D.T2.1.1 REASONS/CONDITIONS LEADING TO THE CHOICE OF THE 5 PILOTS

Austria

19/07/2018

1. Objective of the task:

In DT2.3.1, the pilot locations were selected. The main objective of this deliverable (D.T.2.1.1) is to identify the leading reasons for selecting the pilot locations, in this case the wastewater treatment plant (WWTP) in Prague.

The deliverable draws on four deliverables finalised in Work Package 1.

- D.T1.2.1: Base line analysis of the current situation in the targeted utility companies/ territories
- D.T1.2.2: Relevant models highlighting integration and combination of technologies
- D.T1.2.3: Guiding document to demonstrate the benefits of implementation of REEF 2W plants
- D.T1.4.1: Detailed description of the methodology and criteria for location suitability

The deliverable is divided into three parts. First, an overview is provided about the initial situation at Central Prague WWTP (PCWTP), including the technological setup and its suitability. This is followed by an overview of the planned technological upgrade in the context of Reef2 W and the benefits accruing from it. The last part analyses the leading conditions including socio-economic and institutional aspects that qualified the WWTP for selection in Reef2W.

2. Initial Situation at the Pilot Site

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

The WWTP 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 PE.

The sewage plant consists of:

- Preliminary sedimentation (1 x 1000m3)
- Aeration (2 x 2000m3)
- Final sedimentation (4 xx 1900m3)
- Digesters (2 x 2000m3)
- Gas storage (800m3)
- Sludge press and sludge e hall New built parts of the biogas plant:
- Receiving station (pump p and macerator)
- Storage tanks (3 tanks w with 120m3. 150m3 and 250m3)

• Sanitizing unit (2 x 7 m m3)

• Bio filter

• Flare

• 2 x 360 kWel MAN units

Processes:

The sludge of the preliminary sedimentation and the discharged sludge from the final sedimentation are pumped into the digesters. Per day an average amount of 120m3 sludge with approximately 3% dry matter is digested. Liquid sludge is stored in tanks and solid sludge is stored in the sludge hall. Depending on the sanitizing rules, bio- and slaughterhouse waste has to be sanitized according to o the EU-regulation: >70°C for min. 60 minutes and < 12mm particle size. All other material may be pumped into the digester without any heat treatment. Additionally to the 120m3 sludge a day, an average amount of 50m3 waste is pumped into the digesters. Solid material is re-liquified by inserting it into the thickener ,where the sludge is stored before being pumped into the digesters. With the aid of a powerful stirring unit the solids are mixed with the liquid to end up as a thick paste (up to 10-15%), which can be pumped. The digester can only handle material with no or little dry matter, because the stirring unit is too weak for a strong mixing effect. Additionally the digester has only a small surface on top, so swimming layers are hard to handle. Consequently the plant can more effectivelydigest liquids with a high COD and a low dry matter content. Sewage sludge can also be treated, because it has a small particle size, which does not cause swimming layers.

Co-fermentation

Since 2008 the Biogas Trattnachtal GmbH has been operating an on-site co-fermentation with waste. The Biogas Trattnachtal is fully 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 totally different permits concerning involved topics and technical experts.

Power demand of RHV WWTP

This is an overview of the power consumption of the RHV-Trattnachtal in the year 2016:

- total electricity need 2016 . 2 mio. kWh
- the screening and sand trap needed 9,28%
- the aeration needed 24,46%
- the return activated sludge cylce needed 17,33%
- the digesters incl. sludge line needed 10,51%
- diverse consumers 38,44%

The sewage plant has a maximum performance of 74.000 population equivalents (PE) and an average performance of 50.000PE, so 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 water volume of 2016, which amounts to 2.000.000 kWh of electricity for 5.900.000 m3 waste water, equaling0,34 kWh per m3 of wastewater.

Heat use of a sewage plant

Sewage plants with digesters have a considerable heat demand. On the one hand they have to heat high volumes of sludge day by day, on the other hand the digesters loose heat due to their surface.

