D.T. 4.3.5 ADDITIONAL 3 FEASIBILITY STUDIES ON BEHALF OF THREE NEW PA

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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1. Introduction

1.1. The REEF2W Project

In the wake of the energy transition an increased focus is concentrating on the yet unexploited energy-saving 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. 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 REEF2 Water 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 wastewater treatment plants. 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 make 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 Reef2 Water 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 pilot site (WWTP Karlovac). Implementing the first part of the feasibility will allow to understand how much energy the WTTPs currently use. Furthermore, it will provide a quantitative understanding about the potential to increase energy outputs. In the (fictive) technological upgrades defined for pilot, these include measures to optimise existing processes and to install new technologies that produce renewable energy.

1.3. The Expected Benefits

The implementation of REEF2W technologies entails several advantages from an energetic, economic and environmental point of view.

Table 1: Energetic, economic and environmental benefits of the REEF 2W technological solutions

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 cost**s, especially where cost-intensive waste incineration is the only option. Optimized economics of wastewater treatment plants lead to **financial savings for municipalities.**	Energy savings and reduced use of fossil fuels result in a **lower CO2-footprint** of WWTPs. Biogas obtained from sewage is a **more environmentally friendly biogas** compared to crop-based feedstocks. Recycling of organic waste in sewage treatment plants **replaces the CO2-intensive disposal on landfills.** The wastewater sector increases its **contributions to a sustainable energy transition** and **climate protection.**

2. Description of the pilot site (WWTP Karlovac)

2.1. Characteristics of the WWTP Karlovac

WWTP Karlovac is located in the area of Gornje Mekušje, part of City of Karlovac (55.700 inhabitants). Project of establishing the WWTP was co-financed by the EU ISPA pre-accession fund and started operating on May 30, 2011. Plant has three stages of water treatment. The mechanical and biological stage of purification consists of a series of biological, chemical and physical processes that have the function of removing most organic and inorganic substances present in water. It is designed for a biological load of 98.500 population equivalent (PE) but current daily average is 43.300 PE. In the next period, it is planned to increase the load to 67.000 PE.

Picture 1: WWTP Karlovac (source: Vodovod i kanalizacija Ltd. Karlovac)

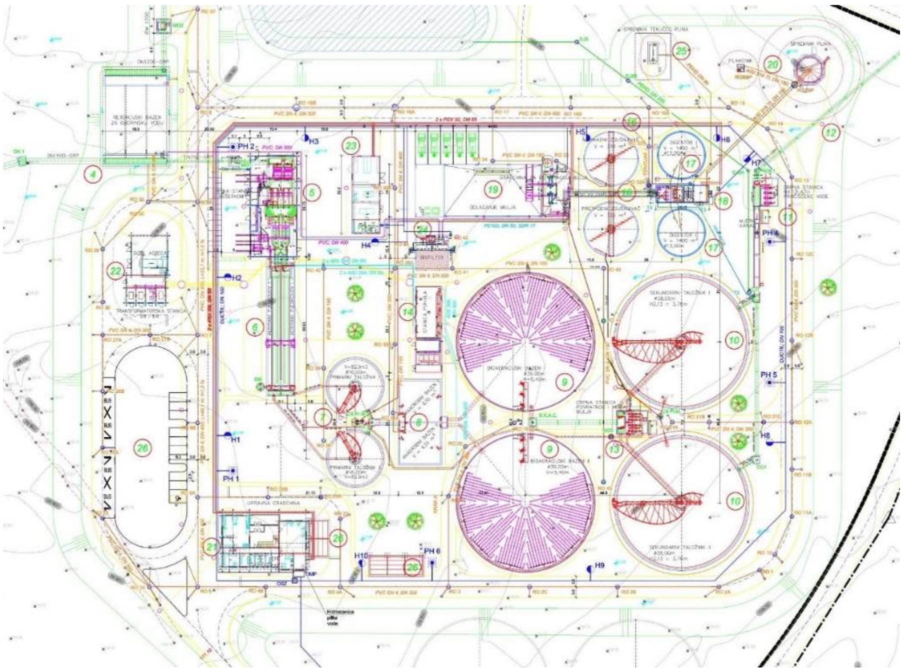

Figure 1: WWTP Karlovac (source: Vodovod i kanalizacija Ltd. Karlovac)

The process (device) consists of:

a) Preliminary (mechanical) stage of purification:
   - Removal of coarse waste
   - Removal of sand and grease
   - Primary precipitation
b) Second and third stage of purification:
   - Process with activated sludge in bioaeration pools and pools for biological removal of nitrogen and phosphorus nutrients
   - Secondary deposition
c) Sludge treatment:
   - Thickening, stabilization and anaerobic digestion
   - Mechanical dehydration
   - Disposal

WWTP is currently loaded below full capacity with the planned expansion of the connection network. As part of the project, it was planned to build a sludge drying plant that would use solar energy and additional thermal energy from the biogas plant. This would realize the degree of drying of the sludge to 90% dry matter.

