D.T4.4.1

CEU PROGRAM AREA STRATEGY

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1. PURPOSE AND SCOPE

1.1. Purpose of the REEF 2W project

In the wake of the energy transition, an increased focus has been laid upon the energy saving and generation potential of the wastewater sector. Wastewater treatment plants are large consumers of energy and often have key shares in the carbon footprint of municipalities and urban governments. In many cases their energy consumption accounts for the bulk of operational costs of wastewater utilities. However, despite bearing a large potential for electricity and heat generation, sewage as a source of energy often has remained untapped so far. Anyway, in recent times an increasing number of wastewater operators have deployed energy-efficiency measures and novel technologies to better harness the energy of sewage. Evaluations of pioneering projects show that utilities are not only capable of becoming energy self-sufficient, but also suppliers of energy thereby diversifying the local energy mix.

The project REEF 2W recognizes that wastewater is an integral part of the water-energy nexus. The project is funded by the European Development Bank's Interreg Central Europe Programme and is carried out through 11 research institutes and wastewater utilities from Italy, Germany, Austria, Czech Republic and Croatia. The project's main objective is to drive up energy efficiency and renewable energy production of wastewater treatment plants to supply both, internal as well as external energy demand. Among others, it considers co-fermentation of bio-waste to increase digester gas (biogas) production, helping to elevate outputs from combined heat and power generation. Furthermore, heat recovery from wastewater can be considered for the generation of (excess) energy to meet demand in the adjacent settlement structures. To prove that wastewater based energy supply is not only technically feasible but also incorporates economic and ecologic (climate related) benefits, project partners developed a comprehensive (integrated) assessment approach. Another key task of REEF 2W is to analyse legal and policy framework conditions and to derive and advocate policy alternatives that spur a broader use of wastewater-to-energy solutions.

1.2. Scope of the deliverable

Problems regarding climate change, energy security, energy independence, energy transition, etc. are emerging and must be addressed on global and local scales. To define the role, wastewater as a source of renewable energy can play in the energy transition two different questions have to be addressed: (1) What is the energy potential available in wastewater, and (2) what measures (strategies) are required to foster it's broader use also towards a more local and independent energy supply.

The purpose of this deliverable is to elaborate a CEU Program Area Strategy that will provide clear goals and actions to encourage and speed up activities for a broader implementation of renewable energy generation and consumption measures in the wastewater sector. In the first part of this document more details on the background and the available energetic potentials in the wastewater sector in the CEU area are described (Chapters 2 and 3) while in second part of this document (Chapter 4) a strategy to support the practical implementation of energetic use of wastewater is presented. This strategy distinguishes four different thematic parts for each introducing related goals and actions. Concluding words and challenges are stated in Chapter 5.

2. BACKGROUND

2.1. Energy generation from wastewater

Basically, wastewater contains two types of energy, chemical one the form of bound carbon and thermal one in the form of hot/warm effluent from domestic, commercial and industrial sites. The former can be accessed by means of anaerobic digestion of the sewage sludge in the form of digester gas (biogas). The latter can be recovered heat exchanges, which are directly installed in the wastewater flow, and a subsequent application of a heat pump. In addition, wastewater treatment plants have large areas of open space (e.g. roofs) which can be used to access solar energy. For the sake of completeness, it shall also be mentioned that the available open space might also be used for wind power installations and the effluent of a wastewater treatment plant might be suitable for hydropower generation. However, in the context of the REEF 2W project the following options for wastewater-based generation of (renewable) energy are in the centre of interest:

- Electric and thermal energy from digestor gas (biogas) combustion (only at wastewater treatment plants with anaerobic sludge treatment)
- Thermal energy from wastewater heat recovery in the effluent of wastewater treatment plants
- Electric energy from solar installations on the premises of wastewater treatment plants

2.2. Wastewater as renewable energy source

European Commission (s. a.) is aware that climate change and environmental degradation are an existential threat to Europe and the world. To overcome these challenges, Europe needs a new growth strategy that will transform the Union into a modern, resource-efficient and competitive economy, where there are no emissions of greenhouse gases by 2050; economic growth is decoupled from resource use and no person and no place is left behind. European Green Deal set by European Commission is plan to make EU's economy sustainable. This can be done by turning climate and environmental challenges into opportunities, and making the transition just and inclusive for all. European Green Deal provides an action plan for making Europe climate neutral by 2050, boosting the economy through green technology, creating sustainable industry and transport, cutting pollution. It is going to be funded through public and private finance.