3. Technological Upgrade

Generally, three strategies exist in order to optimize the energy balance (electricity and heat):

- Reducing the energy demand of the wastewater treatment plant
- 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

Reducing the energy demand of the wastewater treatment plant

As it was shown by co-fermentation the WWTP's self-sufficiency of heat and electricity already exceeds 100 %. In order to use the heatsurplus and tmake 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 allows to install a heating grid of 1 km. For electricity already small amounts are useful if they can be fed into the grid.

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

Reducing heat demand

*Insulation of the digester tower*s: 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 against humidity, but if it is kept between two layers and water can enter, the thermal insulation quality of glass wool decreases rapidly.

There are two options of enhancing insulation performance:

1.) If the problems of humidity is relevant in this case, the glass wool layer should be kept dry. This is a low cost investment.

2.) Extending 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). This is a more considerableinvestment. Using biological insulation materials will be another option to be compared.

Optimize temperature in the digester tower: Another possibility is to optimize the temperature in the digester towers. Presently there is no need to reduce the heat demand as the surplus energy cannot be used anyhow. But 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 larger 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 pumps can still work).

Reducing electricity demand

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 it depends on the amount and quality of the actual wastewater how much oxygen has to be pumped into the wastewater basins.

Other opportunities can be found by checking benchmark values of Austrian wastewater treatment plants.

Optimizing the energy output by using the resources that are available on-site

The two main energy sources of a wastewater treatment plant are:

- The thermal energy of the treated wastewater: It can be used for low temperature heat up to app. 65°C
- The energy in the sewage sludge (digester gas): It can be used for electricity and heat generation.

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

- On-site electricity generation:
  - Wind energy
  - Solar energy
  - Water power by using a height difference between wastewater treatment plant and “Vorfluter”.
- On-site heat generation:
  - Solar energy

The pilot example will deal with wastewater energy and optimized use of the digester gas.

Thermal energy of wastewater

The mean wastewater flow through the wastewater treatment plant is 688 m^3/h or 191 l/s in the years 2016 and 2017.

Analysis of the effluent wastewater on an hourly basis shows that 120 l/s are available permanently.

With a 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. In annual average the wastewater treatment plant has an electric surplus energy of 200 kW (the seasonal variations will be of importance as in January and February show the lowest surplus). This means that – using heat storages with an appropriate volume – most of the energy for heat pumps can come from the surplus energy of the WWTP. Taking into account that strategies for reducing the electric energy demand and maximizing the electric energy consumption are available and will be investigated regarding their practicability on this pilot plant, an even higher fraction of the electric energy for the heat pumps is realistic. Table 3 shows the detailed data for the amount of wastewater and its temperature.

Table 1: Wastewater amount and temperature in the pilot plant in the 2016 and 2017 average, source: RHV Trattnachtal

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

Digester gas (from sewage sludge and cofermentation)

Optimizing the energy output from digester gas 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 wastewater energy explained before:

- it can be used for heat supply without using electric energy (e.g. for heat pumps)
- it can be used for heat at a high temperature level (contrary to wastewater heat)
- and can additionally be used for electricity production

Therefore the two resource groups 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.

Developing strategies to use the surplus (heat) energy at surrounding consumers' sites

WWTPs demand significant amounts of energy for the treatment process, but are at the same time interesting from an energetic point of view, as they can provide thermal energy and electricity. While electricity can be fed into an existing electricity network, the provision of thermal energy requires a district heating network. The spatial context of the WWTP and the presence of existing or future heat consumers, determine the potentials for an efficient integration of surplus heat into local energy supply concepts.

