D.T3.4.1

REPORT ABOUT THE COMPARISONS OF RESULTS OF THE PILOT DEMONSTRATION CASES

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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Content

1. INTRODUCTION

The following report was elaborated as a part of the activity A.T3.4 (Sharing pilot experiences among partners and providing a REEF 2W guide for public administrations).

The report was written after intensive discussion among experts, chosen by project partners, which help to bring as more objective view as possible.

The results of the five the pilot demonstration cases are discussed in order to compare different results and commonly evaluate the advantages of REEF 2W for public administrations

Each project member country verified the specific type of technology by a pilot:

AT - thermal energy recovery from wastewater

CZ – biomethane production

DE – thermal hydrolysis / power to gas

HR – co-digestion

IT – organic waste gasification

The main aims of the pilots operation was:

- Verification of selected REEF 2W technologies in specific conditions of different countries (and different WWTPs)
- Delivery of the feasibility studies focused on:

1) evaluation of EE savings and RES production
2) urban compatibility assessment (Soft. tool)
3) analysis of financial options for supporting investments
4) application of the ISA (Integrated Sustainability Assessment)

2. The pilot demonstration cases results

2.1. AT - thermal energy recovery from wastewater

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

In this context, Figure 1 illustrates a simplified scheme of the REEF 2W solution. Currently there are two digester towers in operation, providing biogas to a CHP unit. Considering the annual energy balance, the WWTP provides surplus electricity as well as thermal energy. Due to this fact, surplus electricity (provided by the CHP unit) could be used to operate (a) heat pump(s), thus recovering thermal energy from the effluent of the WWTP. Since an initial evaluation of the energy demand in the two municipalities already showed that there is sufficient heat demand in the surroundings, the REEF 2W solution of installing a heat pump in the effluent of the WWTP was followed and is evaluated in more detail in the subsequent ISA.

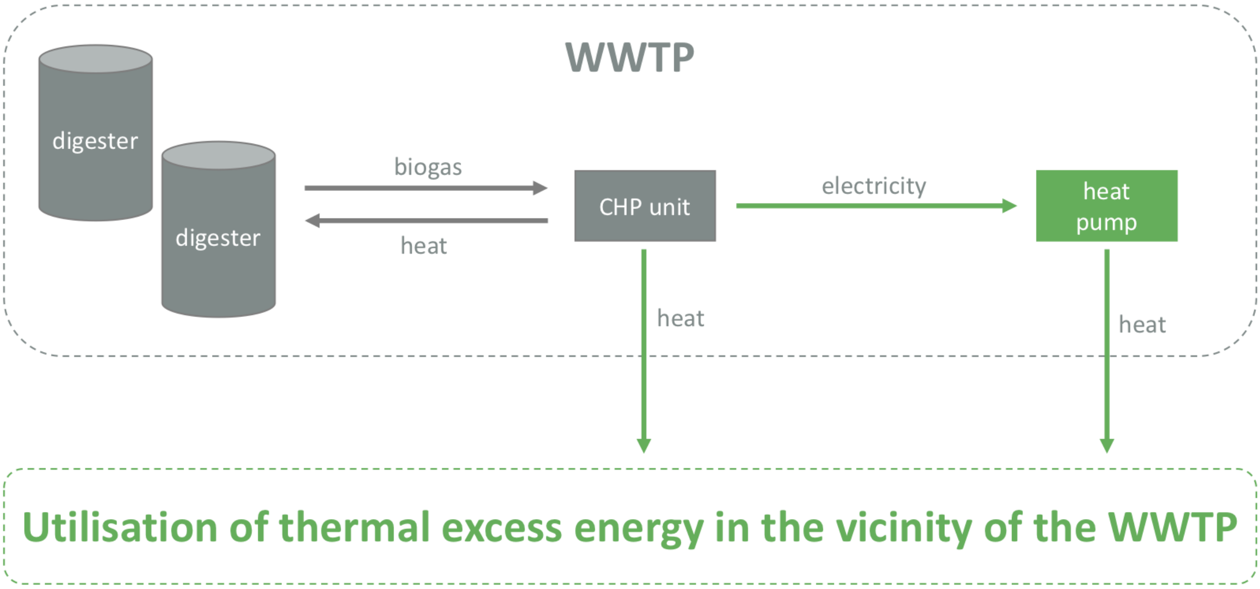


Figure 1: Simplified scheme for the REEF 2W solution at the pilot site in Austria

