BIOMASS AND WASTE WATER AS SUSTAINABLE ENERGY SOURCES

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Abstract: *Limited non-renewable resources and growing problems related to the protection of the environment are main reasons why renewable energy sources are used more and more. This paper presents compared technical and economic analyse of two renewable energy resources, biomass and waste water, for sanitary hot water preparation (DHW). Waste water (sewage) is a source of energy which can be used for heating and cooling buildings with heat pumps. The average waste water temperature such as found in restaurants, laundries, dormitories and etc. varies in the range of 20–40 °C through the whole year. The technology is simple and proven. Biomass as a renewable source of energy has the potential to offer a cost-effective and low carbon alternative to fossil fuels. It is considered as the renewable energy source with the highest potential to contribute to the energy needs of modern society for both the industrialized and developing countries worldwide. Renewable technologies are considered as clean sources of energy and optimal use of these resources are sustainable based on current and future economic and social needs. Compared analyse of the systems is applied for public institution „Home for male children and youth with disabilities" Prijedor, Bosnia and Herzegovina. Currently, this institution use light fuel oil and elektricity for their energy needs. The aim of this paper is to provide specific information about technology, economics and potential savings.*

Keywords: WASTE WATER, BIOMASS, HEAT PUMP, CLEAN SOURCES, RENEWABLE ENERGY SOURCES, ECONOMICS, ENVIRONMENT, SUSTAINABLE DEVELOPMENT

1. Introduction

In the past two centuries, the world has undergone a drastic change due to the steeply increased contribution of fossil fuels. Global population growth, expansion of economies, and higher standards have caused an enormous increase in worldwide energy consumption, which was partly made possible by the supply of cheap fossil fuels. Currently, fossil fuels such as oil, coal and natural gas represent the prime energy sources in the world (approximately 80% of the total use of more than 400 EJ per year) [1]. According to the projections, if the adequate policy initiatives are provided in 2025, 30% of the direct fuel use and 60% of global electricity supplies would be met by renewable energy sources [2].

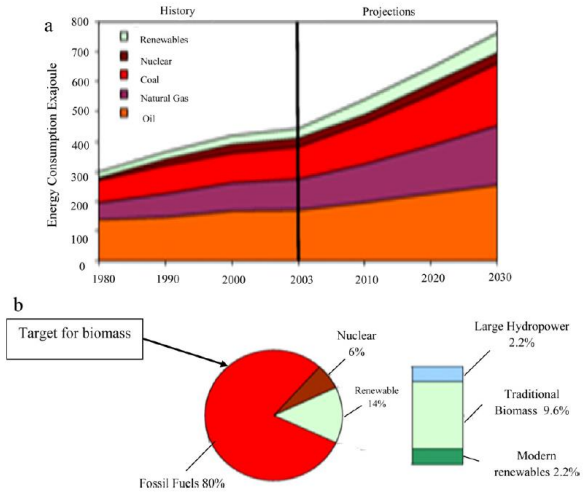

Fig.1(a) World marketed energy consumption. (b) Different fuels contribution to total world energy consumption [1]

Fossil fuel utilization puts pressure on our global ecosystem by contributing to global warming and harmful emissions. Moreover, the reserves of fossil fuels are finite. There are three ways to deal with this global challenge, and they all require drastic innovation development in the respective technologies:

• The energy efficiency of conversion systems should be drastically improved, going hand in hand with reduced use (savings);

• Renewable energy sources should be used in order to supply nonfossil-based energy.

Clean use of fossil fuels also will be needed for several decades to come, including carbon capture and storage (CCS).

The principle of these three energy utilization strategies is also called the "Trias Energetica," as illustrated by Figure 2.