To be more specific on the energy relevant context of wastewater, the recast of Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources shall be briefly addresses and highlighted.

As written in Article 1, "*a common framework for the promotion of energy from renewable sources. It sets a binding Union target for the overall share of energy from renewable sources in the Union's gross final consumption of energy in 2030. It also lays down rules on financial support for electricity from renewable sources, on self-consumption of such electricity, on the use of energy from renewable sources in the heating and cooling sector and in transport sector, or regional cooperation between Member States, and between Member States and third countries, or guarantees of origin, on administrative procedures and on information and training. It also establishes sustainability and greenhouse gas emissions saving criteria for biofuels, bioliquids and biomass fuels.*"

In Article 2 the Directive defines the different types of renewable energies:

Paragraph 1 states, that “ ‘*energy from renewable sources’ or ‘renewable energy’ means energy from renewable non-fossil sources, namely wind, solar (solar thermal and solar photovoltaic) and geothermal energy, ambient energy, tide, wave and other ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas, and biogas*;”

Paragraph 2 concretise, that “ ‘*ambient energy’ means naturally occurring thermal energy and energy accumulated in the environment with constrained boundaries, which can be stored in the ambient air, excluding in exhaust air, or in surface or sewage water*;”

This means that both wastewater-based energies, the digester gas (biogas) as well as the recovered heat are (have to be) fully recognised as renewable sources of energy in the entire European Union. The same applies of solar energy generated at the premises of a wastewater treatment plant. Consequently, the recast of the directive provides an excellent basis for a further promotion of the energetic use of wastewater and the REEF 2W approach in the CEU program area.

3. ENERGY FROM WASTEWATER IN CEU

3.1. Inventory of wastewater treatment plants

A prerequisite to estimate available wastewater-based energy potentials is an inventory of the existing wastewater treatment plants (WWTPs). The CEU program area hereby includes the following countries:

- Austria (AT)
- Czech Republic (CZ)
- the eastern and southern parts of Germany (DE)
- Croatia (HR)
- Hungary (HU)
- The northern part of Italy (IT)
- Poland (PL)
- Slovenia (SI)
- Slovakia (SK)

The basis of the inventory is provided by the “Waterbase” of the European Environmental Agency (EEA, s. a.), which summarizes the reported data of all EU member states concerning the Urban Waste Water Treatment Directive. This database provides, among others, an overview on the existing wastewater treatment plants including information on their location, capacities and current loads. Table 1 summarizes the related figures for the respective countries and the entire CEU area.

Table 1: wastewater treatment plants (WWTPs) in CEU (based on EEA, s. a.)

Country	amount of WWTPs [no.]	Treatment capacity [PE]	Entering load [PE]	Data availability
AT	640	21 582 000	14 526 000	100 %
CZ	671	15 459 000	9 622 000	91 %
DE	2059	69 614 000	52 166 000	99 %
HR	281	4 019 000	3 423 000	34 %
HU	635	14 855 000	10 666 000	100 %
IT	2554	48 107 000	33 568 000	58 - 92 %
PL	1692	52 609 000	47 382 000	100 %
SI	113	2 321 000	1 872 000	90 %
SK	336	6 297 000	3 808 000	82 %
Total CEU	**8981**	**234 863 000**	**177 033 000**	94 %

Table 1 shows, that almost 9.000 wastewater treatment plants with a treatment capacity of nearly 235 million and a current entering load of around 177 million population equivalents (PE) are installed. This gives a very good first impression on the current situation in CEU. However, there are two restrictions related to this data to be considered:

First, data availability varies from country to country: In AT, DE and HU, for instance, information on treatment capacity and entering load are available for (almost) all wastewater treatment plants. In IT, on the other hand, less information on the treatment capacity (58 %)

is available than on the entering load (92 %). Finally, in HR data availability still appears rather low (34 %). This might be explained by the fact, that the “Waterbase” also includes plants under construction/planning. It is obvious, that for those no operational data is available yet.

Second, reported data includes also small wastewater treatment plants: Out of the 8.981 plants included in the “Waterbase” 2.150 (24 %) have a treatment capacity below 2.000 PE. For IT this concerns almost half of the reported sites. Due to their size these plants are only of very limited interest for wastewater-based energy generation. However, the aim of this investigation is to show the theoretical potential for energy generation from wastewater. Consequently, all reported wastewater treatment plants are considered here. For subsequent and more detailed studies the consideration of the size distribution is recommended.

