D.T.2.3.1 FIRST PART OF THE FEASIBILITY STUDY - CROATIA

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

1.1. The REEF 2W Project

In the wake of the renewable energy, 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 a large source of electricity and heat, sewage is generally overlooked. In fact, the amount of energy it contains can be 10 times bigger than that is required to treat it.

Lately an increasing number of wastewater operators have deployed energy-efficiency measures and novel technologies to better harness the energy of sewage. Evaluations of pioneering projects show that utilities are not only capable of becoming energy self-sufficient, but also suppliers of energy thereby diversifying the local mix.

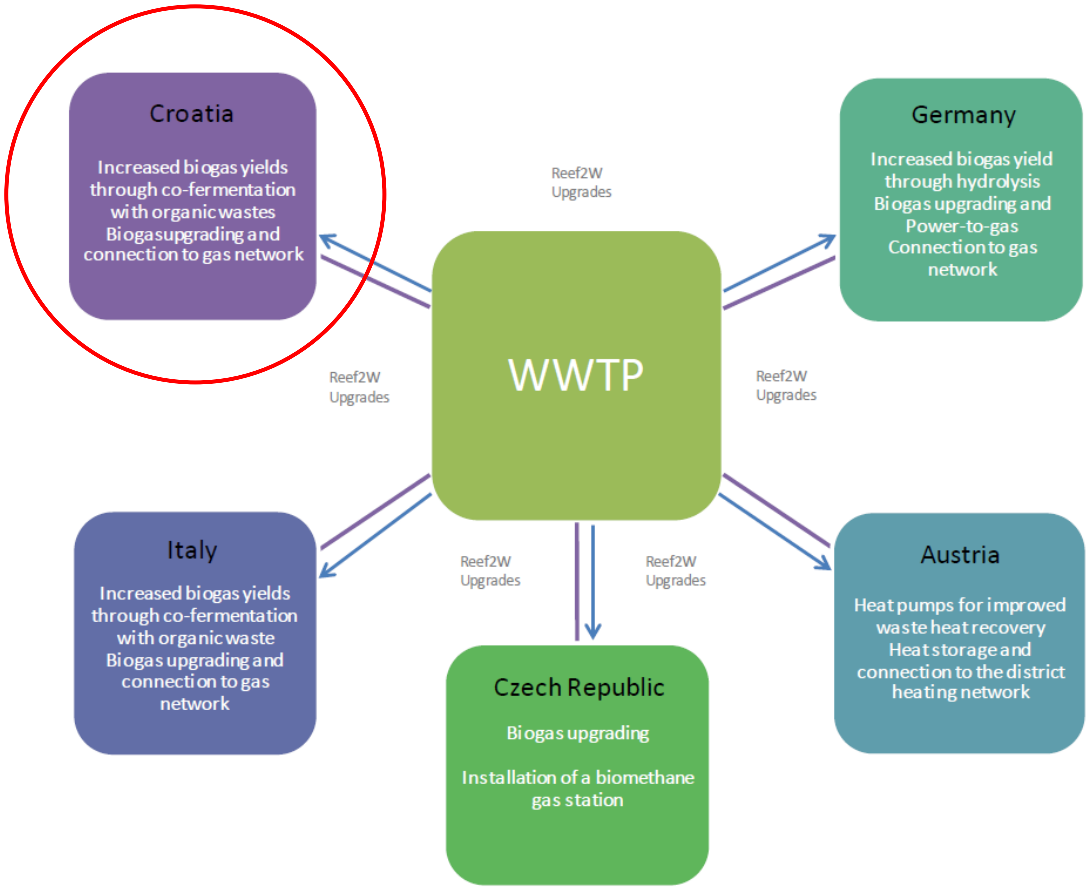
The project REEF 2W recognizes that wastewater is an integral part of the water-energy nexus. The project is funded by the European Development Bank's Interreg Central Europe Programme and is carried out through 11 research institutes and wastewater utilities from Italy, Czech Republic, Germany, Croatia, and Austria. The projects main objective is to drive up energy efficiency and renewable energy production of WWTPs.