2.2. Data availability and quality

For the evaluation, it is important to use high-quality and real data measured at the WWTP. In this case for purpose of this Feasibility Study information requested was provided by the WWTP operator. For this purpose, a questionnaire in form of an Excel file listing all required input data is available to the tool user, comprising:

- Plant and equipment data
- Operating data in annual average

However, detailed information on individual process steps and equipment such as pumps, motors and screens were not provided by the operator of the WWTP Karlovac. For a plant operator, this data is often difficult to collect.

Table 2: WWTP Karlovac Data

Treatment capacity (total)	98.500	PE
Average capacity daily PE for 2019.	43.300	PE
Wastewater flow	17.988	m^3/d
COD inflow concentration	289,06	mg/l
TN in influent	5,08	kgTN/ m^3
Daily electricity consumption (2019.)	4.802	kWh
Daily biomethane production (2019.)	501,1	m^3/d
Daily primary sludge	1.733,2	kg/d

2.3. Evaluation of energy efficiency

WWTP consumes between 20 and 50 kWh of electrical energy per year and per PE120. PE120 is equivalent to the population, assuming 120 g chemical oxygen demand per PE per day.

The energy consumption is about 1.75 GWh of electricity per year.

After entering the data in the tool, the average electricity demand of the WWTP Karlovac is 40 kWh/PE/a, which is within the standard range of energy efficiency.

Considering the EE results, WWTP Karlovac is energetically a well-performing WWTP. However, the energy costs of this plant can still be reduced by improving the energy efficiency of wastewater facilities' equipment and operations and by capturing more of the energy in wastewater to generate electricity and heat.

2.4. Analysis of the WWTP spatial context

WWTP Karlovac don't have much surplus heating energy and is located far from the city centralized heating system so it's rightfully concluded that there is no potential to feed thermal energy to the existing grid.

2.5. Technology upgrade of the pilot

Since the existing wastewater treatment plant has anaerobic digestion and produces biogas, which is currently not fully consumed in the plant, further investigation of possibility to install cogeneration plant on biogas is an option. After checking available surfaces on location- potential of installing a PV plant is clear. With these two in mind- there is a clear potential for reducing the plant operating cost, specifically the cost for electrical energy.

3. Application of renewable energies and associated energy output improvements

Following technologies are evaluated within this Feasibility Study for implementation on the WWTP Karlovac:

- Cogeneration power plant
- Photovoltaic (PV) power plant

The use of these technologies enables WWTPs to generate substantial amounts of energy they can use on site, so that they can become more self-sufficient regarding energy needs. Anaerobic digestion is already implemented in the WWTP Karlovac. From a technical point of view, it is possible to integrate all considered renewable energies in the WWTP Karlovac. However, the plant operator is highly interested in two of these options: cogeneration and PV plant. Therefore, these two technologies were evaluated in this feasibility study. In the following, the selected technologies are briefly described.

3.1. Cogenaration power plant (Scenario #1)

Given that the existing WWTP has anaerobic digestion and produces biogas, which is currently not fully consumed in the plant, it is proposed to install a cogeneration plant on biogas. According to the available amount of gas, since one part of produced gas is used for heating the digester, it is proposed to install a container cogeneration plant with a capacity of 64 kW electrically / 85 kW thermally. The proposed system comes complete with biogas pre-treatment equipment (inlet gas cooling / heating, activated carbon filter to remove H2S), heat exchangers, and all control and monitoring devices and drive software. The produced electricity would be used on site to meet the needs of the process itself, with the possible possibility of selling surpluses to the grid. The purchase price to the grid is significantly lower that the price of electricity consumed from the grid, so it is essential to consume all the electricity on site. Given that this way covers about 20% of the electricity needs of the entire WWTP, we should not have a problem with that.

Since the power of cogeneration is limited by the amount of fuel, it is proposed to install a photovoltaic (PV) power plant along with the cogeneration, which could cover another part of the need for electricity. In this case, it is important to properly dimension the entire system to avoid unnecessary transmission of electricity to the grid.

The heat produced from the cogeneration plant would be used to heat the digester. The actual required thermal energy is, on annual level, higher than the thermal power of the cogeneration plant, and the difference would be obtained from the existing boiler room as before.