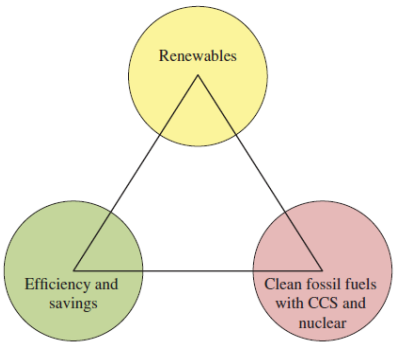

Fig 2. Concept of the "Trias Energetica," [3]

Continuous increase of energy prices from one side and need to ensure energy supply and comfort of the buildings from the other, gives complicates assignments to the engineers who are in position to combine different kinds of measures and approaches in order to get optimal solutions for certain type of the building. Basic principles of the sustainable energy supply systems are based on combination of the energy efficiency measures with renewable energy sources on a way which leads to the cost reduction as well as reduction of the harmful impacts on the environment. The aim of this paper was to determine the possibility of using waste water and biomass as a renewable energy sources for DHW preparation and its environmental impact, as well.

2. Waste water and biomass as renewable energy sources

Ever since the dawn of mankind, people have been using wood and other biogenic sources for heating, cooking, and lighting. Biomass consists of material that has an organic origin. That is plant and animal materials such as wood from forests, crops, seaweed, animal waste, material left over from agricultural and forestry processes. In the broader sense, all conversion products such as paper or cellulose, organic residuals from the food industry, and organic waste from households, trade, and industry. The sun's energy when intercepted by plants and converted by the process of

photosynthesis into chemical energy, is 'fixed' or stored in the form of terrestrial and aquatic vegetation. After coal and oil, biomass stands as the third-largest energy resource in the world [4]. Positive aspect of biomass as renewable energy source are:

- Biomass is abundantly available stored solar energy, which is thus indirectly used.
- Biomass is the only renewable energy source that can be coprocessed with fossil fuels in existing energy conversion systems (such as oil refineries or coal gasification plants) so as to ensure a gradual energy transition to a renewable energy source.
- As biomass is formed (indirectly) on a relatively short time scale via photosynthesis from CO2 and water, which are released again in energy conversion systems, in theory, one can speak of a "carbon-neutral" fuel.
- Biomass is already grown for food, animal feed, and natural fiber applications as well as in forestry with its derived products; it is comparatively easily accessible,and man has experience in dealing with this source.
- Biomass growing, harvesting, storage and transportation, trading, and processing to end use for energy conversion purposes can enhance rural economic development via the creation of additional jobs. This leads to extra income for rural regions of both developed and developing countries and eventually offers a way to counteract the constant depopulation of such areas.

Critical issues associated with use of biomass are:

- Conversion of solar energy into biomass is generally low (of the order of 1%, depending on the species); this means that relatively large surfaces are needed to harvest sufficient material for application in energy conversion.
- Biomass is characterized by a low energy density compared to fossil fuels. This low density often make biomass material difficult to store, transport, and utilize.
- Issues with deforestation, associated with serious loss of biodiversity and carbon stock
- There is concern with respect to biomass usage for energy supply as it may compete with food production depending on the types of biomass and technologies used
- Widely different disciplines are involved in the successful implementation of the whole integrated chain from seeding to final conversion and use, ranging from policy development and logistics to chemical, process technology, and agricultural sciences; in this light, implementation of effective policies is complex as bioenergy policies might conflict with other existing environmental or economic policies. For other energy sources, often, the only key is the energy conversion technology, whereas for biomass the whole system is crucial
- Although biomass itself is renewable, during the whole life cycle, fossil fuels are commonly used to produce fertilizers and pesticides, grow and collect the plants, transport the harvested material, and, finally, upgrade it to an actual fuel. Therefore, biofuels still have a fossil carbon footprint to some extent.

Driven by rising demand the global production capacity for wood pellets has more than doubled over the past 10 years. Global production of pellets estimated at 6-7 million tons in 2006 rose to more than 14.3 million tons by 2010 [5].