It provides an innovative approach in integrating organic waste and wastewater streams and infrastructures. Where beneficial, bio-waste will be used to enrich sewage sludge, helping to elevate outputs of heat and electricity in a process called co-fermentation. To prove that the new technologies can be technically feasible and economic viable, project partners will develop a comprehensive assessment tool in close collaboration with utility operators in a series of workshops. Another key task of 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 to analyse the energy efficiency and the potential to produce renewable energy in the project's five pilots. The first part of the feasibility study will give an overview of the baseline scenario of the proposed WTTP and, building on this, will propose an upgrade according to the feasible solutions.

Furthermore, it will provide a quantitative understanding of the potential to increase energy outputs. The (fictitious) technological upgrades defined for each pilot include measures to optimise existing processes and to install new technologies that produce renewable energy.



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

The REEF 2W tool has been continuously improved and tested by the project team and also by external actors during the training courses. While the feedback gathered from the participants of the training course is being integrated, the feasibility studies for the five pilot sites are the first organized attempt to test the tool and document the results.

The second part of the Feasibility Study builds on the results of applying the REEF 2W and ISA tool to the respective pilot site. The results will also be relevant for other communication purposes and form the basis for the regional strategies (DT2.5.1) and MOUs (DT2.5.2), for example.

<u>Structure & Approach</u>

The present first part of the feasibility study on the Croatian pilot site is structured as follows: First, section 2 introduces the pilot site focusing on the current wastewater and sludge management and its challenges, legal frameworks that are in place, and concludes with a description of the pilot site. The third and final section provides an overview of different REEF 2W solutions to optimise the energy management at the pilot site.

Based on the results of this study, the second part of the feasibility study (*Completion of the feasibility studies of the pilot REEF2W proposed solution* DT3.3.5.) analyses the energy performance of the pilot site (WWTP Zabok) and assesses the potential for increasing the energy efficiency and the production of renewable energies at the pilot site by applying the REEF 2W and ISA tool. On this basis, the second part of the feasibility study concludes the most important results and proposes fictitious technological upgrades for the pilot sites.

1.3. The expected benefits

The implementation of REEF 2W technologies entails several advantages from an energetic, economic and environmental point of view.

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 costs**, especially where cost-intensive waste incineration is the only option. Optimized economics of WWTPs lead 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 feedstock. Recycling of organic waste in WWTPs **replaces the CO_2-intensive disposal on landfills.** The wastewater sector increases its **contributions to a sustainable energy transition** and **climate protection.**

2. Description of the pilot site

2.1. General overview

In Croatia it is necessary to align the management of water flows and sludge flows. The sludge management is part of the overall waste management policy, where utilization of produced sludge is not clear due to the regulations and documents from various state and local government bodies. All this has led to the problem of slowing down the implementation of sustainable waste treatment in practice, even stopping the realization of projects, and thus delaying the realization of plans.

The local community in Croatia has a big problem with sludge. Besides the energy potential, the treated sludge (stabilized and dehydrated) can be also used in agriculture or as landfill coverage. However, this sort of utilization is classified as transitional and unsustainable due to the loss of phosphorus and energy that could be used for gas production and cogeneration. In Croatia there is almost no solution to the discharge of sewage sludge. For the development of suitable policies, feasibility studies should be carried out that apply to projects in the 2014-2020 programme period. Policies should include: a satisfactory solution for sludge disposal in Cohesion Fund applications, cost calculation, acceptable ways of disposal without changing wastewater treatment processes.

Moreover, municipal solid waste management in Croatia is facing increasing challenges. The main reason for the increase of generated waste is population growth, changes in lifestyle, development and consumption of products with less biodegradable materials. In that sense, the main objectives of the future EU policies are:

- Reduction of waste generation per capita
- Waste recycling and reuse at highest rate feasible
- Gradual phasing out landfilling practices, and
- Limited incineration of non-recyclable waste.

