PERFORMANCE OF USING WASTE HOT WATER AS AN INNOVATIVE ENERGY SOURCE

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The aim of this paper is study the cost-effectiveness of using waste hot water as an energy source for heat pumps. The research was made in one part of the hotel complex on Kopaonik, in which the whole system is implemented with a heat pump and piping system for collecting hot water from showers and sinks (gray-water). Tap water that is collected in package (reservoirs) has a certain average temperature, which is more than enough for a very high level of profitability of the heat pump. In the paper, a statistical analysis of the test results of two parallel systems for space heating with the difference in energy consumption and emissions of CO2 into the atmosphere. The first system uses fuel oil as an energy source to heat water which is further distributed to the heaters. Another system uses a heat pump water-water, which operates using electricity with high efficiency thanks to the energy that is generated in the sanitary waste water.

KEYWORDS

the innovative source of energy, waste hot water, environment, modern technologies

1 INTRODUCTION

In 1987, Brutland's commission published a report called "Our Common Future", which covered a wide range of topics on environmental protection. This report stated that economic development cannot be stopped, but that it must be fitted into the ecological limits of the planet. The report used the term sustainable development, which is defined as "development in order to meet the needs of present generations, without jeopardizing the ability of future generations to meet their needs." The National Association of Local Authorities of Serbia, a permanent conference of cities and municipalities, has issued a guide to the development of local sustainable development strategies with a supplement - a list of indicators as a recommendation to local governments. All of them are traditional indicators of the ecosystem system [Veljković 2013].

The growth of tourism activities determines tourism as a very important economic social phenomenon. Growth is an increase in the consumption of energy products used in all operations essential for the efficient functioning of the hotel as a single system (preparation of sanitary water, food preparation, heating-cooling rooms, etc.), where the CO_2 emission in the atmosphere is increased. If tourism and hotel industry as its main subject continue to develop as before, the emissions of harmful gases caused by these activities would increase in the next fifteen years two and a half times. This development is simply unacceptable and unsustainable. Today companies have to solve a huge number of problems related to the environmental consequences of their business. Along with the investment programs of technical-technological modernization, environmental programs are in the business plans of a large business. An environmental indicator appears as one of the most important indicators of strategic management of modern corporations [Trivan 2016, Agarski 2016].

2.1. The point of energy efficiency and energy management

The concept of energy efficiency mainly meets two meanings, one of which refers to improving measures for the introduction of energy-efficient devices and equipment, and another to the very measures and behavior of the system. The basic measures related to the introduction of energetically more efficient devices and equipment are: measures for improving the characteristics of the building itself (insulation of facade walls, carpentry, etc.), measures for the improvement of technical systems (heat pumps, use of renewable energy sources, etc.), and optimization measures for exploitation of technical systems.

By measures and behavior it means above all the international standard ISO 50001 which is the basis for establishing the system of energetics efficiency and the introduction of energy management. The standards established by classification and categorization are the most critical factor of the competitiveness of hotel facilities and their total supply [Barjaktarović 2013]. The standard defines the requirements for the establishment, application, maintenance and improvement of the energy management system, with the aim of allowing the organizations introduced to follow the system approach in achieving continuous improvement of energy performance. Under the energy performance it means the use and consumption of energy, measurement, reporting and documentation, designing and supplying equipment, personnel contributing to energy efficiency, etc.

Energy management is a part of the entire "environmental" management system. Its first and foremost goal is the continuing aspiration to operate the company on the principles of optimum and efficient use of energy. This means that there is a need for continuous monitoring and improvement of all parts of the system so that whenever it is financially feasible to implement measures that will contribute to increasing the efficiency of energy use within the company itself. For tourism companies, good energy management means a good business result thanks to savings in energy bill. Benefits achieved by increased energy efficiency are multiple.

In the basis of the business of each business entity is an increase in profits. Increasing energy efficiency directly contributes to reducing energy costs, which implies profit.

Increasing energy efficiency contributes to reducing CO2 emissions, reducing the so-called "carbon" imprint of the company, (there are an increasing number of hotel chains that document energy-related data in their facilities) and, consequently, the company's negative impact on the environment, this is safe and the most important contribution to increasing energy efficiency.

Companies that perform their business activities in the field of tourism in the national park "Kopaonik" in Serbia, which is also the biggest ski center and the most famous tourist destination of both domestic and foreign guests, are obliged to deal with such an environment with special care. They are obliged not to expend the legacy of our ancestors and not leave a great debt to our future generations.