For the estimation of the wastewater-based energy potential two parameters are important: (1) the total wastewater flow to estimate the wastewater heat recovery potential and the (2) availability of anaerobic digestion (AD) to estimate the digester gas (biogas) based electricity and heat generation (from combined heat and power units). Table 2 provides an overview on the related data.

Table 2: wastewater amounts and availability of anaerobic digestion (AD)

Country	Total wastewater flow [m^3/h]	Amount of WWTPs with AD	Share of AD
AT	90 800	155	24 %
CZ	60 100	92	14 %
DE	326 000	379	18 %
HR	21 400	3	1 %
HU	66 700	15	2 %
IT	209 800	98	4 %
PL	296 100	93	5 %
SI	11 700	11	10 %
SK	23 800	52	15 %
Total CEU	**1 106 400**	**898**	**10 %**

Figure 2 shows a total wastewater flow of about 1.1 million m^3/h in the CEU area. Almost 900 wastewater treatment plants with anaerobic sludge management can be found, whereby the share (percentage) on the total amount still varies significantly between the different countries.

The total wastewater flow is derived from the total current load of the wastewater treatment plants multiplied with an assumed wastewater production of 150 l/PE*d. The assignment of anaerobic digestion to the related wastewater treatment plant in the partner countries (AT, CZ, DE, HR, IT) was done by the project partners of the various countries. Concerning those countries not represented in the consortium a plant specific assignment could only be done for SI, for the remaining three countries (HU, PL, SK) total figures (amount of plant with AD, related digester gas production) from literature (Kovac, 2015, Ligetvári et al., 2015, Igliński et al., 2015, Bodík et al., 2011, Hutnan et al., 2015) were used.

3.2. Estimated energetic potential at wastewater treatment plants

Based on the presented inventory the potential for (i) digester gas (biogas) production as well as the related generation of (ii) electric and (iii) thermal energy, the potential for (iv) wastewater heat recovery in the effluent as well as the potential for (v) electricity from photovoltaics at the premises of the existing wastewater treatment plant could be estimated. Table 2 gives an overview on the related results for the different countries as well as the entire CEU program area.

Table 2: wastewater amounts and availability of anaerobic digestion (AD)

Country	digester gas [m³/d]	digester gas el. [MWh/a]	digester gas th. [MWh/a]	heat recovery potential [kW]	heat pump [MWh/a]	PV (solar) el. [MWh/a]
AT	223 800	167 900	335 800	526 600	3 159 300	41 899
CZ	137 000	102 800	205 600	348 800	2 092 700	32 497
DE	717 200	537 900	1 075 700	1 891 000	11 346 100	83 706
HR	21 500	16 100	32 300	124 100	744 500	11 980
HU	100 000	67 900	127 000	386 600	2 319 900	31 998
IT	345 300	259 000	518 000	1 216 900	7 301 100	48 776
PL	55 000	37 300	69 900	1 717 600	10 305 600	99 502
SI	15 200	11 400	22 800	67 900	407 200	5 616
SK	55 000	37 300	69 900	138 100	828 300	11 425
Total CEU	**1 670 000**	**1 237 600**	**2 457 000**	**6 417 600**	**38 504 700**	**367 399**

Table 2 shows, that in the CEU program area the amount of digester gas (biogas) produced is estimated to around 1.7 million m³/d. By means of combined heat and power generation about 1.2 million MWh of electricity and about 2.4 million MWh of (high temperature) heat per year can be provided per year. The heat recovery potential in the wastewater is around 6.5 million kW, by applying a heat pump the significant amount of about 38.5 million MWh of (low temperature) heat could be made accessible. Electricity generation from photovoltaics is estimated to be around 0.4 million MWh per year.

Hereby, the estimation of digester gas (biogas) production is based on the current load of the wastewater treatment plant multiplied by an average gas production of 20 l/PE*d. The estimation of the digester gas-based electricity assumes a generation of 15 kWh/PE*a, for thermal energy 30 kWh/PE*a. These figures are taken from Austrian benchmarking experiences (Lindtner, 2008).

The estimation of the wastewater heat recovery potential is based on the hourly wastewater flow, an assumed cooling of the effluent by 5 K considering a (waste)water heat capacity of 1.16 kWh/m³*K. Subsequent heat generation by means of a heat pump assume a coefficient of performance (COP) of 4 and 4.500 operating hours per year (settlement structures of mixed functions).

The estimation of the PV potential is based on available data from existing wastewater treatment plants from five countries with installed photovoltaic units. Correlation was made between them and rest of the plants in a country including other parameters such as geographical position to obtain a rough annual average rate of electricity generation at a wastewater treatment plant.