The main purposes of these objectives are to increase recycling of municipal waste, to phase out landfilling of any recyclable materials by 2025, to reduce the production of food waste, to increase producer responsibility, to simplify reporting obligations, and to trim down the obligations that affect small and medium enterprises. As in any natural cycle, the introduction of a circular economy would help to reduce the amount of landfilled waste to a minimum and would contribute to the creation of new "green jobs".

It is more evident than ever that Croatia must transform its economic model from a “take-make-use-dispose” growth pattern into one that is based on the reuse, repair, refurbishment, and recycling of existing materials and products. For this reason, the EU addresses today the waste and water sector not only as an important environmental issue, but also as a major opportunity for green jobs.

Figure 1. Waste management hierarchy

Improved waste management also helps to reduce health and environmental problems, to reduce greenhouse gas emissions (directly by cutting emissions from landfills and indirectly by recycling materials that would otherwise be extracted and processed), and to avoid negative impacts at local level, such as landscape deterioration due to landfilling, local water and air pollution, as well as littering.

In line with this, the European Commission has recently adopted the Circular Economy Package, which includes revised legislative proposals on waste to stimulate Europe's transition towards a circular economy that will boost global competitiveness, foster sustainable economic growth, and generate new jobs. Key elements of the revised waste proposal include:

- EU target for recycling 65% of municipal waste by 2030;
- EU target for recycling 75% of packaging waste by 2030;
- A binding landfill target to reduce landfill to a maximum of 10% of all waste by 2030;
- A ban on landfilling of separately collected waste;

One of the solutions for biodegradable waste is its utilization at WTTPs, which is the main focus of this project. In this case, an increase in sludge production is expected. Sludge treatment and disposal processes are controlled by a number of EU directives that prescribe principles, targets, limitations, as well as the impact of sludge disposal on all environmental constituents.

The management of wastewater and purification equipment are covered by the European Council Directive on the treatment of urban wastewater and the European Parliament and Council Directive on establishing a framework for Community action in the field of water policy.

The purpose of these Directives is the establishment of a framework for the protection of surface water, transboundary waters, coastal waters, and groundwater. The Directive on waste water treatment requires water pricing to be managed in accordance with the principle of cost recovery from water services. The water price is also intended to cover the costs of treating sewage sludge from the WWTPs.

The problem of sludge management in Croatia is regulated in the Water Act, which specifies that the sludge generated from the wastewater treatment process can be used in accordance with a special regulation and that its disposal into water is prohibited under the Water Management Plan 2016-2021.

During the transitional period, the disposal of stabilized and dehydrated sludge (with 25-30% DM) on waste landfills was permitted according to the Waste Management Plan for the period 2007-2015. The current approach to sludge disposal is assessed individually, where each agglomeration and plant monitors its needs and capabilities within which it is defined by the regulations.

As mentioned, Croatia hasn't got a proper solution for management of sludge from the WWTPs, which is primarily related to the necessary processing infrastructure. Sludge is mostly temporarily stored or disposed on landfills, exported to neighboring countries, or fewer quantities are used for agricultural purposes or undergo composting. The current practice of sludge disposal in Croatia refers to landfills, which is in direct conflict with the EU Directive on the landfill of waste and its transposition into Croatian legislation. Although landfill disposal is still practiced in Croatia, including some other new EU members, this practice is not sustainable in the long term and should be avoided as such.

According to the Waste Management Plan of the Republic of Croatia for the period 2017-2022, no adequate disposal of sludge from WWTPs has been established in Croatia, which is primarily due to the high requirements on the infrastructure. The targets set out in the Waste Management Plan are to be achieved by 2022 compared to 2015. It is necessary to improve the management system for specific waste categories and to establish a management system for sewage sludge from WWTPs. The treatment and disposal of waste and sewage sludge generated by wastewater treatment in public wastewater systems of towns and municipalities in Croatian counties has estimated that existing WWTPs produce about 35,000 to 40,000 tons of sludge on dry basis annually.