Based on the results gained it was concluded:

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

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

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

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

Table shows the results of the specific indicators. Some cells are indicated with “N/A”, because some indicators were not suitable to be applied.

Table 1: Overview and visualisation of indicator results for the pilot in Austria

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

Indicator	Categories	Graduation	Status Quo	REEF 2W solution
Additional employment	>0 0 <0	A B C	B	B
Local environmental welfare	Positive Neutral Negative	A B C	B	A
Return of Investment (ROI)	<3 3-10 >10	A B C	N/A	C
Additional income	>0 0 <0	A B C	A	A
Energy costs saving	>0 0 <0	A B C	A	A
Degree of electric self-sufficiency	>75 25-75 <25	A B C	A	B
Degree of thermal self-sufficiency	>100 20-100 <20	A B C	A	A
Degree of externally usable excess heat	> 0 0	A B	B	A
Degree of usable excess gas	> 0 0	A B	B	B
Electric energy consumption at WWTP	< 20 20 - 50 > 50	A B C	B	N/A
Thermal energy consumption at WWTP	<30 > 30	A C	B	N/A
Electric energy generation at WWTP (with anaerobic stabilisation)	>20 10-20 <10	A B C	A	N/A
Thermal energy generation at WWTP (with anaerobic stabilisation)	>40 20-40 <20	A B C	A	N/A

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

2.2. CZ - biomethane production

For Prague WWTP there is biomethane unit for biogas upgrading and vehicle refuelling station designed. The biomethane plant can positively affect the energy efficiency of WWTP and reduce the air pollution generated by transport.

Due to the priorities of the project, the membrane biogas upgrading method was selected for Prague project because of lower investment costs of this technology. The technology consists of membrane biogas upgrading unit and bioCNG vehicle filling station.

Simplified scheme of status quo and Reef technology scenario is shown in Figure 2.

Reef scenario

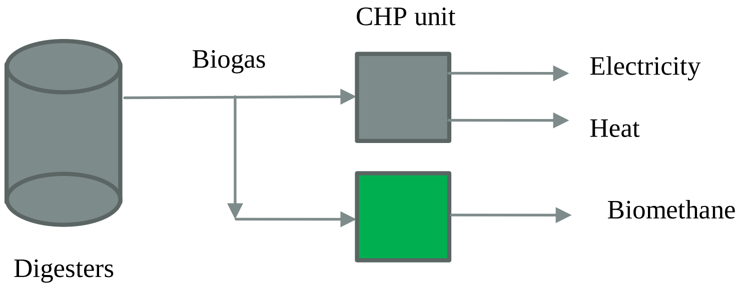


Figure 2. Simplified scheme of Reef technology scenario of Prague’s pilot

The upgrading plant is connected to the existing raw biogas pipeline from digesters to current CHP. It contains a unit for additional special biogas pre-treatment (removal of H2S), gas drying and cooling unit, a compressor unit with filtration, a membrane separation unit itself, and a pressure control device for further distribution. The membrane separation unit is situated in a standard ISO20 container - width = 2.438 m, length = 6.058 m, height = 2.2348 m (or other according to the technology supplier), the container is mounted at the level of the terrain on the concrete blocks.

The filling station for vehicles contains compressor, gas drying device, balancing pressure container - these again in the container version and also covered its own dispenser stand with the payment terminal (here again the assumption of automatic unmanned operation).