3.3. Spatial Context of wastewater treatment plants

Throughout the course of the REEF 2W project it became apparent that it is not only possible to increase the energy efficiency of wastewater treatment plants (WWTPs) but also to make use of potential excess energy from the treatment plants. Hence, in order to do so, it is important to analyse the spatial context of both energy sources (in this case the WWTPs) and energy sinks (settlements, including residential areas, commercial and industrial areas etc.). The spatial analyses of energy sources and sinks is also the main concept behind Integrated Spatial and Energy Planning (ISEP), as described by Stoeglehner et al. (2016). Only by incorporating spatial analyses an efficient energy system can be planned. The examination of the location of energy sources and energy sinks becomes even more important when dealing with thermal energy (heating or cooling). Since the transportation of thermal energy is associated with heat loss it is necessary that potential energy consumers are located close to the treatment plant.

However, WWTPs in the CEU area are located in different proximities to energy consumers. Some treatment plants are located far from the next settlement, whereas others are located even within settlements, making it easier to utilise thermal energy. Therefore, the main goal of the spatial analysis is to detect those treatment plants that could potentially be used as renewable heat sources and those that are less suitable. By using the methodology developed by Neugebauer et al. (2015), every single WWTP in the CEU area was classified into one of the following three categories:

- (A) WWTPs located **within** the settlement,
- (B) WWTPs located **near** to the settlement and
- (C) WWTPs located **far** from the settlement.

Relevant WWTPs, derived from the European Environment Agency (EEA s.a.) as described in chapter 3.1., were taken as a basis. Using GIS software (QGIS.org 2020), a total of 6,944 WWTPs with a treatment capacity > 2,000 population equivalent (PE) could be located within the Central Europe program area (© EuroGeographics for the administrative boundaries derived from Eurostat s.a.). After locating every WWTP it was necessary to evaluate the spatial context whether or not the plant was within, near or far from a settlement. Therefore, the vicinity of the WWTPs was analyzed in circular areas with 150 m and 1000 m radii in which CORINE land cover categories (CORINE 2018) were used to determine the existence of potential heat consumers. Hence, for the spatial examination the following three classes of artificial surfaces were used:

- 111 – Continuous urban fabric
- 112 – Discontinuous urban fabric
- 121 – Industrial or commercial units

As a result, the following figure (Figure 1) shows an overview of the spatial contexts of the WWTPs in the CEU area.