2.2. Location of pilot plant

Zagreb Urban Agglomeration has been found in 2016 and includes the City of Zagreb as the seat of the agglomeration and parts of the Zagreb and Krapina-Zagorje counties (Figure 2). More specifically, the agglomeration encompasses a total of 30 local government units—11 cities and 19 municipalities:

i) **City of Zagreb**,

ii) **Zagreb county**: City of Dugo Selo, City of Jastrebarsko, City of Samobor, City of Sveta Nedelja, City of Sveti Ivan Zelina, City of Velika Gorica, City of Zaprešić, Municipality of Bistra, Municipality of Brckovljani, Municipality of Brdovec, Municipality of Dubravica, Municipality of Pušća, Municipality of Rugvica, Municipality of Stupnik, Municipality of Pokupsko, Municipality of Klinča Sela, Municipality of Orle, Municipality of Pisarovina, Municipality of Kravarsko and Municipality of Marija Gorica, and

iii) **Krapina-Zagorje county**: City of Donja Stubica, City of Oroslavje, City of Zabok, Municipality of Gornja Stubica, Municipality of Jakovlje, Municipality of Luka, Municipality of Marija Bistrica, Municipality of Stubičke Toplice, and Municipality of Veliko Trgovišće.

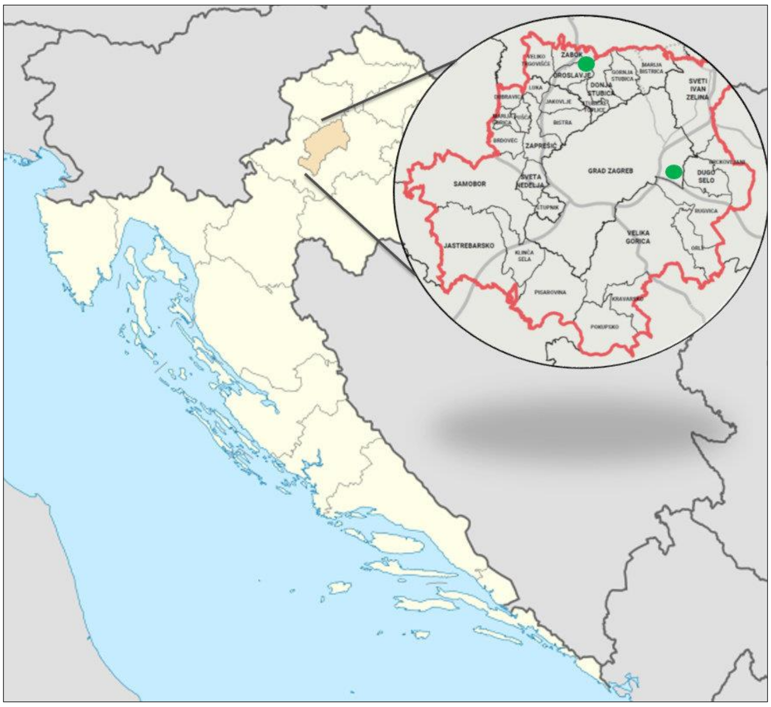


Figure 2. Location of the Zagreb agglomeration

In terms of population, the largest portion of the total agglomeration inhabitants live in the City of Zagreb (72.7%), but the largest area is in the Zagreb County (67.7%). The main data of the agglomeration is presented in Table 1.

Table 1. Zagreb urban agglomeration – main data

Location	Area (km^2)	Population (2011)	Portion (%)	
			Area	**Population**
Grad Zagreb	641,3	790.017	22,0	72,7
Zagreb county	1.969,7	256.689	67,7	23,6
Krapina-zagorje county	300,3	39.822	10,3	3,7
Total	2.911,3	1.086.528	100	100

The WTTP Zabok is in its construction phase and will be built in 2020 and owned by the public company Zagorski vodovod ltd. This company has been found by 26 local self-government units, is engaged in public water supply and public drainage, operates in the urban agglomeration of Zagreb, and supplies water to 90,000 residents in more than 31,000 terminals.