For compressed gas filling stations for motor vehicles, TDG G 304 02 of the Czech Gas Association is available, which specifies the conditions for the location, execution, testing and operation of CNG fast-moving stations for motor vehicles if the inlet pressure does not exceed 0.03 MPa, the compressor does not exceed 20.3/h and the compressor internal volume does not exceed 0.5 m3.

The installation of biogas upgrading unit causes only minor changes to WWTP site. Installed technology is small and compact situated in standard containers. Only small part of produced biogas (now not used) will be upgraded.

Biogas upgrading unit will parameters

250 Nm3/hour of raw biogas upgraded

160 Nm3/hour biomethane production

2,500 kg/day CNG production

1,370 kWh production from – currently unused biogas.

Based on the results gained it was concluded:

Considering the comprehensive environmental, social, economic and technical analysis, the REEF 2W technology – introduction of biomethane production - is beneficial for the selected WWTP. As shown in the table 2, REEF 2W scenario has the better composite index in three categories and it is equal in one of them, which means, that implementation of proposed REEF 2W solution could bring additional benefits in these fields.

Table 2: The result of multi-criteria decision analysis

Criterion	Composite Index (Status Quo)	Composite Index REEF 2W Technology
Environmental	3.2	2.4
Social	3.2	2.0
Economic	4.0	2.4
Technical	2.2	2.2

Note: All indicators are normalized (dimensionless value score within the range of 1-5) allowing the comparison without scale effects (A=1, B=3, C=5) – A=1 means best one.

2.3. DE – thermal hydrolysis / power to gas

The integrated approach envisioned in REEF 2W encompasses a wide range of technological steps and processes. Except the enrichment of sludge through bio-waste to enhance biogas yields, many of them are realized at Schönerlinde. The steps will be established to increase the biogas yield through hydrolysis and to convert biogas into bio-methane. Additionally, facilities will be installed to take lower-value electricity from the grid turning in order to turn it into hydrogen, which will be used together with carbon dioxide from biogas upgrading for generating additional bio-methane. (Figure 3)

Currently, the produced biogas is stored in two gas containers and used for drying the sewage sludge, for heating purposes and for power generation.