For a first analysis of the spatial context, the CORINE land cover (Coordination of information on the environment) program of the European Commission can be used. The CORINE land cover program comprises different land-use categories, from which the following three categories can be used for an initial analysis: (1) "Continuous urban fabric" – built structures with little coverage of vegetation and bare soils; (2) "Discontinuous urban fabric" – mixture of built structures and vegetated areas; (3) "Industrial or Commercial units" – built environment with few vegetated areas. This is an interesting approach to get a first idea about the spatial context of the WWTP and the location of possible heat customers in the surrounding area (Neugebauer et al. 2015). Based on this first analysis a rough classification of the pilot site can be undertaken. According to Neugebauer et al. (2015) three different types of WWTPs can be distinguished: (1) WWTPs "within the settlement"; (2) WWTPs "near to the settlement" and (3) WWTPs "far from the settlement". As illustrated in Figure 2, the pilot site in Wallern an der Trattnach, can be classified as "near to the settlement".

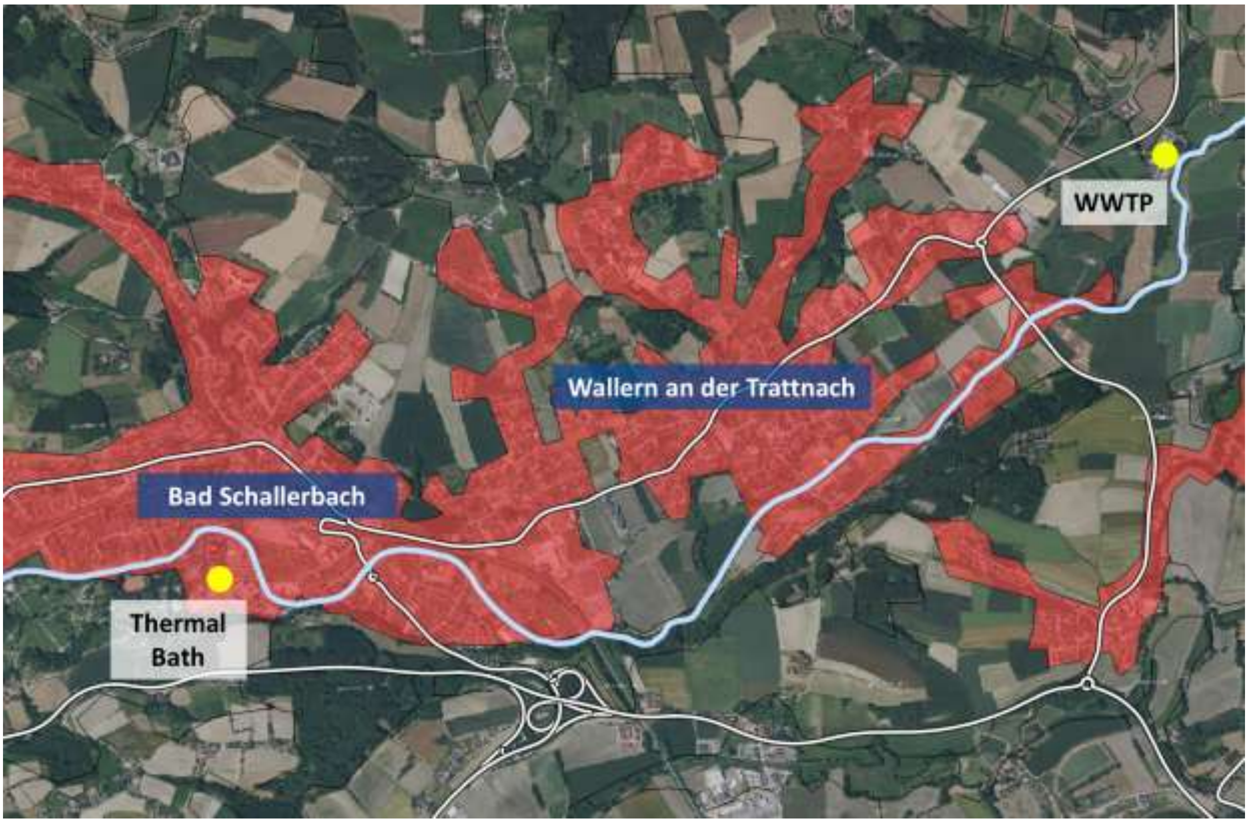

Figure 2: Visualization of the case study municipalities Bad Schallerbach and Wallern an der Trattnach, including CORINE land-cover category "discontinuous urban fabric" and two heat sources: WWTP and the Thermal Bath.