The public water supply system of Zagorski vodovod ltd. includes 6 springs, 60 reservoirs, and 80 hydrophobic and pumping plants. The total distribution network of public water supply is over 2,000 km. The primary activities of Zagorski vodovod ltd. are public water supply and public sewage disposal. In 2006, Zagorski vodovod ltd. registered the activity of public wastewater treatment and started preparations for taking over existing wastewater systems in the Krapina-Zagorje County.

Figure 3. Zagorski vodovod Ltd (www.zagorski-vodovod.hr)

2.3. Current situation

Zagorski vodovod Ltd. plans to build the WTTP Zabok with a capacity of 36.940 PE, which will consist of the following three stages:

- *Prior purification*: separation of particles
- *Second stage*: consists of temporarily holding the sewage in a quiescent basin where heavy solids can settle to the bottom while oil, grease and lighter solids float to the surface.
- *Third stage*: removes dissolved and suspended biological matter, as well as dehydration of the sludge.

The schematic overview of the WWTP Zabok is presented in Figure 4. The main data of the WTTP Zabok is presented in Table 2.

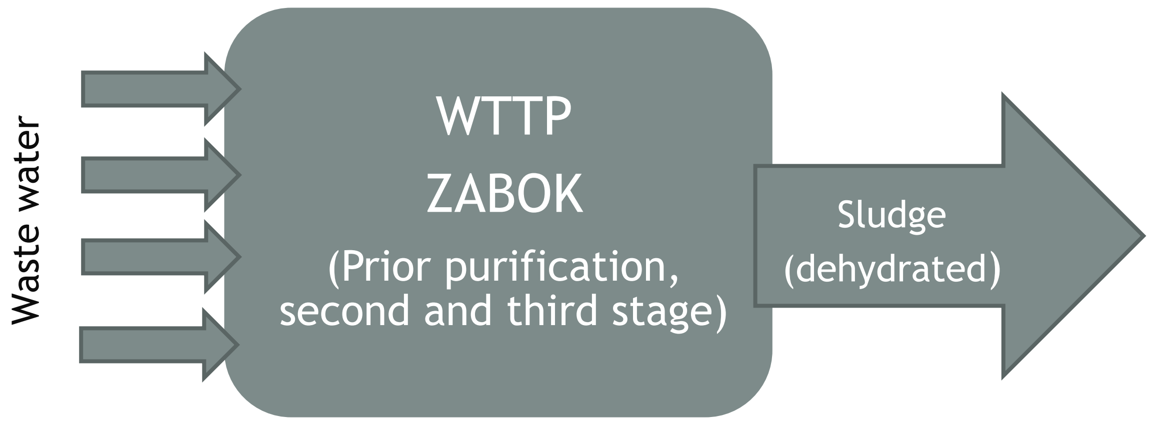


Figure 4. Overview of the WWTP Zabok

Table 2. WWTP Zabok - main data

Zagreb Agglomeration	Location	Population	WTTP size (PE)	Sludge amount (m^3/y)	Dry matter	Total amount (t/y)
WWTP Zabok	City of Zabok	9.000	36.940	1.490	75%	1.117,5

Besides its energy potential, one of the options for sludge treatment is the application in agriculture. There, it is usually used as a soil improver for the usage on non-food land. In this sense, it is important to consider the total costs of sludge disposal. They are not negligible and can account for up to 50% of total business. In some cases, with the addition of other socio-economic and ecological parameters, they can even be significantly higher.

The overall estimation for the cost of sludge treatment is presented in Table 3, while the data on the land availability within the Zagreb agglomeration is presented in Table 4.