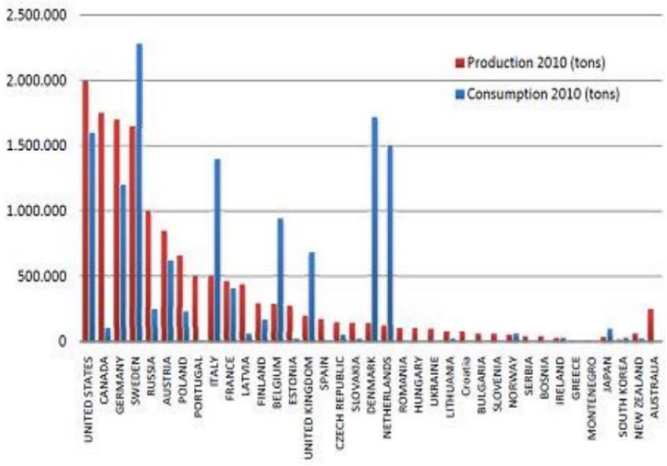

Fig.3 Wood pellet production and consumption by country in 2010 [6]

A "development which meets the needs of the present without compromising the ability for future generations to meet their own needs" has been a globally referred definition of sustainability. It was first characterized as such by the UN Brundtland Commission in 1987 (Brundtland, 1987). Figure 4 shows an overview of the economic, environmental, and social aspects that play a role in the sustainability of biomass supply systems.

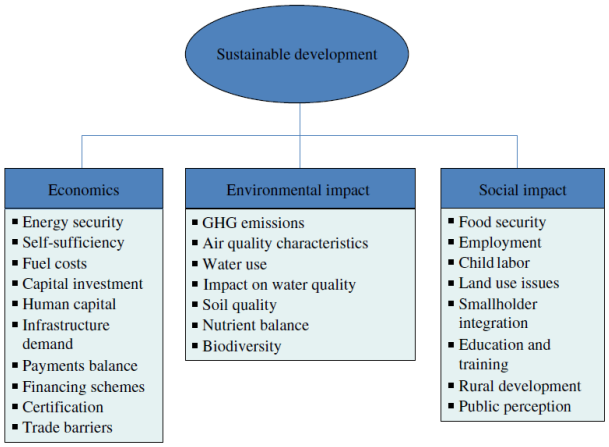

Fig 4. Aspects of sustainable development related to the implementation of biomass supply in society. [3]

The wood pellet market in Europe is currently thriving, predominantly driven by the EU 2020 target for renewable energy. Yet the European Union currently meets only around 4% of its energy needs through biomass. EU member states agreed to a binding 20% target for renewable energy in 2007 that includes 10% from biomass by 2020 as well as a 20% reduction in greenhouse gas emissions. Wood pellets are the most available form of biomass in the EU and this is why they have a crucial role to play in achieving the 2020 target [6]. According to Eurostat, Bosnia and Hercegovina exported 67,815 tons of pellets to the EU in 2012 and 170,389 tons in 2013 making an increase of 151% [6]. Therefore, during the last year Bosnia and Herzegovina surpassed Croatia, Ukraine and Belarus and became the second largest non-EU European exporter of pellets after Russia.

One of the renewable energy sources is also water discharged into sewage systems from households (different objects). Distribution of sewage water around the world has recently caused the increasing awareness of the amount of generated sewage water due to its large mass, the impact on the environment and energy potential. Sewage water is water used in residential areas and industries that have changed the physical, chemical and biological characteristics so can't be used in agriculture or other purposes. In calculating the amount of sewage from households, from 100% of

water from faucet, 70% water is discharged into the sewer and other 30% is irretrievably lost [7]. The average annual temperature of this water is 11 - 20.5 ° C which is sufficient temperature level to be used as a heat source for a heat pump [7]. Heat pump technology has been quickly developed all over the world as a clean and energy efficient heating and air conditioning mode, and it has been widely applied to apartments, houses, hospitals, office buildings etc.The main advantage of the usage of the heat pump is that design and operation conditions can be satisfied anywhere in the world. Waste water heat pump system was implemented for preparation of sanitary hot water in Student Center "Nikola Tesla" Banja Luka, Bosnia and Herzegovina. It's a first system of its kind in Bosnia and Herzegovina. As a basis for designing the system measurement of the temperature of waste water was made. Results are given at Fig 5.