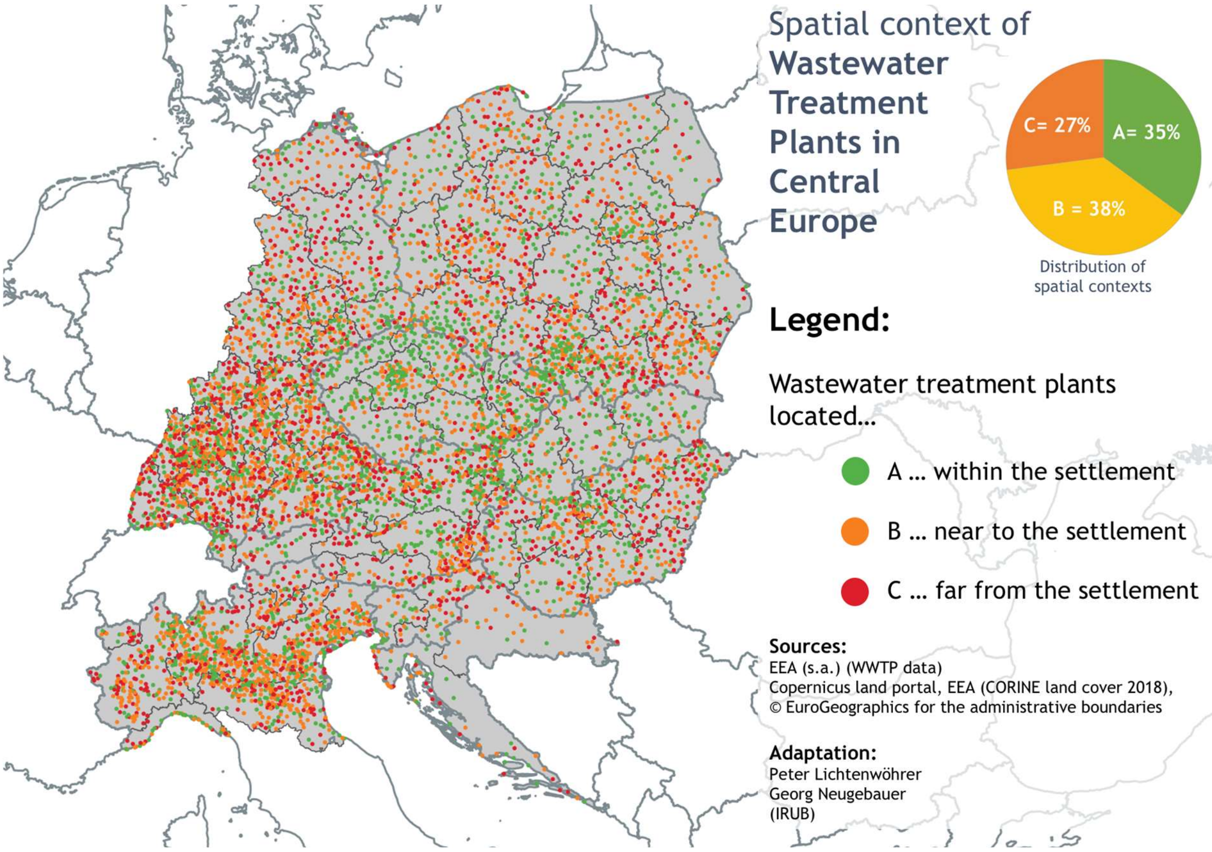

Figure 1: Overview of wastewater treatment plants in Central Europe (own illustration)

A total of 35 % of the evaluated WWTPs were categorised as “within the settlement”. Figure 2 shows an example of a treatment plant associated with this category. It can be seen, that the considered land cover classes are located in a distance up to 150 m and cover an essential share of the circular area with a 1000 m radius.

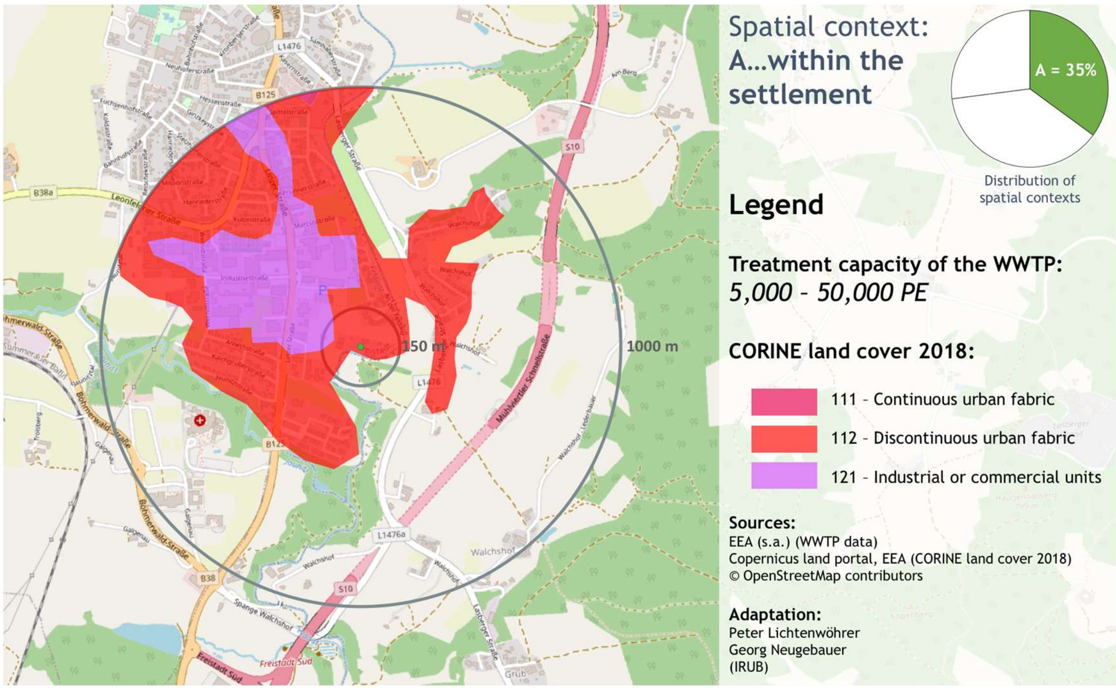

Figure 2: Visualisation of a WWTP located within the settlement (own illustration)

Slightly more WWTPs (38 %) were detected near to settlements, as illustrated in Figure 3. In this category, settlement areas are located within the radius of 1000 m, which still points to potential energy consumers in the vicinity of the treatment plant.