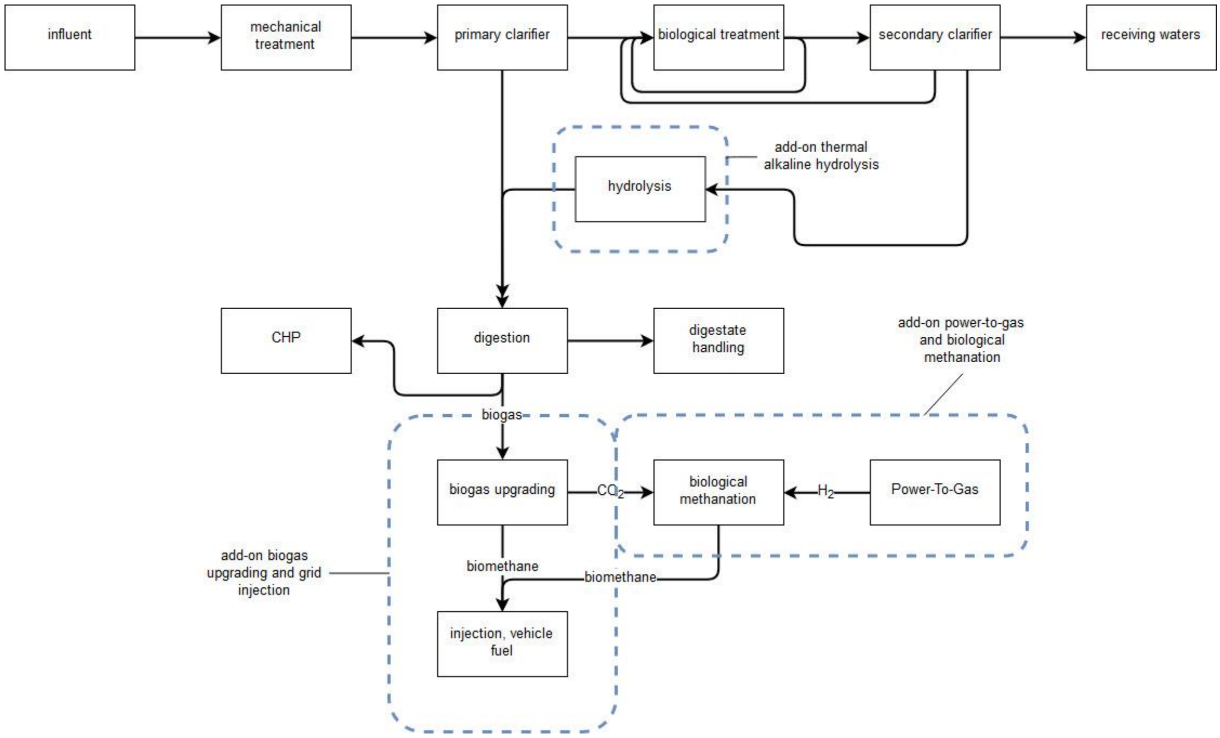


Figure 1: schemata of the new pilot site including the new REEF 2W technologies

Thermal Hydrolysis

The new pilot site will incorporate a thermal hydrolysis stage which will receive a part or the complete flow of the separated sludge from the primary clarifiers to increase the biogas yield during anaerobic digestion and reduce the overall digestate.

Biogas Upgrading

A biogas upgrading unit will receive the biogas produced during anaerobic digestion and upgrade it into bio-methane. Only a small footprint is needed even in the case of upgrading the full biogas stream.

Electrolysis Unit

The electrolysis unit will use electrical energy from the grid during low demand times or during surplus of renewable energies and produces a stream of hydrogen. The inevitably simultaneously formed oxygen stream will be fed into the biological treatment of the wastewater or can be used for the prospective ozonisation step as fourth treatment stage.

Grid Injection

Hydrogen produced in the electrolysis stage and the carbon dioxide stream from biogas upgrading will be injected into a biological methanation unit producing high quality bio-methane. The vessel and its accessories only have a small footprint.

Based on the results gained it was concluded:

Considering the comprehensive technical, social and economic analysis, scenario SI (CHP + thermal hydrolysis) is recommended as the most sustainable and future-proof option for the selected WWTP. As shown in the table above, the scenario SI has the best composite index in these categories, which means, both technologies (CHP and thermal hydrolysis) could bring additional benefits in all views. From an ecological point of view, biogas upgrading will become more interesting in the future to contribute to climate policy. The net GWP is heavily influenced by the electrical consumption from the grid and its substitution depending on the used energy mix. Electrical energy generated by using biogas in the CHP unit (status quo) is more beneficial in GWP than the biomethane credits generated from the same amount of biogas (SII). Similarly, PtG (SIII) is not worthwhile in environmental terms, also because biogas use for electricity production is more beneficial than substituting natural gas in the grid.

It is also observed that a combination of PtG technology (SIII) in the selected WWTP offers the investor no advantage over the scenarios without this technology. This technology severely increases the investment risk. Currently, the lack of support scheme for this technology makes this concept uneconomical.