From financial point of view, estimated investment in cogeneration plant is 200.000 EUR (VAT excluded) for the plant itself. This is the amount that excludes preparatory construction, mechanical and electrical work. Assuming that mentioned work will amount about 20% of the plant price, the total estimate is 240.000 EUR or total of 300.000 EUR (VAT included). The cogeneration plant with a conservative estimate of 5.500 operating hours per year, produces 207.732 kWh of electricity in the higher tariff and 144.252 kWh of electricity in the lower tariff. This amount of energy at current prices at which the plant buys electricity brings savings of 38.044,32 EUR per year (VAT included). Over a period of 60.000 operating hours, the estimated maintenance cost is 3,81 EUR per operating hour (VAT included). With an annual number of working hours of 5.500, the total annual maintenance cost is 20.968,75 EUR (VAT included). The actual savings are thus estimated at 17.075,57 EUR (VAT included) per year. In this way, we come to a simple payback period od 17,6 years. Considering that 5.500 working hours per year provides a period of usage of 11 years before overhaul of the plant is needed we can come to conclusion that the payback period is longer than the service life of plant. Therefore the installation of a cogeneration plant of this power, without a preferential purchase price for electricity is not profitable. To reach a payback period of 7 years or less, that could be considered as profitable, according to previously defined technical conditions, the purchase price of electricity should be higher than 0,18 EUR/kWh.

3.2. Photovoltaic (PV) power plant (Scenario #2)

WWTP Karlovac has one on-site electricity collection point. Leased connection power is 400 kW. The consumption profile for last year is as follows: 1.038.696 kWh of electricity in high tariff and 718.915 kWh in low tariff were consumed. Preliminary analysis determined the area of flat roofs of buildings on the site, a total of 1.486 m^2. An analysis of the possibility of installing a solar power plant was performed.

Structural construction for PV modules at an angle of about 30, facing south, would be placed on flat roofs. 794 PV modules, each with power of 315 W, would be installed on roof surface area of 1.300 m2, that gives total power output of 250 kW. A solar power plant through photovoltaic modules produce direct current (DC) which, in order to be used, must be converted into alternating current (AC). This is done by exchangers so called inverters, for this configuration 11 of them are needed.

According to the location, the annual electricity output of the specified configuration would be 290.420 kWh which would be fully used at the specified location and thus would reduce the cost of electricity taken from the grid.

From the financial point of view, estimated investment is 316.667 EUR (VAT included). Total potential of annual cost savings is 39.666,67 EUR (VAT included) annually, which gives us a simple payback period of 7,98 years. The calculation was made on the basis of unit electricity prices (VAT excluded) of 0,096 EUR/kWh for high tariff and 0,051 EUR/kWh for low tariff. In addition to the above, the calculation of the total price of electricity also takes into account the fee for renewable energy sources of 0,014 EUR/kWh. When calculating the value of investment, a unit price of 1.000 EUR per kW of installed power was taken into account. The cost of connection is not taken into account in the investment price, since the approach is individual and differs from project to project. Upon receipt of the connection request, Operator of Distribution System on site records condition and substation and based on the prepared calculations, sends the user an offer for connection where the cost of the same is visible. According to previous experience, we can estimate the amount of connection up to 13.333,33 EUR.

3.3. Combined Cogeneration power plant and Photovoltaic (PV) power plant (Scenario #3)

This scenario involves the installation of a solar power plant with a combination of a 64 kW cogeneration plant that is planned to be constructed so that the power of the solar power plant is calculated accordingly.

For this scenario, consumption profile for last year is as follows: 830.964 kWh of electricity in high tariff and 574.663 kWh in low tariff were consumed.

Structural construction fot PV modules at an angle of about 30, facing south, would be placed on flat roofs. 635 PV modules, each with power of 315 W, would be installed on roof surface area of 1.050 m2, that gives total power output of 200 kW. A solar power plant through photovoltaic modules produce direct current (DC) which, in order to be used, must be converted into alternating current (AC). This is done by exchangers so called inverters, for this configuration 7 of them are needed.

According to the location, the annual electricity output of the specified configuration would be 231.947 kWh which would be fully used at the specified location and thus would reduce the cost of electricity taken from the grid.

From the financial point of view, estimated investment is 253.333,33 EUR (VAT included). Total potential of annual cost savings is 31.666,67 EUR (VAT included) annualy, which gives us a simple payback period of 8,0 years. The calculation was made on the basis of unit electricity prices (VAT excluded) of 0,096 EUR/kWh for high tariff and 0,051 EUR/kWh for low tariff. In addition to the above, the calculation of the total price of electricity also takes into account the fee for renewable energy sources of 0,014 EUR/kWh. When calculating the value of investment, a unit price of 1.000 EUR per kW of installed power was taken into account. The cost of connection is not taken into account in the investment price, since the approach is individual and differs from project to project. Upon receipt of the connection request, Operator of Distribution System on site records condition and substation and based on the prepared calculations, sends the user an offer for connection where the cost of the same is visible. According to previous experience, we can estimate the amount of connection up to 13.333,33 EUR.