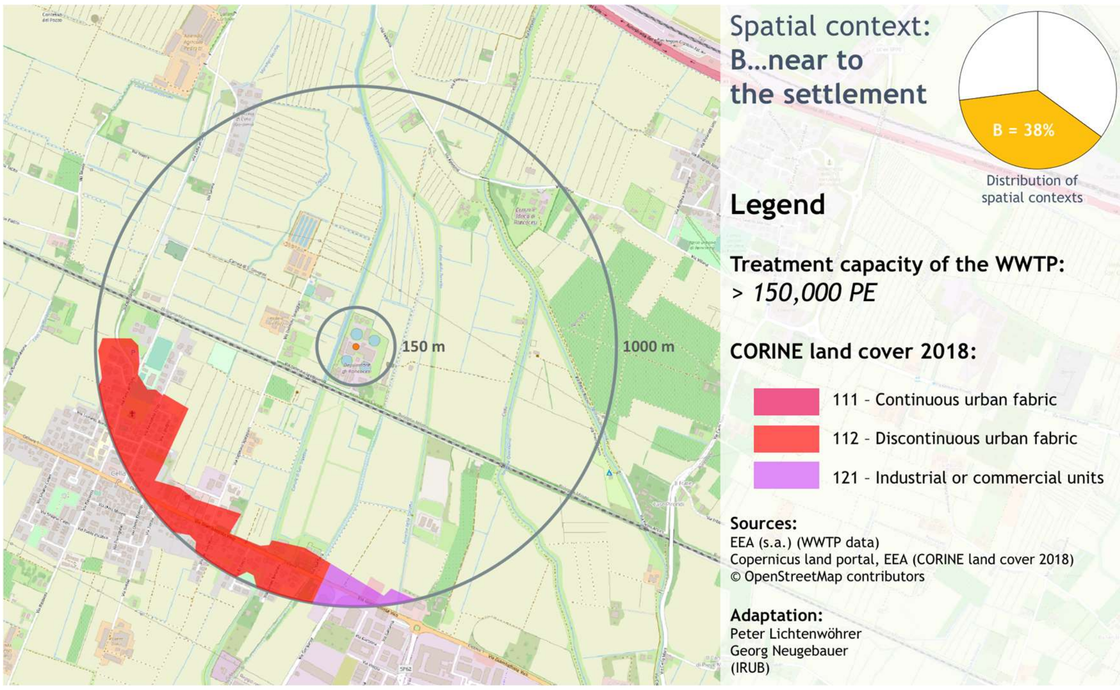

Figure 3: Visualisation of a WWTP located near to a settlement (own illustration)

Finally, less than a third (27 %) of all evaluated WWTPs in the CEU area were categorised as “far from the settlement”, because no significant shares of areas in the considered land cover categories were identified indicating hardly any energy consumers within a radius of 1000 m (see Figure 4 as an example).

