

Table 5: Monthly WWTP wastewater flows and average wastewater temperatures (RHV Trattnachtal, s. a.)

	m³ waste water	T effluent °C
Jan	505.787	9,6
Feb	468.334	10,3
Mar	542.247	11,4
Apr	555.607	12,9
May	647.611	15,0
Jun	444.780	18,3
Jul	472.397	19,2
Aug	451.656	19,4
Sep	417.945	17,1
Oct	460.046	15,0
Nov	455.621	12,4
Dec	602.284	10,6
year	**6.024.315**	**14,3**

Depending on the assumed delta T of the wastewater in the WWTP effluent, the available energy potential changes. However, as described, the electric energy surplus is limited and a stable system power is preferable. Therefore, a permanent power of 1 MW from the wastewater source plus 250 kW from the compressor is an adequate dimensioning for running the heat pump system. This leads to an annual energy potential of 8.8 GWh/a from ambient heat and 2.2 GWh/a electricity demand for the heat pump system (lower demand in summer, repairs, shutdowns, etc. will in reality reduce the potential).

Digester gas utilization

Optimizing the energy output from digester gas (from sewage sludge and co-fermentation) is a task that will be investigated.

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 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 2.68 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 a potential of geothermal heat. At this stage the exact energy potential of the geothermal source is not known.

Other technologies

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

4. Analysis of the WWTPs spatial context – Application of Software tool N.2

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

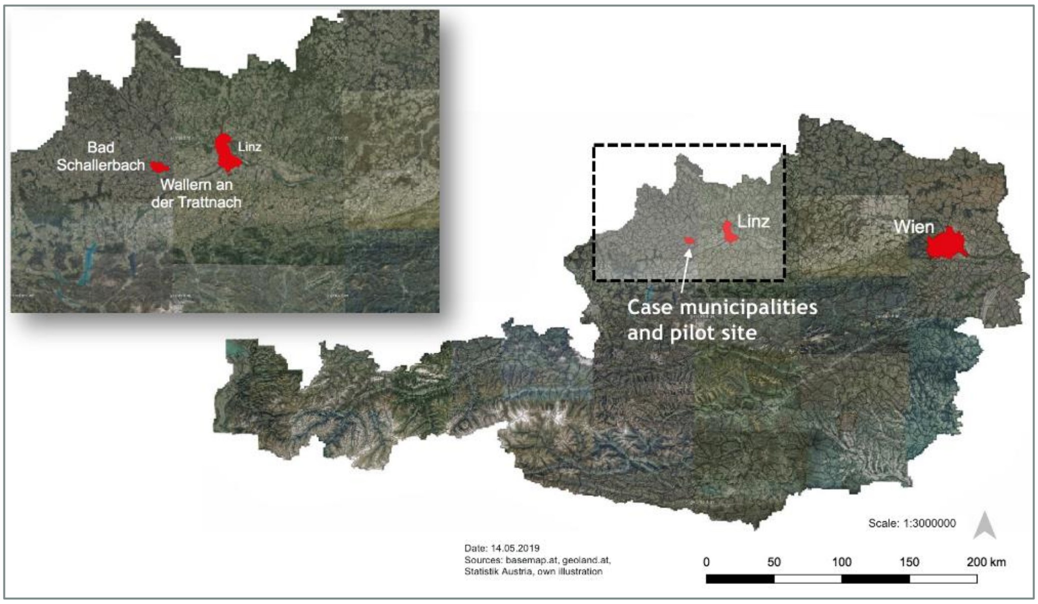

Figure 2: Location of case municipalities and pilot site (own illustration)

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*. In addition to the REEF 2W pilot WWTP, the *EurothermenResort Bad Schallerbach* (thermal spa) is also marked in Figure 3. Besides the WWTP, the thermal spa could also provide excess heat. This is especially interesting for a detailed scenario analysis with respect to increase the feasibility of a district heating network. In the following analysis of this deliverable the scenario of including the thermal spa is not followed.