3.4. Discussion and Conclusion

Three scenarios for implementing renewable energy sources at WWTP Karlovac were considered: installing cogeneration power plant (Scenario #1), installing photovoltaic power plant (Scenario #2) and installing both cogeneration and power plant (Scenario #3). All scenario showed potential for reducing electricity energy needs of WWTP by approximately 20-40% but as shown in analyse Scenario #1 & #3 are not financially feasible because of long payback period. Scenario #2 has a payback period of 7,98 years which is considered acceptable.

4. ISA of pilot WWTP Karlovac

4.1. Introduction

The main aim of this deliverable is to apply ISA procedure described in D.T3.1.1 to evaluation of WWTPs chosen for feasibility studies, tailoring the framework conditions to specific case of each of them.

ISA should compare two scenarios:

a) Status quo in evaluated WWTP

b) Situation after REEF 2W technology application, using data of pilots

In the general framework of ISA there was recommended to divide evaluation into the two sections:

The first section contains relevant indicators for the pre-assessment of sustainable REEF 2W solutions, whereas the second section provides a list of specific indicators that can be used for the MCDA. With the final list of indicators, a MCDA can be carried out in order to determine the most sustainable option.

Finally Multi-criteria decision analysis (MCDA) is performed according to general procedure defined in D.T3.1.1.

4.2. The Integrated Sustainability Assessment

The Integrated Sustainability Assessment (ISA) tool is used to systematically assess technical innovations for energy optimisation of wastewater treatment plants (WWTPs) on different sustainability criteria. The instrument allows for making predictions about potentials to improve energy performance, the technical feasibility or the environmental sustainability of the REEF 2W solutions. For more detailed information, please check DT.1.4.1-3.

The ISA instrument, which was developed as an Excel spreadsheet and online tool, comprises five core steps:

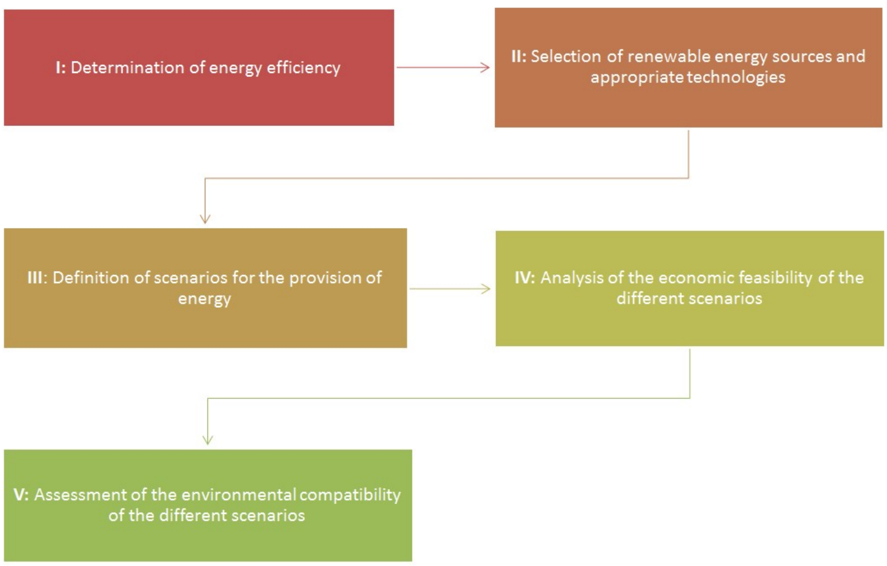

Figure 2: The five steps of the ISA method

I: Energy efficiency is determined through a comparative analysis that measures current energy consumption against recognized efficiency standards. This benchmarking shows the optimization potential for heat and electricity savings.

II: Suitable technologies are selected through a potential analysis that compares different renewable energy sources.

III: Different scenarios demonstrate how excess energy can be used for self-supply of the WWTP and feed-in into the gas, electricity and heat grid. These consider the amount of available surplus energy, energy consumption and energy demand of neighbouring settlements as well as existing grid infrastructures.

IV: The economic feasibility assessment of planned measures will be carried out through a life-cycle cost analysis incorporating generated revenues from energy savings and sales, and investment and maintenance costs.

V: To assess the environmental impacts, a Life Cycle Assessment (LCA) focusing on CO_2-reduction potentials is carried out for each scenario.

4.3. General indicator evaluation

In this chapter, the status quo of selected WWTP in Karlovac was compared with the implemented REEF 2W technologies. For this pre-assessment, the following cases were selected:

- Status quo of WWTP as described in the previous section
- Scenario I: integration of cogeneration power plant
- Scenario II: integration of photovoltaic power plant
- Scenario III: combined integration of cogeneration power plant and photovoltaic power plant

The pre-assessment was done by software tool N1 and N2 and the result are shown in table 3-1.

