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Abstract

To overcome the impact on the environment and the declining source of fossil fuels, renewable energy sources must meet the growing demand for both electricity and heat. Solar energy is clean and endless, suitable for being a good substitute for fossil fuels and meeting energy demands. Solar collectors are a major part of solar thermal systems, there are a variety of types of solar collectors which we can use depending on the conditions in which they will operate. In this study, the energy performance of the flat plate solar collector with working medium water and air for climatic conditions of Kosovo was analytically analysed. This paper will provide a clearer picture of these two analyzes for both types of solar collectors for a given location. As it is known, the main purpose of using one type of solar collector is to maximize its use and achieve the highest parameters of the energy used. At the end of this paper it will be clear which type of collectors with a certain working medium produce more energy and have greater efficiency given the importance of better use of solar energy and achieving maximum benefits of the collector used.

1. Introduction

Energy is the most valuable resource and foundation of civilization. It is also our heritage for future generations. Preserving this resource for future requires a thorough understanding of energy resources, optimal operation and sustainable usage. Solar energy is one of the most important sources of energy as it is free and other country can’t charge for the use of the sun. Solar energy, on the other hand can be important because this energy is infinite [1].

The sun, as main source of light and heat for the earth, is considered an inexhaustible resource of energy, of easy access, free, clean, and renewable; from which it is possible to obtain direct benefits through systems capable of transforming the direct solar radiation into other types of useful energy to then be used in industrial processes or in small applications for the home [2].

Solar energy collectors are special kind of heat exchangers that transform solar radiation energy to internal energy of the transport medium. The major component of any solar system is the solar collector. This is a device which absorbs the incoming solar radiation, converts it into heat, and transfers this heat to a fluid (usually air, water, or oil) flowing through the collector. The solar energy thus collected is carried from the circulating fluid either directly to the hot water or space conditioning equipment, or to a thermal energy storage tank from which can be drawn for use at night and/or cloudy days [3].

1.1. Water solar Collectors

Flat-plate collectors are the most common solar collector for solar water-heating systems in homes and solar space heating. A typical flat-plate collector is an insulated metal box with a glass or plastic cover (called the glazing) and a dark-colored absorber plate. These collectors heat liquid or air at temperatures less than 80°C [4].

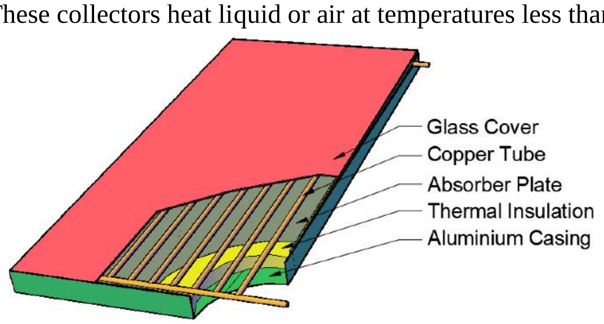

Fig. 1. The structure of a flat plate collecto [5].

Sunlight passes through the glazing and strikes the absorber plate, which heats up, changing solar energy into heat energy. The heat is transferred to liquid passing through pipes attached to the absorber plate. Absorber plates are commonly painted with "selective coatings," which absorb and retain heat better than ordinary black paint. Absorber plates are usually made of metal typically copper or aluminum because the metal is a good heat conductor. Copper is more expensive, but is a better conductor and less prone to corrosion than aluminum. In locations with average available solar energy, flat plate collectors are sized approximately one-half- to one-square foot per gallon of one-day's hot water use [6].

1.2. Air solar collectors

An air-based collector is a type of solar collector in which air is is used as the medium for heat transfer instead of a liquid. The heat thus obtained from the incident solar energy is stored in holders, which may be filled with gravel, for example. The energy collected from air-based solar collectors can be used for ventilation air heating, space heating, or crop drying [7].

Fig 2. The structure of air solar collector [8].

Solar hot air collectors are mounted on south-facing vertical walls or roofs. Solar radiation reaching the collector heats the absorber plate, and the air passing through the collector picks up heat from the absorber plate [9].

1.3. Literature survey

Flate-plate collectors are widely used in various engineering applications. Despite this type of collectors have been well analyzed for a long time, there is still much interest in the different aspects of efficiency analysis. As solar collectors are an important technical component when energy sustainability is considered, a substantial performance evaluation becomes inevitable to evaluate possible configurations improvements of these systems. Exergy analysis has proved to be one of the useful tools when considering either the solar collectors alone or the complete system to identify sources of irreversibility [10].

An optimisation analysis of the solar collectors by the use of the exergy method leads to a conclusion that the energy efficiency increases without extremum points with the change of operating parameters. The absence of such maximum points has created difficulties in the design of flat plate solar collectors. However, the exergy efficiency analysis demonstrates the existence of local maxima points and a point of overall maximum [11].