After the rough CORINE-analysis a selective identification of "key" heat customers in the WWTP's surrounding should be carried out. Energy demand can arise from heating and cooling of

- Residential buildings
- Public buildings (e.g. schools, kindergarten, public swimming pools, hospitals, etc.)
- Commercial or industrial buildings

Additional thermal energy demand is generated by agriculture and forestry, as summarized in Neugebauer and Stöglehner (2015):

- Dewatering of wood chips, crops, medicinal or spice plants
- Heating and cooling of barns (e.g. for piglet breeding)
- Heating of greenhouses for the production of fruits, vegetables etc.
- Heating of aquaculture (for breeding fish or growing micro-algae)

If a district heating network should be developed, the distances between the heat source and the heat sink should be as short as possible. For the heat supply, two different supply systems can be distinguished: Warm district heating and cold district heating. Depending on the supply temperature, there are less heat losses in a cold district heating system, which means that greater distances can be covered. However, the closer the heat consumer is located to the WWTP the better, also for the economic feasibility of a district heating grid. Table 4 shows a rough estimation of the maximum distance between the WWTP and the energy consumer, depending on the particular heat capacity.

Table 2: Rough estimation of the economic feasibility, depending on the distance to the heat consumer (after Abwasserenergie 2017).

Estimating the economic feasibility	**Dimension of energy consumer (Heat capacity in kW)**				
	250 kW	500 kW	1000 kW	2000 kW	3000 kW
Maximum distance in m	100 m	500 m	1000 m	2000 m	3000 m

Depending on the consumer, different temperature levels might be necessary (e.g. high temperatures for industrial use and rather low temperature for new buildings with residential use). Furthermore, an optimization of spatial structures in order to enhance the overall heat demand can be carried out. In this context, the following questions arise: Is it possible to add additional buildings on open space? Is it possible to add additional storeys to already existing structures? Planners and authorities should also think about future agricultural or industrial/commercial developments close to the WWTP. Specifically, in our case-study, the town of Bad Schallerbach is known for its thermal spring. Therefore, this potential heat source located in appr. 4 km distance to the WWTP could be used to support and feed the district heating network.

After the initial rough analysis, more detailed analyses can be carried out. There are two main options for a more detailed identification of the energy demand: (1) Settlement related heat demand identification and (2) Buildings related heat demand identification. Using the first option, specific heat demand is allocated to a certain settlement type. Each settlement type is characterized by a particular building arrangement (e.g. density or population), building type (single family house, multi-storey building, etc.) and utilization (residential, commercial, mixed use, etc.). For the second option, a detailed calculation of the heat demand for every single object in the vicinity of a WWTP is carried out. For instance, heat demand values (kWh/m^2.a) dependent on building types and construction periods can be used in order to estimate the heat demand of residential buildings. The specific heat demand can be multiplied with the energy related area (e.g. m^2 of living space) which results in a total heat demand of a building.

4. Expected Benefits

<u>Self-supply and additional energy for grid injection:</u>

With co-fermentation it is possible to deliver 100% of the heat and electricity needed to operate a sewage plant. So the costs for the external power will minimize. At the RHV WWTP the energy production rose by nearly 400% after starting the co-fermentation, so the biogas plant can now easily provide the needed electricity for the sewage plant.

The surplus heat now has to be chilled with no extra benefit. With the district heating the whole CHP heat can be used for heating purposes.

The bulk of the surplus heat can be captured in summer. From a supplier's perspective, this is a challenge. Heat is mainly needed in winter for residential heating. At the same time, the WWTP itself requires considerably more heat for warming the sewage plant digesters.

The heat pumps have the task to deliver additional heat in winter, therewith balancing out the summer-winter gap.