Table 3: General indicators used for the pre-assessment

Sustainability criteria	General indicator	Measurement	Categories	Graduation	Status Quo	REEF 2W S I	REEF 2W S II	REEF 2W S III
Availability of excess energy (Software tool N.1)	Electric excess energy provision	Difference between electric energy production and consumption in kWh	> 0 ≤ 0	A B	B	B	B	B
	Thermal excess energy provision	Difference between thermal energy production and consumption in kWh	> 0 ≤ 0	A B	B	B	B	B
	Excess digester gas provision	Difference between digester gas production and consumption in m^3	> 0 ≤ 0	A B	B	B	B	B
Availability of energy consumers	Excess electricity demand	Electricity demand in the vicinity of the WWTP and in kWh	> 0 = 0	A B	B	B	B	B

	Excess heat demand	Heat demand in the vicinity of the WWTP and in kWh	> 0 = 0	A B	B	B	B	B
	Excess digester gas demand	Digester gas demand in the vicinity of the WWTP and in kWh	> 0 = 0	A B	B	B	B	B

4.4. Specific indicator evaluation

As explained before, the implementing the REEF 2W technologies changes the energy flows (electric and thermal energy demand and /or production). In the table below (table 3-2), the status quo of the selected WWTP was compared with the selected REEF2W scenarios. The comparison includes a set of indicators, which are split into four types: environmental, social, economic and technical.

Table 4: The comparison of sustainability criteria

Sustainability criteria	Indicator	Measurement	Categories	Graduation	Status Quo	SI	SII	SIII	Weight
Environmental context	CO_2 emissions reduction for consumed electric energy (internal and external)	%	> 0 = 0	A C	C	A	A	A	0,3
	CO_2 emissions reduction for consumed thermal energy (internal and external)	%	> 0 = 0	A C	C	A	C	C	0,1
	Share of renewable electricity (internal and external)	%	> 100 100-0 0	A B C	C	B	B	B	0,2
	Share of renewable thermal energy (internal and external)	%	> 100 100-0 0	A B C	B	B	B	B	0,1
	Share of renewable gas (external)	%	> 100 100-0 0	A B C	C	C	C	C	0,2
	Sludge production change	Delta t DM / year	<0 0 >0	A B C	B	B	B	B	0,1
Social context	Number of applied technologies for electric energy provision (*Resilience*)	Quantity	3 1-2 0	A B C	C	B	B	B	0,3

Sustainability criteria	Indicator	Measurement	Categories	Graduation	Status Quo	SI	SII	SIII	Weight
	Number of applied technologies for thermal energy provision (*Resilience*)	Quantity	3 1-2 0	A B C	C	B	C	B	0,3
	Additional employment	Change of employment, job creation or loss	>0 0 <0	A B C	B	A	A	A	0,3
	Local environmental welfare	Indication of local welfare change	Positive Neutral Negative	A B C	B	B	B	B	0,1
Economic context	Return of Investment (ROI)	Years	<3 3-10 >10	A B C	C	C	B	C	0,4
	Additional income	€	>0 0 <0	A B C	B	B	B	B	0,3
	Energy costs saving	€	>0 0 <0	A B C	B	A	A	A	0,3
Technical context (energetic & spatial)	Degree of electric self-sufficiency	Ratio between electric energy production and consumption in %	>75 25-75 <25	A B C	C	C	C	B	0,2
	Degree of thermal self-sufficiency	Ratio between thermal energy production and consumption in %	>100 20-100 <20	A B C	C	C	C	C	0,2
	Degree of externally usable excess heat	Ratio between	> 0 0	A C	C	C	C	C	0,1

Sustainability criteria	Indicator	Measurement	Categories	Graduation	Status Quo	SI	SII	SIII	Weight
		heat production and consumption in %							
	Degree of usable excess gas	Ratio between gas production and consumption in %	> 0 0	A C	C	C	C	C	0,1
	Electric energy consumption at WWTP	$kWh/PE_{120}.a$	< 20 20 - 50 > 50	A B C	B	B	B	B	0,2
	Thermal energy consumption at WWTP	$kWh/PE_{120}.a$	<30 > 30	A C	A	A	A	A	0,2

The change in energy flow plays an important role for multi-criteria decision analysis (see next chapter). The increase / decrease in energy consumption and production affect directly the economic, ecological and technical criteria.

4.5. Multi-criteria decision analysis (MCDA)

To have detailed information about specific parts of ISA (social, environmental, economic and technical) will be calculated separately and decision maker can use it for own analysis and decision (see chapter 8). The following formula was used for the evaluation of each criterion.

$$CI_{s,en,ec,tech} = \sum_{i=1}^{n} w_i \, u_i$$

where CI is the composite index of the ISA for social, environmental, economic and technical segment, w is value of indicator and u is weight of indicator.

The result of each ISA criterion is shown in the following table (table 5).