A way to present the thermal performances of a flat plate solar collector, including the collector efficiency has been shown in [4]. A more precise and detailed analysis should include the complex interaction among the overall heat loss coefficient (U_L) and other factors as the heat removal factor (F_R).

By increasing total solar radiation, the energy and exergy efficiencies increase. But when the ambient temperature rises, the exergy efficiency decreases [12]. In general, although the performance of solar collectors can be examined from the exergy standpoint, that is a useful method to complement, not to replace the substantial energy analysis [13].

Another method to describe the thermal performance of a flat plate solar collector in specific conditions has been presented in [14].

In this paper will be presented the energy analysis of two different types of solar collectors for a given location. Their energy performance depends on different climatic conditions.

2. Analysed solar collectors

Location analysed is the roof of laboratory buildings at the Faculty of Mechanical Engineering in Prishtina (latitude 42.6667◦N, longitude 21.1667◦E) Kosovo. The region is characterized by a mild continental climate accompanied by warm summers and cold winters. The modules are fixed, inclined at an angle of 45◦, facing south and with no buildings or other structures around, which would possibly shade them and cause lower power output to be generated [15]. Energy analysis will be done for the same location but for solar thermal collectors with working medium water and air. Energy analysis will be done for climate change in the location where solar thermal collectors can be located.

Table 1. Specification of water solar collector and air solar collector [16] [17].

Parameters	Water solar collector
Zero heat loss efficiency η_0, %	78.1
Heat loss coefficient a_1, W/m^2/k	3.83
Absorption, %	95
Emission, %	5
Max operating pressure, bar	10
Nominal flow rate, l/min	2
Thickness, mm	3.2
Collector length (mm)	1870
Collector width (mm)	1150
Wight (kg)	34

Parameters	Air solar sollector
Max air volum, m^3/h	98
Appro temperature rise, ℃	11
Max performance, W/h	550
Product size, cm	101 × 72 × 6
Gros weight, kg	19

3. Performance of the solar collectors

The useful heat gain (Qu) by the working fluid is:

$$Q_u = \dot{m}C_p(T_{out} - T_{in}), \tag{1}$$

where T_{in}, T_{out}, C_p and $\dot{m}$ are the working fluid inlet and outlet temperature, its specific heat capacity and mass flow rate, respectively. The Hottel–Whillier equation for the useful heat gain (Q_u) of a flat plate solar collector system, considering the heat losses from the collector to the surroundings, is:

$$Q_u = A_p F_R[S - U_I(T_{in} - T_a)], \tag{2}$$

where T_a is the ambient temperature and the heat removal factor (F_R) is defined as:

$$F_R = \frac{\dot{m}C_p}{U_I A_P}\left[1 - exp\left\{-\frac{F'' U_I A_p}{\dot{m}C_p}\right\}\right], \tag{3}$$

where F" and ϕ are the collector efficiency factor and plate effectiveness. An energy balance on the absorber plate yields the following equation for a steady state operating conditions:

$$Q_u = A_p S - U_I A_p(T_p - T_a), \tag{4}$$

In Eqs. (2) to (4) Tp, S and Ap are the average temperature of the absorber plate, absorbed radiation flux by unit area of the absorber plate and the area of the absorber plate, respectively. For simplification, the overall loss coefficient U_I, is often assumed as a constant. However, a serious study on collector efficiency must take into account its variability. The calculation of U_I is based on simulation of convection and radiation losses from the absorber plate to the surrounding ambient, taking into consideration the real ambient conditions.

Thermal efficiency of the collector is given by

$$\eta_{en} = \frac{Q_u}{I_T A_p}, \quad (5)$$

where I_T is the incident solar energy per unit area of the absorber plate.

4. Results and discussion

As it is known, the purpose of using a solar panel is to achieve the best parameters from it and to have more energy generated. Solar collectors have the sun as a source of energy and depending on solar radiation we also have the change of energy gained by the collector.

Knowing that solar collectors for water heating are used to meet thermal needs, and inside the collector there is a change in temperatures that is achieved. The following is a diagram of how much thermal energy is gained depending on the change in temperatures expected to be reached by the collector.

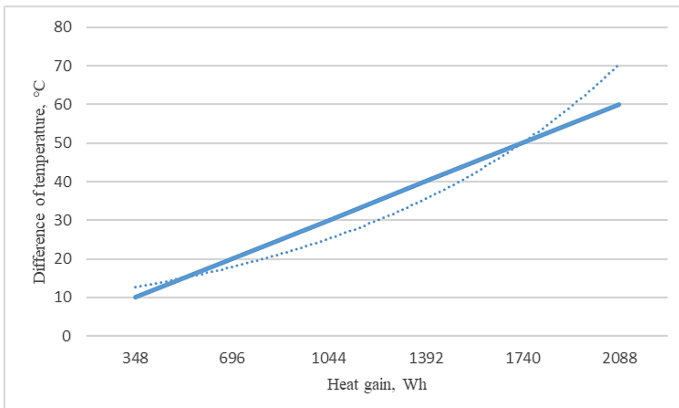

Fig 3. Thermal energy gained from changing temperatures.