<u>Environmental benefits of the REEF2W solutions</u>

Using wastewater as a thermal energy source can significantly reduce the environmental impacts (expressed in terms of CO_2 emissions, ecological footprint calculations or global warming potential – GWP) compared to the use of fossil energy sources like natural gas. In order to generate thermal energy from wastewater, heat exchangers and heat pumps are needed. For the operation, electricity is required and therefore an electricity mix that mainly consists of renewable energy sources should be used.

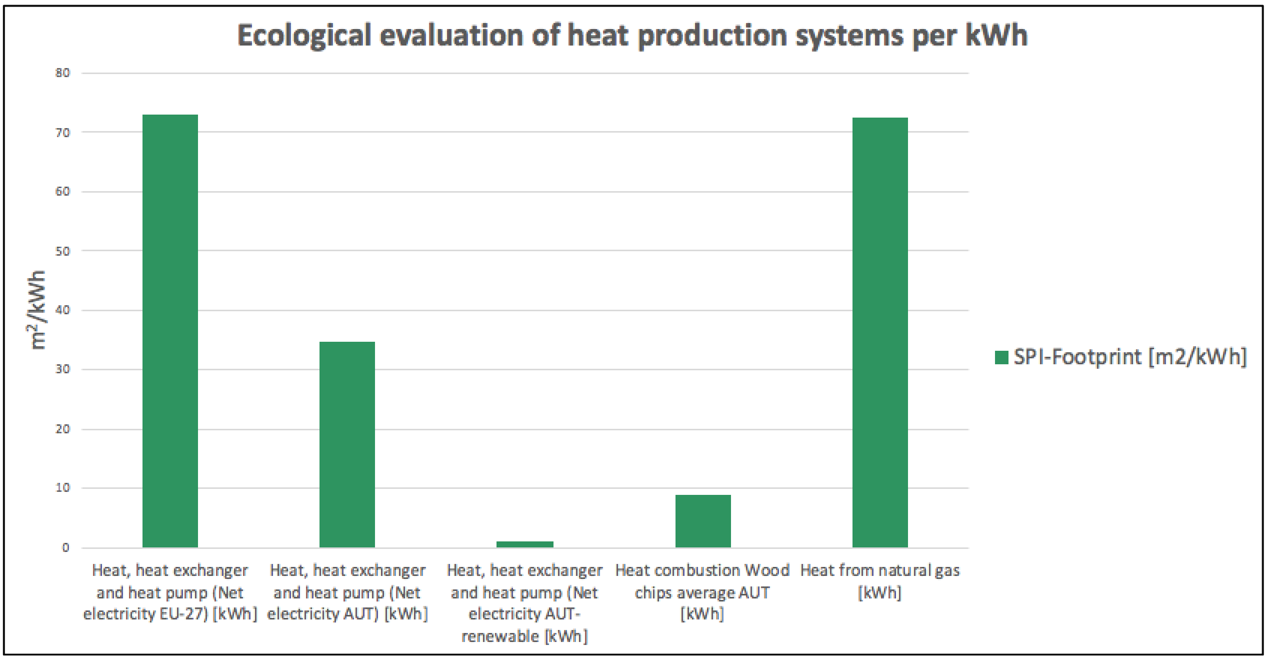

Figure 3: SPI calculations for different heat production systems (after Neugebauer et al. 2015)

Figure 3 illustrates a comparison between different heat production systems, that shows the influence of the electricity mix on the environmental impacts of the respective waste water related heat generation systems. Neugebauer et al. (2015) used the Sustainable Process Index (SPIonWeb) to calculate the ecological footprint of different heat production systems. The SPI is part of the ecological footprint family and is compatible with the EN ISO 14040 (ISO 2006). It assesses the life cycle impact and can therefore be used to evaluate environmental pressure. In figure 3 it can be seen that heat generated with heat exchangers and heat pumps, using a typical Austrian renewable electricity mix features the lowest footprint (m^2/kWh). In this case, the applied electricity mix has a huge impact on the footprint calculations.