Table 3. Estimation of the sludge management costs in Croatia

Treatment	Costs (€/t of DM)
Agriculture application	150-400
Composting	250-600
Drying	300-800
Incineration	450-800
Landfilling	200-600

Table 4. Agricultural data of the Zagreb Agglomeration

Zagreb Agglomeration	Used land (different crops), ha	Unused land (ha)	Total land potential (ha)
Grad Zagreb	16.470	5.467	21.937
Zagreb county	117.056	32.791	149.847
Krapina-zagorje county	39.433	14.640	54.073
Total	172.959	52.898	225.857

3. Proposed REEF 2W solution

The Zabok WTTP in its full capacity will be producing 1.117,5 tonnes of dehydrated sludge. The proposed REEF 2W solution focuses on:

i) Possibility to use biowaste fraction of municipal waste,
ii) Anaerobic treatment: co-digestion of sludge and biowaste,
iii) Utilization of biogas: combined heat and power (CHP) and biomethane,
iv) Application of digestate as a soil improve.

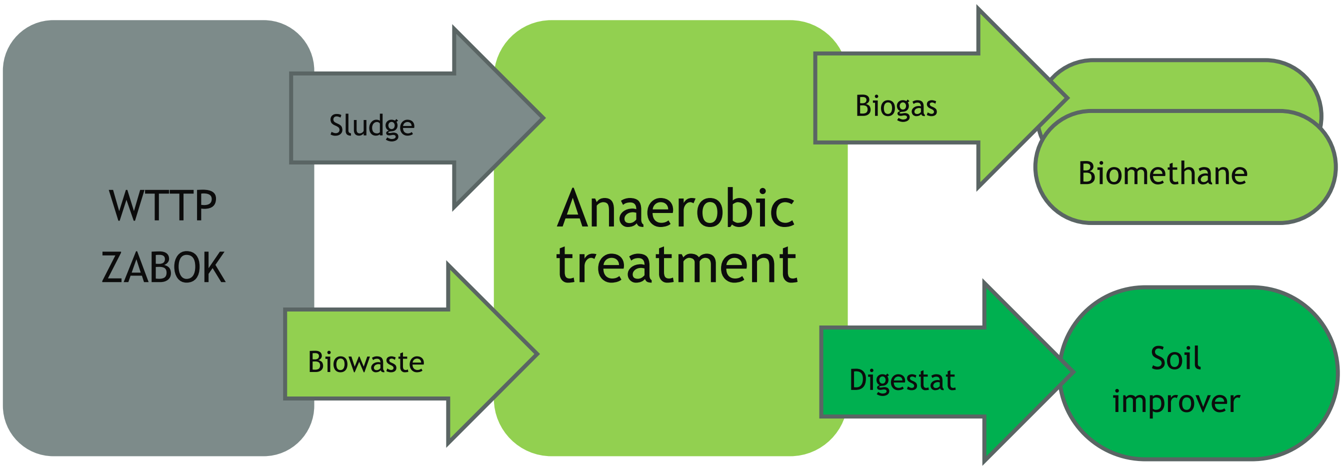


Figure 5. Proposed REEF 2W solution for WWTP Zabok

3.1. Utilization of the biowaste fraction

Biowaste is defined by the EU as biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises, and comparable waste from food processing plants. It does not include forestry or agricultural residues, manure, sewage sludge, or other biodegradable waste, such as natural textiles, paper, or processed wood. It also excludes those by-products of food production that never become waste.

Currently, the main environmental threat from biowaste (and other biodegradable waste) is the production of methane from such waste, which is landfilled and accounted for some 3% of total greenhouse gas emissions in the EU-15 in 1995. Considering the options for biowaste management and the related EU policies, the most sustainable option is anaerobic digestion (Table 5).