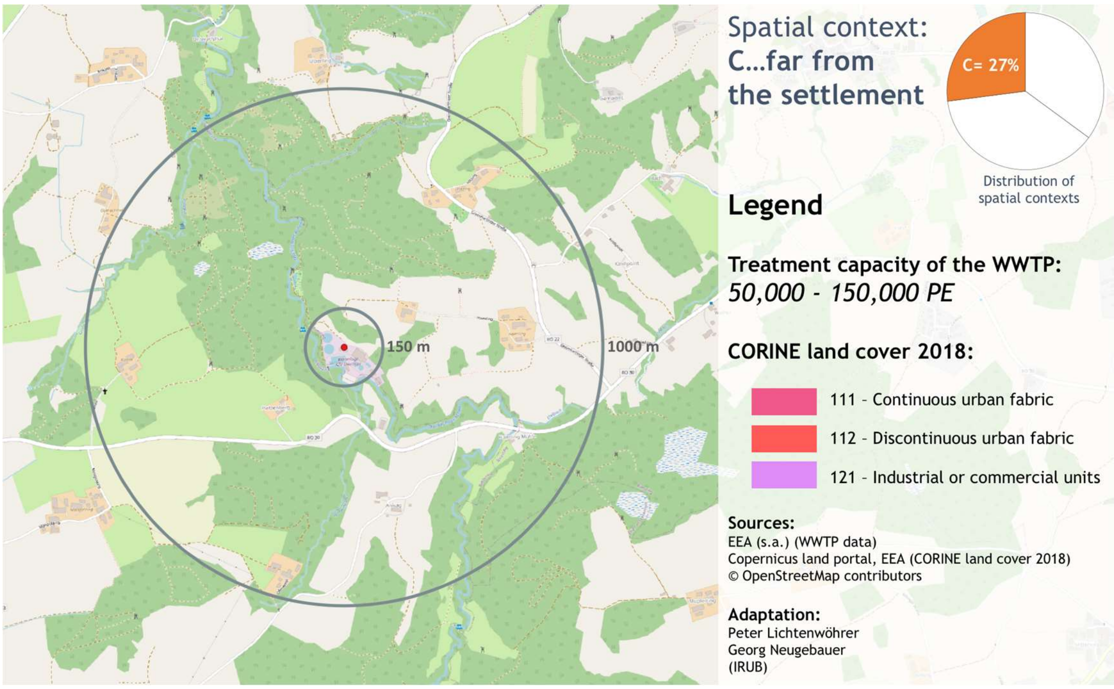

Figure 4: Visualisation of a WWTP located far from a settlement (own illustration)

4. CEU PROGRAM AREA STRATEGY

4.1. Basis and Structure

The supposed CEU Program Area Strategy is based of the five regional strategies from Germany, Austria, Czech Republic, Italy and Croatia elaborated in Deliverable D.T2.5.1 and on the position paper on legislation barriers prepared in Deliverable D.T2.5.3. It is considered a further developed strategy paper that highlights opportunities and impacts of REEF 2W at CEU level. Hereby, the strategy consists of four parts/thematic fields: A (1) legislative, an (2) operational, a (3) financial and a (4) connection part. Each part comprises its specific actions. The overall vision of the CEU Area Strategy is to form a set of actions to foster the use of energy from wastewater and the application of the REEF 2W approach in a broader context.

4.2. Legislative Part

The first part of the strategy is about legislation. In order to foster the use of renewable energy from wastewater legal and policy frameworks have to be adjusted in order to link energy, wastewater and solid waste sectors with the intention to maximise synergies and remove barriers for implementing joint renewable energy sources solutions. The required actions are as follows:

Action 1.1. Regulatory pressure

Policy makers, higher officials and other appropriate stakeholders on EU and national level should introduce a certain regulatory pressure in regard to apply renewable energy solutions also considering energy from wastewater and its use and adjacent areas (beyond the premises of a wastewater treatment plant). Regulatory pressure is expected to speed up all processes.

Action 1.2. Adaption of legal frameworks and boundary conditions

Wastewater as renewable source of energy must be integrated in (national, regional, municipal) legal frameworks as well as in energy and climate planning and spatial planning frameworks. For wastewater based renewable energy sources implementation (including sludge treatment) all legal and policy boundary conditions must be set. Overall aim of this actions is to remove all barriers that are preventing renewable energy implementation in the wastewater sector and beyond.

4.3. Operational Part

The second part of Strategy is about operation. It concerns the adjustment of operational models of utilities running wastewater treatment plants in order to improve their business cases. Implementation of these actions allows wastewater treatment plants to also perform as a sort of energy provider. The required actions are as follows:

Action 2.1. Integration into existing supply systems

The purpose of this action is to adjust existing but possibly inhibitory regulations on national levels so that utilities running wastewater treatment plants can better invest in energy from wastewater solutions. In order to fully activate available renewable energy potentials, wastewater treatment plants must be recognised as energy producers and providers for their municipalities and communities. Operational preconditions for enabling the integration of electricity, gas and heat to local energy supply systems is imperative.

Action 2.2. Practical application of energy from wastewater

The practical implementation of energy generation from wastewater can be fostered by applying REEF 2W concepts and methodologies. A clear presentation of the benefits (e. g. support for domestic economy, decrease of dependency on energy imports and increase of innovation and research) related to the site-specific context as well as its technical and energetic characteristics will be supportive.

Action 2.3. Including biowaste in sewage sludge digestion

If available, municipal liquid and solid waste can be added to the anaerobic digestion of sewage sludge in a wastewater treatment plant to improve its energetic, the economic, and possibly also the ecological performance.

Action 2.4. Sludge disposal scenarios

There is also a need to offer a holistic approach for sludge disposal. The different disposal scenarios (soil improver, incineration etc.) should be integrated into energy from wastewater considerations to allow comprehensive solutions.