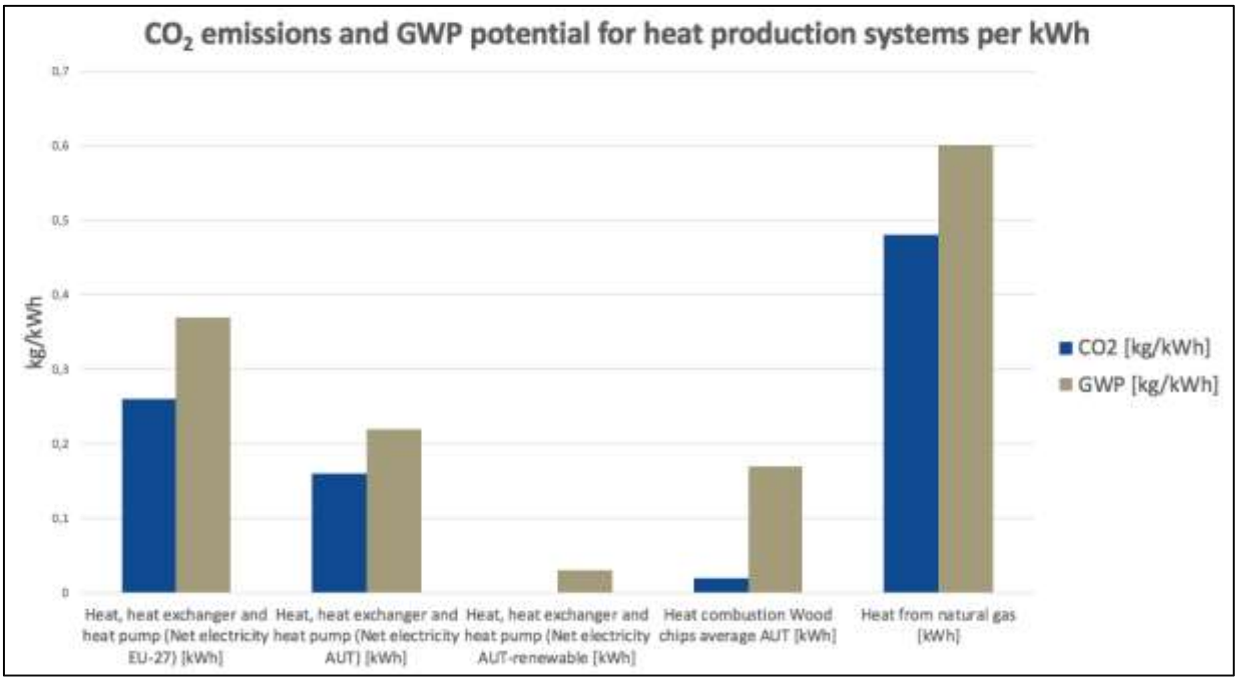

Figure 4: Calculation of CO_2 emissions and global warming potential for different heat production systems (after Neugebauer et al. 2015).

In figure 4, CO_2 emissions and GWP of different heat production systems are presented. Also in this case, heat produced with heat exchangers and heat pumps, using a typical Austrian renewable electricity mix is the most environmentally friendly option, especially compared to heat produced from natural gas.

A substitution of fossil energy sources is possible, if an economically feasible concept for a heating grid can be developed. As the rough energy potential from the wastewater treatment plant is 1 MW from wastewater + 0,25 MW electricity from renewables (resulting in 11,7 GWh/a) and approx. 1 GWh/a from digester gas (energy surplus after optimization), about 13 GWh/a of fossil energy consumption can be replaced by renewables from the wastewater treatment plant.

Economic benefits

Usually, the Biogas plant has to sell surplus electricity for a relatively low price (3-6c/kWh over the last six years) to the grid. With the upgrade through the heat pumps, the whole electric energy could be sold internally (to the RHV Trattnachtal) for app. 12c/kWh.