2 SANITARY WASTE WATER ANALYSIS

The heat pump is a thermodynamic process that allows the energy of a medium of a typically lower temperature level to be consumed in the circular process, in order to then use that energy for heating at a higher temperature level by transferring another medium. Heat pumps are machines that provide heat transfer from the body down to the body of higher temperatures. Unlike refrigeration units (refrigerators and freezers), heat pumps are used to heat some space or matter (air or water) at the expense of cooling some environment [Đukanović 2009]. In doing so, the amount of heat produced by the heat pump operation and which can be used to heat the space is manifold higher than the thermal equivalent of the consumed work. Modern heat pumps have a utilization rate of six times the amount of energy invested in its work, which means that we can get 6kW or 21600 kJ of heat energy for 1kWh of consumed electricity. It is generally known that with a direct heating resistance for the consumed 1kWh of electrical energy, a maximum of 1kW of thermal energy or 3600 kJ can be obtained [Reknage 2004].

The total available energy is composed of the low temperature heat generated by the medium which in this case is a sanitary waste water (gray-water), whose energy is used to lift the heat pump to a higher temperature and the thermal equivalent invested for the circular operation of the heat pump.

The availability of the most economical and in every sense of the most inefficient energy source is certainly the basis for a high degree of utilization of the heat pump. Since this is a water-supply system that uses waste water, it is necessary to further clarify the advantages of using waste water as a heat source in relation to geothermal waters drawn from drilled wells.

The heat pump VODA-WATER uses the energy obtained from ground water whose temperature is constant and ranges between 8 °C and 10 °C, which is very good and allows the maximum possible rate of utilization of the heat pump irrespective of the temperature of the external blade that cannot be no influence on the temperature of the geothermal waters. There are certain limiting factors in the exploitation of geothermal waters, for one functional system that uses the energy of geothermal water, two wells are needed. One well serves as a feeder from which water flows through the heat exchanger and takes heat away from it. The second well serves as an abyss or absorber into which the cooled water returns. Wells involve a great expense, first of all, a borehole is needed, a permit for the use of a plot, since the water supply and sewage wells must be at a distance between 15 meters and 20 meters, and for the use of underground and surface water, a permit is required from the competent water management institution Issues a "water permit".

For the use of waste water that is collected in its own area, there are no drilling costs of the wells, no other person's plots or own plots, and no permits required by the competent state authorities.

Sanitary wastewater, which can be called gray water, means waste water that is generated by the use of water in a building (residential buildings, commercial buildings, hotels, etc.) and which does not contain solid soluble and insoluble substances and urine.

The basis for the possibility of using heat from waste water is separated by fecal sanitary water (black water) from other hot water.

Other sanitary waters include: water from showers, washbasins, bath tubs, chains or all wastewaters that are not contaminated with dissolved or undissolved solids.

Such water has a high energy potential and can reach temperatures up to 30 °C in collectors. Table 1 shows calculation of wastewater from sanitary devices according to Samgin.

The yield of the sanitary water depends on the size of the object. The observed example is the block A of the hotel "Grand" Kopaonik Serbia, where the building is six floors, 19 apartments and 60 rooms. Considering that we can accommodate at least two persons in one accommodation unit, we come to the conclusion that the accommodation capacity of this building is at least 158 persons, Table 2. According to some studies, the average water consumption in the hotels ranges on average up to 160 l/day per person, of which about 70 l/day of gray water is wasted. In gray sanitary water lies a large energy potential, since the temperature of the shower water is above 38 ° C. Water is collected by gravity through the tube system into 30 m^3 collectors, then passing through a system of coarse filters that serve to contain possible mechanical matter, then go to a heat exchanger that has the ability to take away the heat that goes beyond the heat pump. From such cooled wastewater it is a "waste" energy that is returned via the heat pump to the fan-coil heating system of the facility. Filled water is poured into the sewage system together with fecal water (black water). There is also the possibility that this water can be used to wash the toilet bowl, but this is not the subject of this work.

Sanitary device	No of devices [N] (piece)	Coefficient of filling [K]	N·K	P [%] Part of grey sanitary water in total splendid water	Qn [l/s] flow at the current site	Q [l/s] quantity of water per person
Shower	79	0.70	55.3	70.0	0.22	12.17

Table 1. Calculation of wastewater from sanitary devices according to prof. Ing. Samgin

One shower per day requires 12.17 l/room, with a capacity of 70% of room occupancy. If we take into account that the rooms are double, then we have at least two showers per day in one room, which is then 24.34 l/room. If one shower lasts for an average of 7 minutes or 420 seconds, then we calculate that the average daily production of gray sanitary water is 10,222.8 l/day [Rysulova 2015].