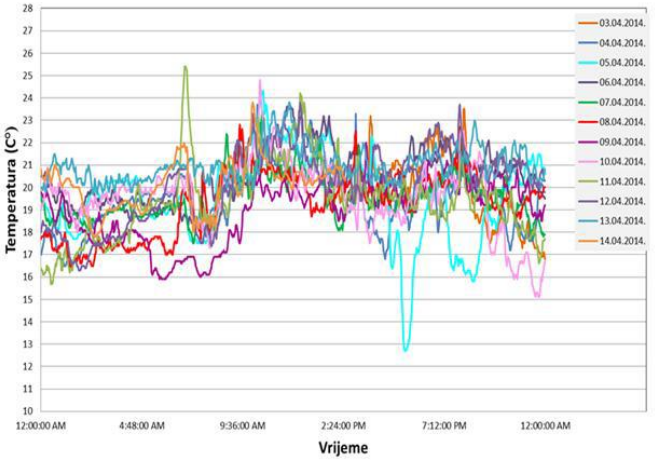

Fig 5. Waste water temperature in the period of measurement

As can be seen from the Fig.5, the temperature of the waste water fluctuates throughout the day. The highest values of temperature waste water are in period 8am-10pm and minimum are in period 11pm-5am. The highest measured temperature is 25.4 ° C and the lowest is 12.70 ° C. This measurments present basis for design of the system which is analyzed in this paper. Measurement shows that waste water has a high temeperature so it can be used as a source of energy for heat pumps. By integrating a heat pump to utilize this heat, it can be produced higher temperature supply while waste water is cooled and deprived to the sewer. This leads to the possibilitty of directly regenerating the hot water supply through wastewater heat recovery. Utilization of waste water as a source of energy for the heat pump for is analyzed by different researchers [8-13]. Similar systems are installed in other countries for example Schwitzerland and Norway [12]. In Japan and Korea, researchers did a simulation study of district cooling and heating systems using sewage water as an energy source [8]. Results show that compared with conventional air-source heat pumps, waste water heat pump could help reducing energy consumption by 34%, lowering the emission of carbon dioxide (CO2) by 68% and controlling the generation of nitrogen oxides (NOx) by 75% [8].

The most important characteristic of the heat pump is coefficient of performance (COP). The high and constant temperature of the heat source during operation is very important because it directly increases the COP and therefore operational costs of the heat pump decreases. The heat source must have a large capacity - to uniformly supply heat pump with energy. Based on the above mentioned, waste water as an energy source meets these two important conditions. Changing the flow for a period of 24 hours is determined by lifecycle of the population. Waste water is a finite source of energy. Available amount depends on the use of water in buildings. The possibilities for use that are economically interesting are concentrated at places where waste water is available both continuously and in large quantities. Those are buildings with large quantities of waste water such as hospitals, industry, student centers, restaurants, hotels, waste water treatment plants, etc. The quantity of waste water is increasing in countries with strong economic development and increasing standards of living. Energy from waste water is normally used to cover of constant loads; conventional back-up systems are used to meet peak loads. The use of waste water energy can further be subdivided into three categories depending on where the energy is extracted: a) energy recuperation in house (place where waste water is generated), b) energy recovery from sewers and c) energy recovery from cleansed wasre water at sewage treatment plant [12]. Recognition of waste water as a renewable energy leads to increasing stimulation of obtaining energy from it, create new jobs and a reduction in greenhouse gas emissions due to lower consumption of primary electricity which is basically derived from fossil fuels. Waste water as an energy source can be used as follows:

- anaerobic digestion for biogas,
- recovery of heat from waste water,
- different processes of conversion of energy from sewage water in other forms (pyrolysis, growing culture of algae, microbial fuel cells and other microbial conversion).

The economic vitality of the use of heat from sewage water depends on three crucial factors:

- the price of traditional energy sources
- the size of the system (the need for heat)
- the amount of sewage water.

Use of this renewable energy source reduces the use of primary sources (fossil fuels) which is a positive effect in protecting the environment. Since in many cases the wate water is discharged into rivers, and their average annual temperature is between 11 - 20.5 ° C, these waters contribute to the thermal pollution of the rivers. Whit increasing temperature and decrease of free oxygen in rivers, the effect of harmful substances in the water increases. For fish applies Van 't Hooff's rule that when temperature of water increase up to 10°C, chemical-physiological processes, in this case taking harmful substances, increases double or triple [14]. Discharge of cooled sewage water into rivers reduces thermal pollution and this is one more positive effect of using this energy source.