Table 5: The result of multi-criteria decision analysis

Criterion	Composite Index (Status Quo)	Composite Index SI	Composite Index SII	Composite Index SIII
Environmental	5.8	3.6	4.0	4.0
Social	4.2	2.4	3.0	2.4
Economic	3.8	3.2	2.4	3.2
Technical	3.8	3.8	3.8	3.4

Considering the comprehensive environmental, social, economic and technical analysis, the REEF 2W technology is beneficial for the selected WWTP. As shown in the table 5, REEF 2W scenarios have better composite index in environmental, social and economic categories, and are at least equal or better with Status Quo index in technical category, which means, that implementation of proposed REEF 2W solution could bring additional benefits in these fields.

Sažetak studije izvodljivosti primjene obnovljivih izvora energije izrađene za uređaj za pročišćavanje otpadnih voda u Karlovcu u sklopu Interreg Central Europe REEF 2W transnacionalnog projekta

Na slici Uređaj za pročišćavanje otpadnih voda u Karlovcu (Izvor: Vodovod i kanalizacija d.o.o. Karlovac)

1. KOGENERACIJSKO POSTROJENJE (Scenarij 1)

1.1. Opis postojećeg stanja

UPOV Karlovac je sufinanciran sredstvima pretpristupnog fonda ISPA i počeo je s radom 30. svibnja 2011. godine. Uređaj ima tri stupnja pročišćavanja. Mehanički i biološki stupanj pročišćavanja sastoji se od niza bioloških, kemijskih i fizikalnih procesa koji imaju funkciju uklanjanja većine organskih i anorganskih tvari prisutnih u vodi. Projektiran je za biološko opterećenje 98.500 ekvivalentnih stanovnika (ES). Trenutno uređaj radi sa kapacitetom od 43.300 ES.

Proces (uređaj) se sastoji od:

a) Prethodni (mehanički) stupanj pročišćavanja
- uklanjanje grubog otpada (rešetke i sita)
- uklanjanje pijeska i masnoća (pjeskolov-mastolov)
- primarno taloženje

b) Drugi i treći stupanj pročišćavanja:
- postupak s aktivnim muljem u bioaeracijskim bazenima i bazenima za biološko uklanjanje nutrijenata dušika i fosfora
- sekundarno taloženje

c) Tretman mulja:
- zgušnjavanje, stabilizacija i anaerobna digestija
- strojna dehidracija
- odlaganje

Trenutno je opterećene ispod punog kapaciteta uz planirano proširenje priključne mreže.

U sklopu projekta planirala se izgradnja postrojenja za sušenje mulja koje bi koristilo Sunčevu energiju i dopunsku toplinsku energiju iz bioplinskog postrojenja. Time bi se realizirao stupanj sušenje mulja na 90% suhe tvari.

1.2. Tehnički opis predloženog kogeneracijskog postrojenja

Obzirom da postojeći pročistač otpadnih voda ima anaerobnu digestiju te proizvodi bioplin, koji se u ovom trenutku ne potroši u potpunosti u postrojenju, predlaže se ugradnja kogeneracijskog postrojenja na bioplin. Prema dostupnoj količini plina, obzirom da se jedan dio proizvedenog plina koristi za grijanje digestora, predlaže se ugradnja kontejnerskog kogeneracijskog postrojenja snage 64 kW električno/85 kW toplinsko. Predloženi sustav dolazi u kompletu sa opremom za predobradu bioplina (hlađenje/grijanje ulaznog plina, filter s aktivnim ugljenom za uklanjanje H_2S), izmjenjivačima topline, te svim regulacijskim i kontrolnim uređajima te pogonskim softwareom.

Proizvedena električna energija koristila bi se na lokaciji za zadovoljavanje potreba samog procesa, uz eventualnu mogućnost prodaje viškova u mrežu. Otkupna cijena u mrežu je značajno niža od cijene električne energije koja se troši iz mreže, tako da je bitno potrošiti svu električnu energiju na lokaciji. Obzirom da se ovim putem pokriva oko 20% potreba za električnom energijom cjelokupnog UPOV-a ne bismo trebali imati s time problema.

Obzirom da je snaga kogeneracije ograničena količinom goriva, predlaže se uz kogeneraciju ugradnja fotonaponske elektrane kojom bi se još jedan dio potrebe za električnom energijom mogao pokriti. U tom slučaju je bitno pravilno dimenzionirati cjelokupni sustav da se izbjegne nepotrebno predavanje električne energije u mrežu.

Proizvedena toplinska energija iz kogeneracijskog postrojenja koristila bi se za grijanje digestora. Stvarna potrebna toplinska energija je, na godišnjem nivou, viša od toplinske snage kogeneracijskog postrojenja te bi se razlika kao i do sada dobivala iz postojeće kotlovnice.

1.3. Financijska analiza predloženog rješenja

Procijenjena investicija u kogeneracijsko postrojenje iznosi 1.508.060,40 kn bez PDV-a za samo postrojenje. To je iznos bez pripremnih građevinskih, strojarskih i elektro radova. Uz pretpostavku da će ostali radovi iznositi oko 20% cijene postrojenja, ukupna procjena je 1.800.000,00 kn + PDV ili 2.250.000,00 kn sa PDV-om.