However, for this deliverable a straight forward approach considering the WWTP as the exclusive heat source is followed.

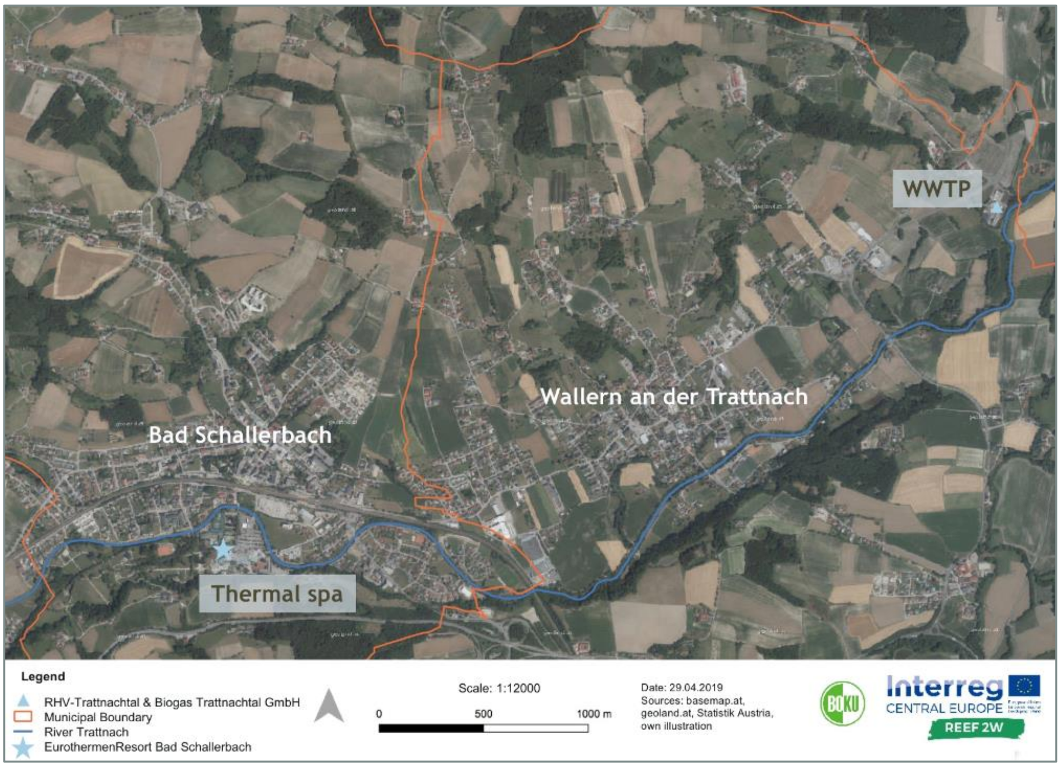

Figure 3: Overview of the Trattnachtal with two municipalities including the WWTP and the thermal spa (own illustration)

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. Some of these relevant areas of interest were used for the first assessment.

Consequently, relevant areas 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 another natural barrier for a potential district heating network/grid.

It can be summarised that two essential steps for the delimitation of the relevant supply areas and the district heating network were considered:

(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 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.).

If available, additional information like a zoning plan, specifying the actual land use or contour lines to evaluate the slopes, can be used for a more distinctive and specific differentiation of the relevant areas. The following illustration (Figure 4) shows a differentiation of seven relevant areas in the Trattnachtal that can consequently be used for an analysis with software tool N.2.