Establishing the connection to the heating grid will be a completely new business (although already now one nearby building is supplied with surplus heat). The economic feasibility of the grid is yet not calculated. However, an amount of 13 GWh/a at a price of 6 ct./kWh would mean a net turnover of € 780.000 per year.

In 2016 nearly half of the produced electricity was sold, so it is a much better option to get a subsidized tariff (usually around 8-10 c/kWh) from the state if there is one. The natural gas costs were below 5.000€ (mainly measuring and net costs) in 2016, 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) because of the waste fermentation.

Improved Societal Perception

It is still relatively unknown that wastewater has a huge heat potential. Expanding the purpose of WWTPs from exclusively treating wastewater to providing electricity and heat will change the view by the public drastically. Heat from wastewater can replace natural gas and oil for heating purposes. This reduces the ecological footprint of WWTPs. But as decentralised form of energy supply wastewater-to-energy systems will also increase energy securing as they decrease the need for natural gas and oil imports.

5. Key Selection Criteria

In summary, the RHV Trattnachtal was chosen as a pilot because of the following reasons:

- It counts as a middle-sized WWTP with 74.000 PE, so best practices and learnings can be applied to other plants
- Infrastructure and operation of biogas production from sewage is in place
- Thecofermentation unit (the BiogasTrattnachtal GmbH) has been successfully implemented
- Good operation data material exists from 2010 up to now
- There is a surplus of heat which presently cannot be used
- A ainimum of 10.000m3 waste water a day is produced
- Distance to the next 2 villages with >5000 inhabitants is smaller than five km
- The management of the pilot plant is interested in installing a heat grid

Grid injection

The plant is connected to the natural gas grid and to the electrical grid.. Currently the plant does not need any natural gas because there is enough heat to cover internal demand. The same applies to electricity. The plant produces more electricity than needed, so it is delivering electricity up to 500kW to the grid. Only very infrequently is electricity needed from the grid run the plant.

The provision of thermal energy requires a district heating network, which there isn't currently. However, the municipalities of Bad Schallerbach and Wallern an der Trattnach are located within 5 Kilometers from the plant and especially in Bad Schallerbach there are a lot of hotels, baths, etc. in addition to residential areas with a rather high heat consumption density. Furthermore geothermal sources near Bad Schallerbach could be included which makes the grid more flexible.

Suitability of Technological Setup

Without certain minimum technological setup in place undertaking a comprehensive upgrading of wastewater-to-energy technologies is impossible. At RHV Trattnachtal, many of the technological pre-conditions exist that allow establishing and testing Reef2W solutions – from co-fermentation to grid-injection of electricity and natural gas. For example, running co-fermentation since 2008, many preconditions about the project's central goal – the integration of infrastructures and streams of the solid waste and wastewater systems – can be explored (e.g. the collection and logistics of bio-waste).In a similar vein, the plant already produces surplus energy, which allows to tap into experience with grid supply of the operator.

Innovation champion

Efforts to improve the energy performance at RHV-Trattnachtal have been mainly driven by the utility operator. This entails several advantages, which weighed into the decision to choose the RHV Trattnachtal as a pilot site in Reef2W. The utility operator has an intrinsic motivation in the topic and into further improving the EE and RE production. It was anticipated that such attitude will facilitate the various planned tasks in the context of Reef2W, for which good collaboration between the utility and BOKU are required. Additionally the operator's in-depth knowledge and expertise on the topic are promising in that the operator can provide key insights for the science the Reef2W consortium is developing.

Availability of bio-waste

Some food processing companies are located in the area surrounding the WWTP. The share of the agro industries is around 40% of the waste water, and 60% is coming from the population. The impact on the territory is mainly that a high share of the treated waste is coming from the surrounding area, so the transport is relatively short.

Nutrient recovery

The produced sludge used as fertilizer can replace fossil mineral fertilizer and is a perfect example of closed circle economy. It is also important to say, that the use as fertilizer is the only possible way to date how phosphorus can be returned into soils without using further guano-phosphor from abroad.