Kogeneracijsko postrojenje, uz konzervativnu procjenu od 5.500 radih sati godišnje proizvodi 207.732 kWh električne energije u višoj tarifi i 144.252 kWh električne energije u nižoj tarifi.

Ta količina energije po sadašnjim cijenama po kojima postrojenje kupuje električnu energiju donosi uštedu od 285.332,41 kn godišnje sa PDV-om.

Kroz period od 60.000 radnih sati procijenjeni trošak održavanja iznosi 3,05 € po radnom satu, bez PDV-a. Uz godišnji broj radnih sati od 5.500, ukupni godišnji trošak održavanja iznosi 157.265,63 kn sa PDV-om. Stvarna ušteda je na taj način procijenjena na 128.066,78 kn sa PDV-om godišnje.

Na taj način dolazimo do jednostavnog perioda povrata investicije od 17,56 godina. Obzirom da 5.500 radnih godišnje daje period od 11 godina do generalnog remonta postrojenja, vidimo da je period povrata dulji nego radni vijek postrojenja, te sama ugradnja kogeneracijskog postrojenja ove snage, bez povlaštene otkupne cijene za električnu energiju nije isplativa.

Za dostići period povrata investicije od 7 godina, po prije definiranim tehničkim uvjetima, otkupna cijena električne energije bi trebala biti veća od 1,36 kn/kWh.

2. SUNČANA ELEKTRANA (Scenarij 2)

2.1. Opis postojećeg stanja

UPOV Karlovac ima jedno mjesto za preuzimanje električne energije na lokaciji (OMM). Zakupljena priključna snaga je 400 kW. Profil potrošnje za prošlu godinu je sljedeći: potrošeno je 1.038.696 kWh električne energije u visokoj tarifi te 718.915 kWh električne energije u niskoj tarifi.

Preliminarnom analizom utvrđeno je površina ravnih krovova zgrada na lokaciji, ukupno 1.486 m2. Izvršena je analiza mogućnosti ugradnje sunčane elektrane.

2.2. Tehnički opis predložene sunčane elektrane

Na ravne krovove postavile bi se konstrukcije za prihvat fotonaponskih modula pod kutom od oko 30^0, orijentacije prema jugu. Na površinu do 1 300 m^2 postavlja se 794 modula snage 315 W što daje ukupnu izlaznu snagu elektrane od **250 kW**. Sunčana elektrana, odnosno fotonaponski moduli proizvode istosmjernu struju (DC) koja, da bi se koristila, mora biti pretvorena u izmjeničnu (AC) struju. To se radi izmjenjivačima, tzv. inverterima, kojih je u ovoj konfiguraciji prema broju fotonaponskih modula- predviđeno 11 komada.

Prema lokaciji, godišnja proizvodnost električne energije navedenom konfiguracijom bila bi **290.420 kWh** koji bi se u cijelosti koristili na navedenoj lokaciji i na taj način bi se smanjio trošak električne energije preuzete iz mreže.

2.3. Financijska analiza predloženog rješenja

Procjena investicije, prema modelu „ključ u ruke“ je 1.900.000,00 HRK + PDV. Ukupni potencijal godišnjih troškovnih ušteda je 238.000,00 HRK + PDV što nam daje jednostavni period povrata investicije od 7,9 godina.

Napomena: Proračun je napravljen na temelju jediničnih cijena električne energije (bez PDV-a) od 0,7237 kn/kWh u vrijeme visoke tarife i 0,3851 kn/kWh u vrijeme niske tarife. Osim navedenog, u kalkulaciju ukupne cijene električne energije uzeta je u obzir i naknada za obnovljive izvore energije od 0,1050 kn/kWh. Prilikom izračuna vrijednosti ulaganja po modelu ključ u ruke uzeta je jedinična cijena od 1.000,00 Euro po kilovatu (kW) instalirane snage, što je preračunato u kune po tečaju na dan 15.04.2020. U cijenu ulaganja nije uzet u obzir trošak priključenja budući da je sam pristup tome individualan i razlikuje se od projekta do projekta. HEP ODS po primitku zahtjeva za priključenjem izlazi na teren i snima stanje trafostanice te na temelju izrađenih proračuna šalje korisniku ponudu za priključenje gdje je vidljiv trošak istoga. Prema dosadašnjim iskustvima možemo procijeniti iznos priključenja do 100.000,00 kuna.