4.4. Financial Part

The third part of the strategy is about finance. The application of energetic use of wastewater and the REEF 2W approach requires sufficient, predictable and long-term financial models also tailored to best use synergies between the energy, wastewater and waste sectors. The required action is as follows:

Action 3.1. Establishing financial models

To increase investments in wastewater based renewable energy sources a coordination of EU and national/regional governmental levels must be ensured for establishing clear subsidies, co-financing and other suitable financial models. Established models should include public-private investment models such as PPP (public-private partnership), EPC (energy performing contract) and various community energy investment models.

4.5. Connection Part

The fourth part of the strategy is about connection. This concerns the connection of stakeholders from the energy, the wastewaster and the waste sector through national platforms, increase information, communication, education and capacity building measures. The required actions are as follows:

Action 4.1. National/transnational platform

A national platform should be established to inform and coordinate all relevant and interested stakeholders of the different institutions (public and private) and sectors (energy, wastewater and waste). Furthermore, the mission of the national platform shall encourage, promote and proactively support the broader implementation of the energetic use of wastewater and the REEF 2W approach. Although the presented strategy is elaborated in the scope of the CEU area it can be expanded towards additional transnational cooperation, to share knowledge and experience in only one transnational platform (representing all national ones).

For all stated actions there is need for a combined approach, i.e. synchronized across sectoral legislations and policies at different political-administrative levels (national, regional, municipal). Hereby, a key aspect is to identify all relevant stakeholders on the different levels.

Action 4.2. Raising awareness by education and communication

For establishing energy from wastewater and the REEF 2W approach on as broader scale targeted communication, promotion and education is crucial. Related activities could be coordinated and organised by the before mentioned national platform.

Action 4.3. "Buddy system"

Experience from REEF 2W project shows that there are substantial differences in knowledge and experience concerning the energetic use of wastewater at wastewater treatment plants and the adjacent settlement structures among the different countries and regions involved in the project. To close related gaps the strategy proposes establishing a "buddy system" by matching unexperienced utilities/stakeholders with experienced ones. In this way transfer of good practice and direct education with an even bigger impact is expected.

Action 4.4. Renewable energy community model

Aligned with the Directive (EU) 2018/2001 and the European Green Deal wastewater treatment plants can be introduced into renewable energy community models where citizens, who are aware of energy sustainability, participate. Because of their spatial location and specific function WWTPs are often perceived as isolated assets and not included in the community's (supply) infrastructure, that perception should be changed in the future.

5. CHALLENGES AND CONCLUSION

5.1. Challenges

The main challenges public and private operators of wastewater treatment plants are likely to face when implementing (some of the) suggested strategic actions can be summarised as follows:

- Adequate support from municipal/regional/national level of the government;
- Sufficient support from local community;
- Adequate legislative, policy and operational framework;
- System of incentives and finance models in general.

The suggested CEU program area strategy is structured and written in a way to deal with and to overcome those challenges.

5.2. Conclusion

The estimations on the available energy potential (presented in chapter 3) clearly show that there is a large amount of energy available at CEU's wastewater treatment plants. Activating this today still widely unexploited potential can support the energy transition towards more climate-friendly systems and thus support the aims and goals of the European Green Deal.

Additional proactive efforts and actions are needed from all involved institutions, sectors and stakeholders to better harness this great potential of renewable energy sources found in wastewater. In this context it is crucial to link energy, wastewater and (solid) waste sectors in their specific spatial context (compare figure 4) also to maximise synergies from the implementation of joint renewable energy solutions to obtain a cleaner, healthier and more sustainable environment and society.

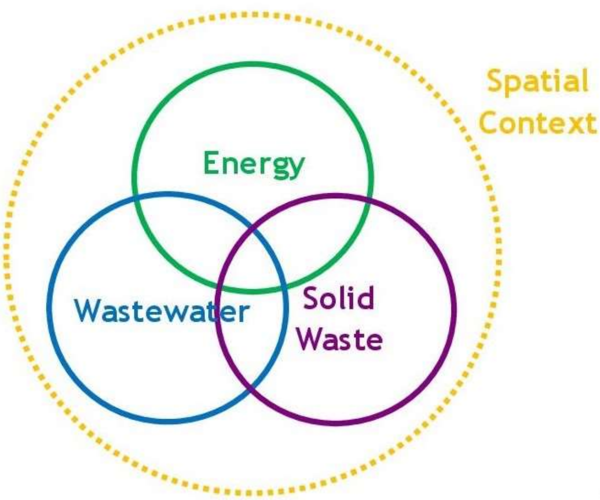

Figure 4: Energy, wastewater and (solid) waste sectors in a subordinate spatial context

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