Table 3: the result of multi-criteria decision analysis

Criterion	Composite Index (Status Quo)	Composite Index SI	Composite Index SII	Composite Index SIII
Environmental	2.8	2.8	4.2	3.6
Social	3	2.4	3.2	2.6
Economic	3	3	2.2	3.8
Technical	3.4	2.4	3.5	3.5

Scenario I: integration of thermal hydrolysis for production more biogas in status quo

Scenario II: integration of biogas upgrading (biomethane injection)

Scenario III: integration of biogas upgrading and PtG technology (biomethane injection)

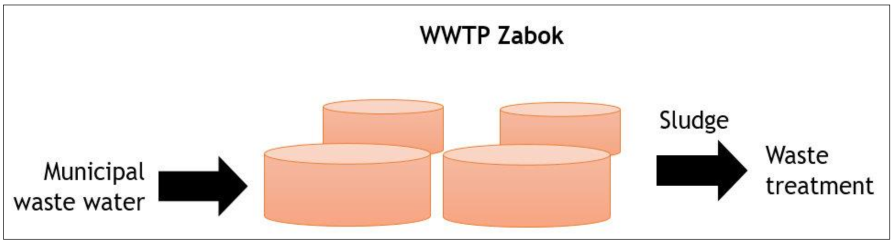
2.4. HR - co-digestion

The main intention for the pilot site in ZUA is to establish a pilot case and test the possibility to utilize the separately collected biowaste, as well as the sustainable usage of produced sludge. This will be the main challenge for the WTTP Zabok operator in the future period. The WTTP in its full capacity will be producing 1.117,5 tonnes of dehydrated sludge. The main aspects of the proposed solution are: i) Possibility to use biowaste fraction of municipal waste, ii) Anaerobic treatment - co-digestion of sludge and biowaste, iii) Utilization of biogas - CHP and biomethane, and iv) Application of digestate as a soil improver.

Besides the treatment of waste water treatment plant, one of the most important issues is the sustainable waste management in the ZUA. The combined treatment of waste and waste water is one of the main benefits of the proposed REEF2W solutions. The main idea behind this proposal is to successfully utilize separately collected biowaste with current waste water treatment. This extension will also result in a production of renewable energy. The overview of all solutions is presented in the following scenarios:

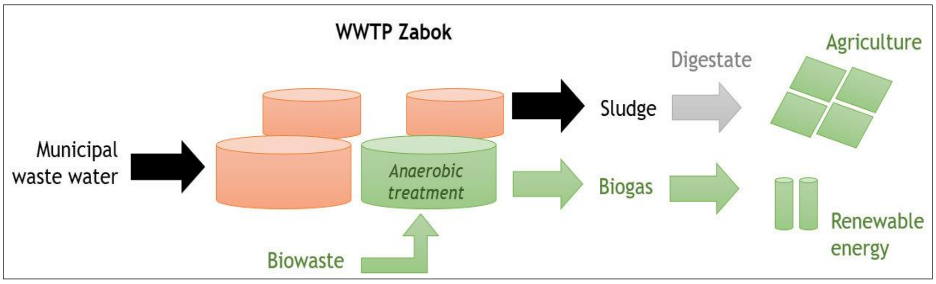
Scenario 1: Local sludge utilization

In this scenario business as usual is foreseen, where the plant is s processing waste water and produce 1,117.5 tonnes of sludge each year. In this scenario no energy utilization will be provided. The produced sludge will be treated as a waste and will be facilitated as a soil improver at the available local land.



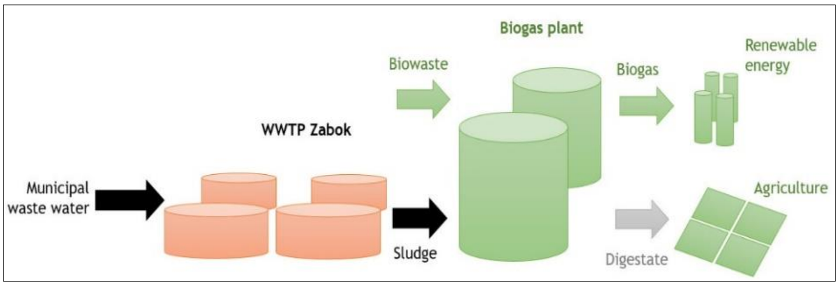
Scenario 2: Anaerobic digestion on site

This scenario is proposing the upgrade of the current facility in Zabok. The upgrade is consisted of the onsite anaerobic treatment of the sludge at the WWTP Zabok as well as the installation of gas engine for the utilization of produced biogas. The WWTP Zabok will produce energy and utilise it via cogeneration. Also, produced sludge will be used locally.