3. Compared analyze of waste water and biomass as a source of energy for DHW preparation system for public institution „Home for male children and youth with disabilities" Prijedor

The aim of this study was to determine the possibility of using waste water heat pump and biomass boiler as technical systems for DHW preparation in public institution „Home for male children and youth with disabilities" Prijedor, Bosnia and Herzegovina. Waste water heat pump system can be classified into two types:

- Using untreated waste water as heat source.This type of system is located close to the collector (sewers), but also close to the users Heat exchanger should be located between the sewer and water evaporator to avoid corrosion of evaporator. Quality of the sewage water has a significant influence on the corrosion on the supporting parts of the system (heat exchanger).

- Systems using treated waste water or neutral water as heat source. These systems have good water quality and are simple. Since sewage water treatment plant is generally at the verge of a city, it is far from heat consumers. If heat pump station is established in the sewage water treatment plant, the heating pipes would be very long and heat loss would be huge.

Waste water heat pump system which uses untreated waste water was analyzed. Accommodation capacity of the building is 200 people and it is fullfield through the whole year. Inside the building

is also a restaurant and a laundry. Demand for hot water is on daily basis and on large scale. Scheme of the system is given on Fig. 6. Waste water is collected in the collector, cooled and discharged into the sewer and temperature of water is low. Deprived heat of waste water is used in heat pump for the preparation of DHW.

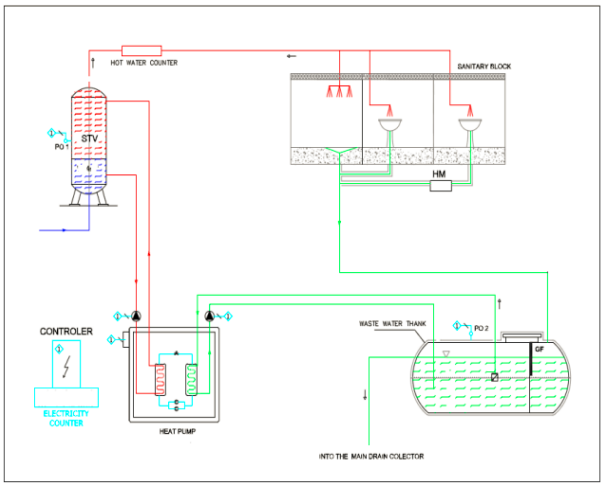

Fig. 6 Scheme of WWHP system

In order to calculate capacity of the system, temperature of waste water as a source of heat for heat pump, is very important. Waste water temperature which is used in calculations, is based on measurements for similar system where waste water was used as heat source for heat pump. As it's mentioned before in this paper, this system was implemented in Student centar "Nikola Tesla" Banja Luka. As both of buildings have same purpose, restaurant and laundry, assumption is that temperature of waste water is similar. Fig 5 shows results of measurements and average temperature for a whole period is 19.73 ºC. Required amount of a hot water for public institution „Home for male children and youth with disabilities" Prijedor is a base for the DHW system design. According to the literature [7], recommendation for the amount of hot water per capita is 60 l/day. Inside of this object is also a restaurant. Restaurant use approx. 300 l/day of hot water. The system is defined with the heat pump to the 23 kW heating capacity (water inlet temperature 12°C, heated water outlet temperature 50º C, freon R407 C). Calculating COP for this system is 3.12. Currently electric boilers are used for DHW so monthly bills are very high. The cost of annual energy consumption for the DHW is currently approx. 7300€. Compared to the WWHP system, system with woods biomass boiler is also analyzed. Wood pellets production is currently considered one of the most attractive investment opportunities in Bosnia and Herzegovina. Huge market demand in the neighboring EU market countries and the proven availability of the raw material are the key factors that drive investment opportunities in the production of wood pellets in Bosnia and Herzegovina. Due to that wood pellets prices are still low in Bosnia and Herzegovina, Republic of Srpska. Table 1 lists investment costs for both systems, estimated savings per year and payback period.