Month	Day	Production of gray sanitary water during full capacity of hotel		Occupancy of hotel	Production of gray sanitary water l/month
		Daily l/day	Monthly l/month		
January	31	10.222	316.882	95%	301.038
February	28		286.216	95%	271.905
March	31		316.882	83%	263.012
October	31		316.882	78%	247.168
November	30		306.660	86%	263.727
December	31		316.882	92%	291.531

Table 2. The quantity of gray sanitary water in block A of the hotel "Grand" Kopaonik

3 APPROPRIATE ANALYSIS OF THE HEATING SYSTEM WITH EMISSION OF SMOKE GASES

Estimated operating time of the system in the observed period is shown in Table 3. In the following part, a comparative analysis of the heating system with flue gas emissions was carried out:

I system - In the hotel complex "Grand" there is a central boiler room, which uses a fuel oil as a fuel and heats the whole complex as well as the newly built block A, Table 4.

II system - Also, during the construction of a new block A, a system for collecting sanitary waste (gray) water with a heat pump was also implemented, Table 5.

III system - Thirdly, the theoretical system of direct transmission of electric energy in the thermal energy of boilers is shown. In Serbia, this kind of use of electricity for heated areas is very much represented by the investor, because at the beginning it is characterized by low price of equipment and works, neglecting the completely negative environmental aspect of this type of used electricity, Table 6.

Considering that there are two pre-heating systems for space heating, the table shows the consumption of energy systems in the system using fuel oil and heat pump systems that use electricity for the pump operation.

Operating time of system	Month per year	Days per month	Ours daily	Working hours per year
	6	30	18	3240

Table 3. Estimated operating time of the system in the observed period

To compare the consumption of oxygen and the emission of flue gases produced by combustion of fossil fuels, we turned the electricity to start the pump into a lignite. We emphasize that the electricity generation structure in Serbia is as follows: 71% comes from thermal power plants, 28% from hydro power plants and 1% from other renewable sources.

Energy resource	Spender	Power	Air volume L min.	Amount of flue gases of coal- Vaf	Spending of O_2	Emission of CO_2
Oil	4,6 kg/h	52,44 kWh	10,8 m^3/kg	11,7 m^3/kg	14,90 kg/h	16,70 kg/h
			49,68 m^3/h	53,82 m^3/h	48.303 kg/year.	54.108 kg/year.
			160.963 M^3/year.	174.377 m^3/year.	54.613 kg	64.443 kg
Electric energy	2,4 kWh 2.38 kg/lignite.*		2,73 m^3/kg	3,48 m^3/kg	1,94 kg/h	3,19 kg/h
			6,49 m^3/h	8,28 m^3/h	6.310 kg/year.	10.335 kg/year.
			21.027 M^3/year.	26.827 m^3/year.		

*Electrical energy needs for heating of oil, pump for transportation and heater.

Table 4. I System

Energy resource	Spender	Power	Air volume L min.	Amount of flue gases of coal- Vaf	Spending of O_2	Emission of CO_2
Electric energy for thermal process	9 kWh 8.94 kg/lignite.**	52,2 kWh	2,73 m^3/kg	3,48 m^3/kg	7,32 kg/h	12 kg/h
			24,4 m^3/h	31,11 m^3/h	23.729 kg/year	38.880 kg/year.
			79.056 m^3/year.	100.796 m^3/year.		

**Structure of electric energy production in Serbia: 71 % fossil fuel, 28 % hydroelectric power and 1% renewable energy resources. For production of 1kWh in „TENT Obrenovac" is needed 1.4 kg of lignite from Kolubara or 10.800 kJ, because energetic value of lignite is about 7.500 kJ.

Table 5. II System

Spending of energy resource	Electric energy	Lignite	Air volume L min.	Amount of flue gases of coal- Vaf	O2/kg	CO2/kg
56 kWh	37 kWh	51,8 kg	2,73 m^3/kg	3,48 m^3/kg	42,43 kg/h	69,60 kg/h
			141,4 m^3/h	180,26 m^3/h	137.473 kg/year.	225.504 kg/year.
			548.136 m^3/year.	584.055 m^3/year.		