Scenario 3 – Utilization of biowaste and sludge at remote biogas plant

In this scenario it is foreseen that the WWTP Zabok will be operating as in scenario 1 but the produced sludge will not be used locally for agriculture, but rather transferred to the remote biogas plant where it will be used for renewable energy production. Also, separately collected biowaste from all three counties that are part of the Zagreb agglomeration will be transferred to the biogas plant in order to be utilize for renewable energy production (cogeneration or biofuel production). The main reason for this approach is the need to define complete energy potential of the biowaste fraction in the ZUA. This is one of the main goals of the REEF2W project.



Based on the results gained it was concluded:

The principles of sustainable development are becoming more and more important in modern societies and as such more acceptable to the public. The analysis performed within this study indicates that waste water treatment is sustainable and can be combined with the utilization of separately collected biowaste. This approach could have not only positive environmental, but also financial impact on the investigated location.

The application of sludge in agriculture is already part of practice in many EU regions, and its implementation could be a solution for waste water treatment plants. New regulations of the sludge application and its monitoring of the environmental condition are assuring its safe application in agricultural production. This will be especially interested for larger capacity plants (with already constructed anaerobic digestion) from their economic and technological point of view due to the lack of thermal processing in the area. Also, this is much easier to perform because NIMBY (not in my backyard) effect in the local community is avoided.

According to data, the WWTP Zabok will produce 1,117.5 t/y of sludge possible to use on 673.2 ha of agricultural land. Since the investigate area has sufficient land availability, it can be assumed that possibility of local sludge application is realistic.

This study has also investigate the possibility to use sludge for renewable energy production, and in that sense proposed different scenarios. Besides the first proposed scenario, others are giving the overview of the plant upgrade when the separately biowaste fraction is involved in the process. This will for sure improve cash flow of the plant (scenario 2) but certain investment are expected which cannot be foreseen in detail in this stage of plant construction.

This practice of energy recovery of biowaste is still not widely implemented in Croatia and its implementation is at its beginnings. Also, produced electricity is without feed-in tariff so adoption of existing plants is challenging. This is especially the case when the biofuels are being produced and its limited consumption.

Considering the comprehensive environmental, social, economic and technical analysis, the REEF 2W technology is beneficial for the selected WWTP and has better composite index in all categories, which means, that implementation of proposed REEF 2W solution could bring additional benefits in these fields.

Finally, it can be concluded that the use of sludge on agricultural soils is nowadays efficient way to sustainably treat wasted generated in wastewater treatment plants. Also plant operators will have to take into consideration the fact that sludge has energy potential which can be sustainably combined with the biowaste produced at local or broader area.

Table 4: the result of multi-criteria decision analysis

Criterion	Composite Index (Status Quo)	Composite Index REEF 2W Technology
Environmental	4.8	3.0
Social	4.0	2.4
Economic	3.8	3.2
Technical	4.4	3.4

2.5. IT – organic waste gasification

Italian pilot study is focussed on waste treatment plant intensification. At this moment, any environmental technology is applied to reduce the energetic impact of the treatment technologies at the waste treatment site.

In the meantime, there is a plan by the company to reallocate different working sites and offices in one place to optimise space and working time. For this reason, there is a strong interest in the evaluation of the possibility to identify technologies capable of recovering energy from collected wastes. Gasification technology represents one of the most probable options, as it can be used with locally available material, offers the possibility of combining electricity and heat recovery, and can be switched on and off as required.

The other interesting aspect of the gasification process is that the end products are ash and biochar. The advantage of this treatment technology is the reduction of volume and weight of the input material during the treatment. The ashes could provide inorganic elements that can be reused in agriculture. If this is not possible, the ash could also be disposed as a stable material in landfills or used as an inert material in building or road construction.