Table 5. Different treatment options for organic waste

Waste treatment	Description
Landfilling	All organic waste goes to landfilling.re The landfill gas is recovered and used in a CHP unit.
Incineration	All organic waste is incinerated (together with the mixed waste). Ash is dumped in a landfill site. The energy is used to generate power.
Composting	All organic waste is collected separately at source and then composted in a large-scale composting facility. No energy recovery is made. The compost is used as fertilizer and substrate substitute. Organic waste from mechanical biological treatmentis not considered here as recycled material, as the use of the output is usually very limited due to high levels of contamination.
Anaerobic Digestion (AD)	All organic waste is collected separately at source and then digested. The biogas is upgraded to biomethane and used to substitute transport fuels. The digestate is used as fertiliser and substrate substitute. Organic waste from mechanical biological treatment is not considered here as recycled material, as the use of the output is usually very limited due to high levels of contamination.

The separate collection of food waste is still a challenge within the whole food supply chain: from the farm, to the processing and manufacturing, sales in shops, and consumption in restaurants, canteens and households. The main groups of food waste types are shown in Figure 6.

Figure 6. Different food waste types

Most common waste producers of food waste in urban areas are: households, restaurants and canteens (kitchen waste), market places and retail stores (expired food waste), and also waste from food and beverage industry. The complete analysis of potential biowaste that can be collected within Zagreb Agglomeration will be presented in an integrated study for the pilot location (**deliverable D.T3.3.5**.).

In addition, it is important how the biowaste is being collected. The main challenge is to achieve efficient collection with the lowest possible portion of impurities in the segregated biowaste. Some of the options are:

- **Door to door collection**: biowaste is collected at specified intervals near homes (brown bin). Citizens have to make sure that the biowaste bin is available for collection at specific time, usually once per week. The citizens should put the container in front of their house where the biowaste is usually collected once a week.
- **Special containers on public roads for households and door to door collection for businesses**: Citizens place food waste in special containers on public roads (near traditional containers with other waste, glass, cardboard, etc.). Businesses (markets, supermarkets, restaurants, etc.), however, place food waste in special containers that are put on the street at certain times. It is recommended to use biodegradable bags as they facilitate subsequent treatment. For both, households and businesses system, the collection is performed daily.

- **Special containers on public roads for households and businesses:** This case is basically as described above, but without distinguishing between households and businesses.

3.1. Renewable energy production through biogas

The focus of this study is on the energetic use of organic matter and the production of renewable energy. In this case biogas is produced.

Biogas is a mixture of methane and carbon dioxide that are produced during the decomposition of organic material. Today, the majority of biogas that is produced in Europe is utilized in CHP plants where electricity and heat are produced simultaneously. Hence, the profitability of these plants is directly dependent on a continuous utilisation of the heat produced.

From today's perspective, biogas is considered as an essential energy source in a future energy systems. This is mainly due to the fact that biogas plants usually have an integrated storage system that gives them the flexibility to balance fluctuating power generation from sun and wind. On the other hand, biogas can also be injected into the existing gas networks or it can be used as a biofuel for compressed natural gas (CNG) vehicles. The energy utilization of waste is presented in Figure 7.

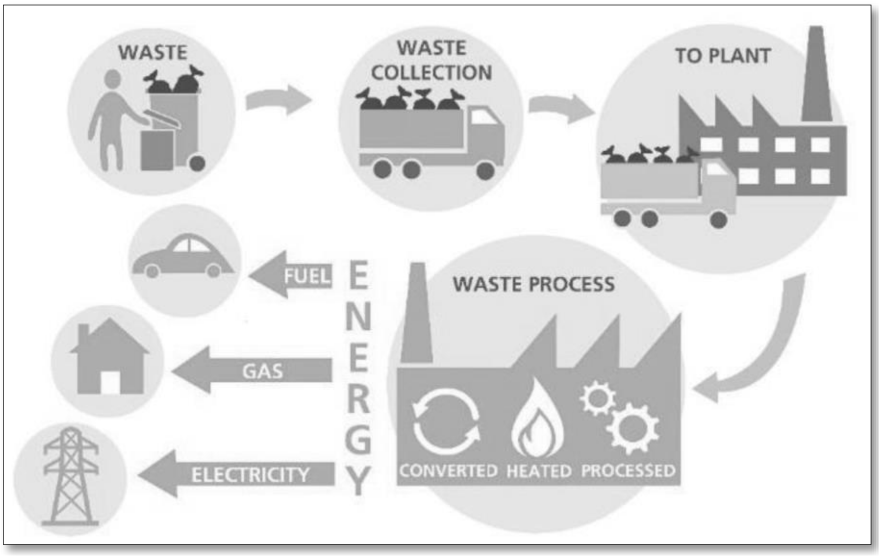


Figure 7. Diagram of the waste-to-energy-cycle (Okello, 2016)

The energy potential of the pilot location is presented in Table 6.