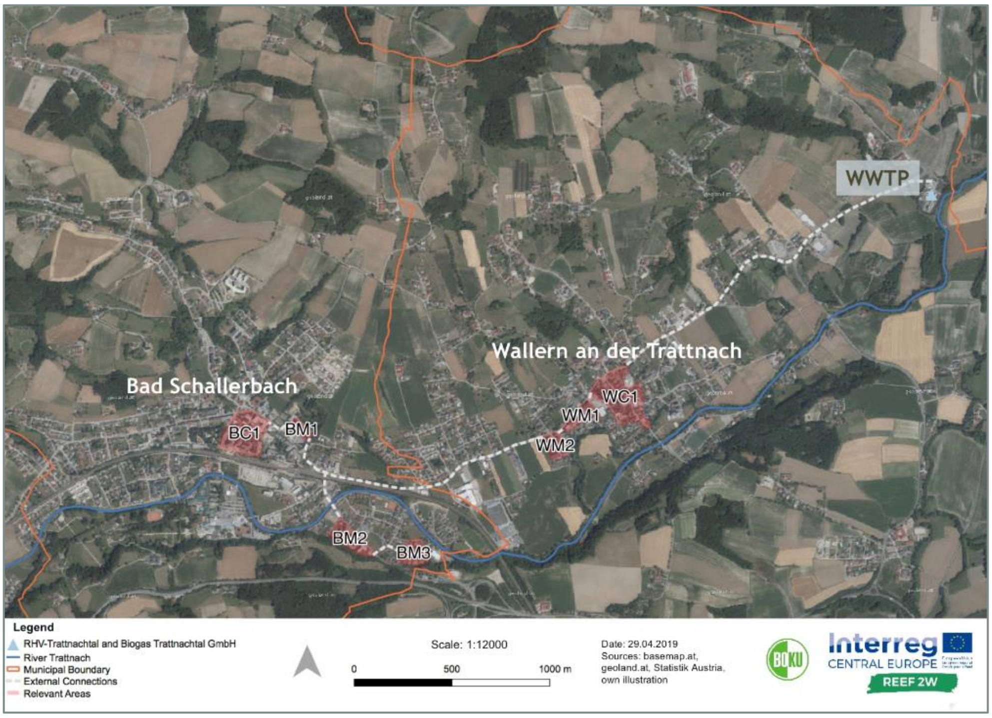

Figure 4: Illustration of relevant areas representing a mix of different energy consumers (own illustration)

The first relevant area (Area_ID: WC1) represents the village centre of *Wallern an der Trattnach*. As Table 6 shows, the village centre comprises 4.44 hectares corresponding to around 4,000 MWh/a of thermal energy consumption. The required internal district heating length to supply all buildings within the area is estimated to about 890 m. The same key data was calculated for the other six relevant areas in the Trattnachtal. In total, the supply area accounts for almost 14 hectares and 12,500 MWh/a, respectively, with an internal grid length of approximately 2.5 km.

Table 6: Summary of the relevant areas including the heat consumption and internal grid lengths (own illustration)

Area_ID	ha	MWh/a	Internal grid length (m)
WC1	4.44	3,993	887
WM1	0.98	688	147
WM2	1.10	768	164
BM2	1.67	1,166	250
BM3	1.35	946	203
BM1	0.43	434	65
BC1	3.72	4,473	746
Sum	**13.70**	**12,468**	**2,462**

In addition to the results presented in Table 6, the external grid lengths, connecting the thermal energy source (WWTP) and the relevant areas, was estimated to almost 4 km. As a result of the spatial context analysis the connection density was calculated to be 1.94 MWh/m. 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 almost 2 MWh/m in the Trattnachtal, a detailed analysis of the heat demand and further investigation on how and where to build a district heating network is suggested and should be followed.

5. Conclusions

This deliverable describes the analysis of the energetic (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.

Although the investigations revealed a certain potential for increasing energy efficiency (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 being considered.

The spatial analysis showed, that there is also potential heat demand available in the close vicinity of the WWTP.

Consequently, the findings after applying tool N.1 (EE/RES) and N.2 (UCA) 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 run by the “green” electricity produced at the WWTP (from digester gas application).

The economic benefits will be investigated in the course of another deliverable. Same can be said for the improvement requirements concerning the applied tools N.1 and N.2.

6. Literature

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.

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