Table 1: Investment costs, savings per year and payback period for analyzed systems

	Investment cost [€]	Savings per year [€]	Payback period [years]
WWHP	23000	4980	5.76
Biomass boiler	1700	4430	> 1

As Table 1 shows, system which use biomass has lower investment costs then WWHP system. Savings per year are higher for WWHP system but payback period is less then one year for biomass system.

Fig 7 shows comparing annual operating costs of old and new systems. Waste water heat pump system has the lowest annual operating cost. This is due to the low electricity prices in Republic of Srpska. Biomass boiler system has annual costs also lower compared to the old system.

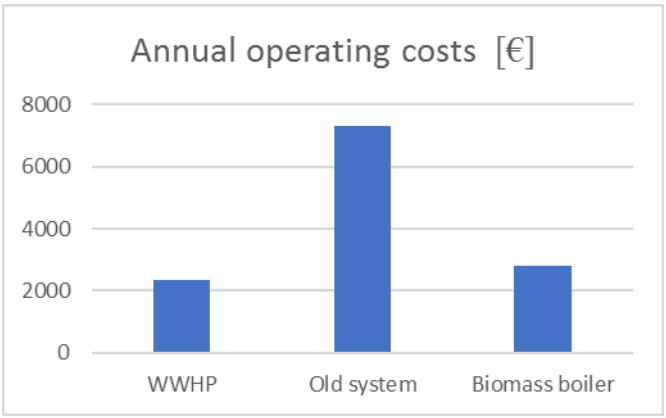

Fig. 7 Annual operating costs for new and old system

Figure 8 shows operating costs for a period of ten years for analyzed new systems and also a old one. As it's shown, old system has a biggest growth in operating costs through the years and wood biomass boiler has the smallest. If we consider that prices of electricity will grow in Bosnia and Herzegovina in the future, we can say that old system with electric boilers will have big trend of growth in operating costs.

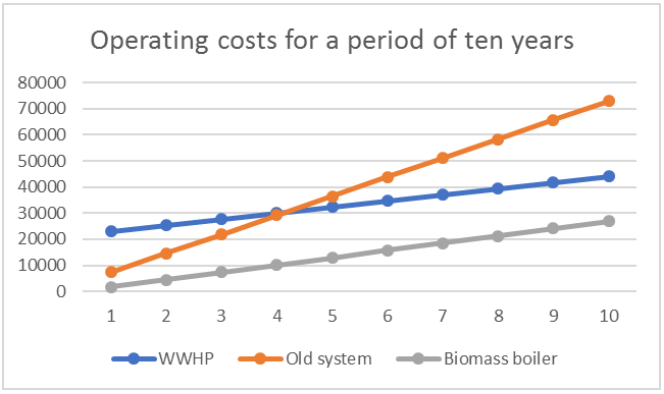

Fig. 8 Operating costs for a period of ten years

4. Conclusion

Renewable energy sources may significantly contribute to the protection of the environment from harmful emissions and costs reduction in the field of DHW production. Aim of this paper was to show how waste water and wood biomass as renewable sources can be used for DHW production for specific type of building such as public institution „Home for male children and youth with disabilities" Prijedor, Bosnia and Herzegovina. From technical point of view both sources are accepotable. Temperature of waste water is on high level so it can be used as heat source for heat pump. Heat pump is a simple and proven technology and uses a less primary energy then other systems. Duo to that its impact on environment is reduced. On the other hand, cooled waste water has less impact on rivers where in most cases goes. Biomass is one of the most available renewable sources in Bosna and Herzegovina, both economicaly and technicaly. It can be say that wood biomass has „zero emission" so this energy source is also acceptable in term of environment protection. Economic analyze showed that wood biomass is more justified source of energy than waste water. System with biomass boiler has lower investment costs and payback period less than one year. Waste water heat pump has bigger savings per

year then biomas boiler. Savings per year, for both systems, go up to 60%. All technical and economics aspects in this paper showed that these renewable sources should be used more and that can be one of the main keys in further sustanable development in Republic Srpska, Bosnia and Herzegovina.

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