Table 6. Overview of the energy potential at the pilot location

Total amount (t/y)	Energy content (MW/t)	Annual energy potential (MWh/y)	Anaerobic digestion				
			Biogas potential (m^3/y)	Biomethane (m^3/y)	CHP (kW)	Electricity (MWh/y)	Heat Energy (MWh/y)
1.117,5	4,1	4.581,8	67.050	40.230	50,3	152,9	169,0

3.2. Application of sludge

The Waste Management Plan states that it is necessary to improve the management system for specific waste categories and to establish a sludge management system for WWTPs. It is important to note that projects for the construction of WWTPs that do not address the costs and technology of sludge disposal/recycling, as a by-product of wastewater treatment, are not considered fully completed.

The application of sludge in agriculture is subject to a series of regulatory obligations to protect the environment. Disposal of sludge within global practice is carried out in several ways. There is neither a singular strategy nor unique guidelines for the disposal of sludge at global level. Each country addresses the problem of sludge disposal in its individual way.

Sludge can contain heavy metals, which, at certain concentrations, are toxic to humans, animals, and plants. Some of these elements are also present in the soil as nutrients (microelements), which are necessary for the growth and development of plants and are therefore often introduced into the soil through fertilizers.

Sludge found to have a higher concentration than prescribed by law should not be applied to agricultural land. On the other hand, the sludge that complies with this basic condition is permitted for use in agriculture.

Moreover, sludge may also contain various organic pollutants of synthetic origin from industrial wastewater, hygiene products, and pesticides. However, most sludge contains a small portion of these chemicals and doesn't pose a risk to human health or a threat to the environment.

The produced sludge in Croatia doesn't contain heavy metals above values prescribed by law and according to these standards, it in accordance with the conditions for application in agricultural purposes as a soil conditioner or fertilizer. Total amount of estimated sludge and required land for its application is presented in Table 7.

Table 7. Estimated amount and required land for the pilot project

Total amount (t/y)	Required land for sludge utilization (ha)
1.117,5	673,2

4. Conclusion

In recent years the EU has made significant efforts in order to improve current wastewater treatment and waste management. Through different initiatives and actions, the EU identified potential environmental, economic and social benefits of these streams, such as energy material utilization.

The analysis carried out in this study strongly indicates that WWTPs currently constructed and operated can be improved through the implementation of solutions for the production of renewable energies, such as biogas, and for environmental protection, such as sustainable biowaste management and agriculture sludge application.

Environmental policies are usually a key instrument to boost the improvement of certain solutions. Separate collection of biowaste will reduce landfilling of biodegradable waste and thus reveal significant potential for reducing greenhouse gas emissions, such as methane, and increase resource recovery from municipal waste management. The current legal policy obliges local communities to collect biowaste separately. This triggers source-separation as a standard waste management practice for biowaste and contributes to the increase of recycling rates.

Solutions should bring both environmental and financial benefits for municipalities. This should be particularly important in countries with a high dependence on landfill, such as Croatia.

The present analysis provides a brief overview of different possibilities towards the improvement and sustainability of the WWTP Zabok in the Zagreb Agglomeration, and serve as an introduction to the second part of the feasibility study (*Completion of the feasibility studies of the pilot REEF2W proposed solution* DT3.3.5.). The second part analyses the possibility to implement proposed REEF 2W solutions at the WWTP.

5. References

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End of the report