Table 6. III System

In systems II and III emissions of flue gases take place at the place of electricity production as opposed to system I where flue gas emissions take place at the energy consumption point, which is only a cosmetic but not a fundamental difference in relation to the environment. In order to calculate the above values, the following parameters were used:

- For combustion of 1 kg of oil, 3.24 kg of oxygen (O_2) is required.
- For the combustion of 1 kg of said lignite, 0.8 kg of O_2 is required.
- The amount of air required for combustion of 1 kg of oil = 10.8 m^3/kg.
- The quantity of flue gases released during combustion of 1 kg of oil = 11.7 m^3/kg.
- The amount of air required for combustion of 1 kg of lignite = 2.73 m^3/kg.
- The quantity of flue gases released during the combustion of 1 kg of lignite = 3.48 m^3/kg.
- Weight O_2 = 1,429 kg/m^3.

- Weight CO_2 = 1,977 kg/m³.
- The CO_2 content of 1m³ of flue gases released during combustion of fuel oil is 15.70%.
- The content of CO_2 in 1m³ of flue gases released during combustion of lignite is 19.56%.
- Formula for calculating the required amount of oxygen O_2 for combustion of 1 kg of oil:

  10.8 m³/kg (required amount of combustion air 1 kg of oil) x 0.21 (percentage of O_2 content in air) = 2,268 O_2/m³ air x 1,429 (weight O_2) = 3.24 kg O_2.
- Calculation formula for kWh of consumed (produced) electricity:

  9kWh x 0.71 = 6.93 kWh (electricity generated from the TE) x 1.4 kg/kWh = 8.94 kg of lignite.
- Approximate formula for minimum air volume: L min. = 0.25 m³ for 1000 kJ.

Note that for the same amount of energy consumed for space heating, have quite different values in O_2 consumption and emissions of flue gases depending on how this energy is used. It is easy to see that the II system using the heat pump (water-water) with sanitary wastewater is far more economical (Figure 1). Using the heat pump whose medium is gray sanitary water, and considering that the optimal heating time for Kopaonik is 3240 h, the difference in the oxygen consumption required for combustion of fossil fuels in relation to the other two observed systems is 30.884 kg/O_2.

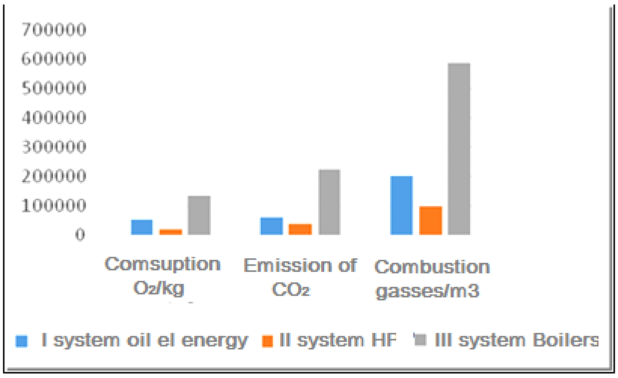

Figure 1. Differences in consumption of the systems under consideration

4 CONCLUSIONS

Waste water (gray water) collected from showers, washbasins and shunts contains significant energy potential. It can be used as a very affordable medium in the environment of which the heat pump works with the maximum possible degree of exploitation from the technical, economic and legal-legal side.

The progress report on the implementation of the National Sustainable Development Strategy, published as a publication, provides essential indicators that represent a smaller group of highly representative indicators that are not interlinked but their main role is to provide a general picture of whether The system is approaching the goals of sustainable development. Indicator trends in this report are presented with a graphic symbol (arrow) and indicate a positive trend towards a higher level of sustainability and a negative trend towards a lower level of sustainability. Indicators such as: the number of adopted strategies for local sustainable development, the number of environmental accidents and damages in them, the percentage of budget funds spent on environmental protection and energy intensity have a positive trend and an arrow to a higher level of sustainability. The indicator of total annual emissions of greenhouse gases has a negative trend and an arrow towards a lower level of sustainability.

Inefficient use of energy leads to a growing resource scattering and inefficient economic development, which undermines the concept of justifiable sustainability.

By analyzing this example of the use of waste gray water as a source of energy for a heat pump, we can conclude that the system is efficient in the conditions of reducing the emission of harmful gases into the atmosphere and that its use can save a considerable amount of energy sources with financial growth. Costs of wastewater management are in second place by the amount in the structure of waste management costs and amount to an average of 13.82 % of the average annual cost of environmental protection [Vukadinović 2016]. It is precisely the economic aspect that can be one of the reasons for increasing the justification of sustainable development. Moral reasons are the most important reasons that impel us to the concept of sustainability. Today this concept has become widely accepted as a condition of survival and progress of mankind.

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