2.4. Aktivnosti potrebne za provedbu projekta

Procedura za provedbu projekta (prema modelu vlastitog ulaganja):

1. Idejni projekt sunčane elektrane/tehnički opis
2. Slanje dokumenata iz točke 1 kao prilog zahtjevu za ishođenjem elektroenergetske suglasnosti i ponude za priključenje prema HEP ODS-u
3. Procjena složenosti projekta od strane HEP ODS-a (moguća potreba za izradom *Elaborata optimalnog tehničkog rješenja priključenja*)
4. Po dobivanju elektroenergetske suglasnosti- slijedi izrada Glavnog projekta sunčane elektrane i troškovnika
5. Potvrda Glavnog projekta
6. Odabir izvođača radova i izvođenje
7. Puštanje u probni pogon
8. Dozvola za trajni pogon i konačno puštanje u trajni pogon

3. SUNČANA ELEKTRANA NAKON UGRADNJE KOGENERACIJSKOG POSTROJENJA SNAGE 64 kW (Scenarij 3)

3.1. Opis postojećeg stanja

UPOV Karlovac ima jedno mjesto za preuzimanje električne energije na lokaciji (OMM). Zakupljena priključna snaga je 400 kW. Profil potrošnje za prošlu godinu je sljedeći: potrošeno je 830.964 kWh električne energije u visokoj tarifi te 574.663 kWh električne energije u niskoj tarifi.

Preliminarnom analizom utvrđeno je površina ravnih krovova zgrada na lokaciji, ukupno 1.486 m2. Izvršena je analiza mogućnosti ugradnje sunčane elektrane.

3.2. Tehnički opis predložene sunčane elektrane

Ovaj scenarij podrazumijeva ugradnju sunčane elektrane sa kombinacijom kogeneracijskog postrojenja snage 64 kW koje je već izvedeno ili se planira izvesti tako da je snaga sunčane elektrane računata u skladu sa tim.

Na ravne krovove postavile bi se konstrukcije za prihvat fotonaponskih modula pod kutom od oko 30^0, orijentacije prema jugu. Na površinu do 1 050 m^2 postavlja se 635 modula snage 315 W što daje ukupnu izlaznu snagu elektrane od **200 kW**. Sunčana elektrana, odnosno fotonaponski moduli proizvode istosmjernu struju (DC) koja, da bi se koristila, mora biti pretvorena u izmjeničnu (AC) struju. To se radi izmjenjivačima, tzv. inverterima, kojih je u ovoj konfiguraciji prema broju fotonaponskih modula-predviđeno 7 komada.

Prema lokaciji, godišnja proizvodnost električne energije navedenom konfiguracijom bila bi **231 947 kWh** koji bi se u cijelosti koristili na navedenoj lokaciji i na taj način bi se smanjio trošak električne energije preuzete iz mreže.

3.3. Financijska analiza predloženog rješenja

Procjena investicije, prema modelu „ključ u ruke" je 1.520.000,00 HRK + PDV. Ukupni potencijal godišnjih troškovnih ušteda je 190.000,00 HRK + PDV što nam daje jednostavni period povrata investicije od 8,0 godina.

Napomena: Proračun je napravljen na temelju jediničnih cijena električne energije (bez PDV-a) od 0,7237 kn/kWh u vrijeme visoke tarife i 0,3851 kn/kWh u vrijeme niske tarife. Osim navedenog, u kalkulaciju ukupne cijene električne energije uzeta je u obzir i naknada za obnovljive izvore energije od 0,1050 kn/kWh. Prilikom izračuna vrijednosti ulaganja po modelu ključ u ruke uzeta je jedinična cijena od 1.000,00 Euro po kilovatu (kW) instalirane snage, što je preračunato u kune po tečaju na dan 15.04.2020. U cijenu ulaganja nije uzet u obzir trošak priključenja budući da je sam pristup tome individualan i razlikuje se od projekta do projekta. HEP ODS po primitku zahtjeva za priključenjem izlazi na teren i snima stanje trafostanice te na temelju izrađenih proračuna šalje korisniku ponudu za priključenje gdje je vidljiv trošak istoga. Prema dosadašnjim iskustvima možemo procijeniti iznos priključenja do 100.000,00 kuna.

3.4. Aktivnosti potrebne za provedbu projekta

Procedura za provedbu projekta (prema modelu vlastitog ulaganja):

1. Idejni projekt sunčane elektrane/tehnički opis
2. Slanje dokumenata iz točke 1 kao prilog zahtjevu za ishođenjem elektroenergetske suglasnosti i ponude za priključenje prema HEP ODS-u
3. Procjena složenosti projekta od strane HEP ODS-a (moguća potreba za izradom *Elaborata optimalnog tehničkog rješenja priključenja*)
4. Po dobivanju elektroenergetske suglasnosti- slijedi izrada Glavnog projekta sunčane elektrane i troškovnika
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4. ZAKLJUČAK

Nastavno na analizirane scenarije predlaže se izvedba sunčane elektrane u scenariju bez izvedbe kogeneracijskog postrojenja (Scenarij 2).

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