Biochar, on the other hand, is a carbon concentrate that can be used in agriculture to return the carbon to neighbouring lands.

The electricity produced could be used for the different appliances in the treatment platform. The heat could be used for heating the offices during winter time and all year round to warm up the water in the worker's sanitary facilities.

At this stage, it is not yet decided which specific gasification technology will be applied. This will strongly depend on the current evaluation. But it is clear that gasification is the only possible technology that can be applied at the pilot site at this moment under the conditions under consideration.

The organic material available for gasification at that moment will consist of the organic fraction of the municipal solid waste, the excess sludge of the WWTPs, and brushwood. The available amount of these materials is not very large and for this reason the company has carried out a survey of the territory to evaluate alternative available substrates.

Based on the results gained it was concluded:

The analysis with the REEF 2W tool and methodologies shows that the pilot in Emilia-Romagna proposed by the multiutility Montefeltro Servizi can produce an excess of renewable electricity by using a local gasification system fed by already available biomass, coupled with a photovoltaic plant.

The analysis also shows that the excess thermal energy produced by the power unit can be only be used to a small extent, for the internal needs of Montefeltro Servizi, because the lack of users in the immediate vicinity of the pilot and the high installation costs make its use not convenient considering the quantities involved.

The most favourable option for the pilot is the direct use of the excess electricity by the seven municipalities that own the plant thanks to a specific measure provided by the Italian legislation called "scambio sul posto altrove" (exchange on the site elsewhere). Based on this regulation, public bodies can produce electricity in any place of the Italian territory and use it in any other place where the same public bodies have a utilization point. In our case of the place where the electricity will be produced, that is the Montefeltro Servizi treatment platform is directly owned by the seven municipalities and the excess of electricity produced can be used by the same municipalities for all their electricity needs (public lighting, provide energy at schools, and social centres, etc.).

This makes particularly convenient the investment of the pilot, for which the investment costs will be easily covered by the annual saving for the electricity costs, with a payback period of 5 years.

Table 4: the result of multi-criteria decision analysis

Criterion	Composite Index (Status Quo)	Composite Index REEF 2W Technology
Environmental	4.1	2.4
Social	4.2	1.8
Economic	3.0	1.7
Technical	4.8	2.5

The table shows how the REEF 2W implementation allowing the production of both electricity and heat using all available biomass coupled with photovoltaic panels can improve the present situation (status quo) not only for a best composite index but also under all the single aspects: environmental, social, economic, technical.

3. Results comparisson of the pilot demonstration cases

It was confirmed that for all pilot cases there is possible to find a REEF 2W technology configuration which brings the positive satisfaction of the energy production and the energy demand. It is illustrated in the summary of the general ISA (integrated sustainability assessment) indicators in Table 6.

Because the pilots are covering broad range of technological solutions also the combinations of general indicators are also varied significantly.

The Austrian demonstration case is showing the compliance of needs and offers in the thermal energy.

The Czech demonstration case is showing the compliance of needs and offers in the digester gas (biomethane).

The German demonstration case is showing the compliance of needs and offers in the digester gas (biomethane).

Table 1: Overview and visualisation of general indicator results for the different pilots – REEF 2W solutions

General indicator	Categories	Graduation	AT	CZ	DE	HR	IT
Electric excess energy provision	> 0 ≤ 0	A B	B	B	B	A	A
Thermal excess energy provision	> 0 ≤ 0	A B	A	B	A	A	A
Excess digester gas provision	> 0 ≤ 0	A B	B	A	B	B	B
Excess electricity demand	> 0 = 0	A B	A	A	A	A	A
Excess heat demand	> 0 = 0	A B	A	B	B	B	B
Excess digester gas demand	> 0 = 0	A B	A	A	A	B	A