The working medium in most cases in this type of collectors is the water which comes to the collector with a certain flow, in the following is presented the change of thermal energy depending on the change of water purification in the collector for a certain temperature change.

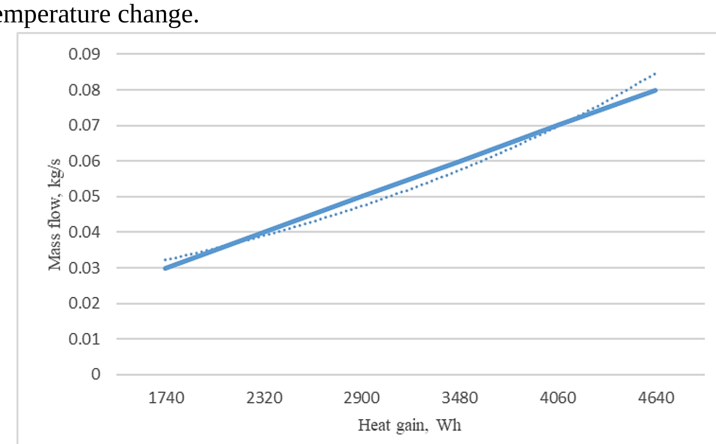

Fig 4. The change of thermal energy depending on the change of the mass flow of water.

The main indicator of the solar collector is the efficiency of the collector which indicates the degree of adequate utilization of solar energy. Here we present the diagram of efficiency for the main types of solar collectors.

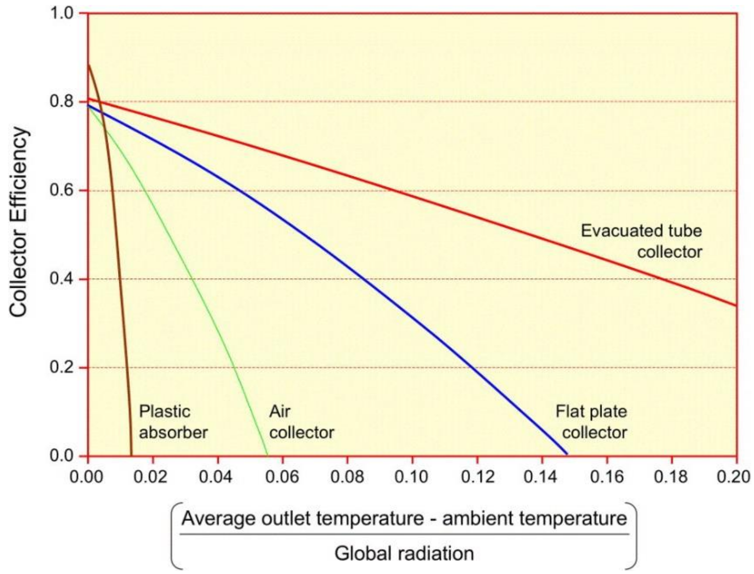

Fig 5. Efficiency diagram of solar thermal collectors [18].

Air collectors which are used for heating air for heating systems as working medium use air which transfers heat. The following is a diagram of the change of thermal heat depending on the change of temperatures reached in the collector.

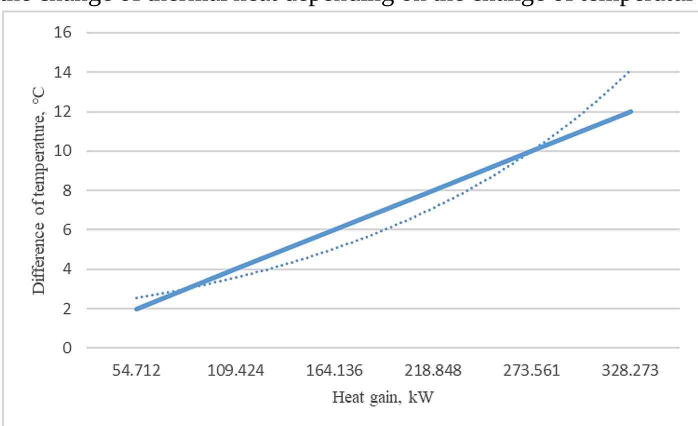

Fig 6. Heat change depending on the change of air temperatures.

The change in thermal heat depending on the change in air volume is shown in the following figure.

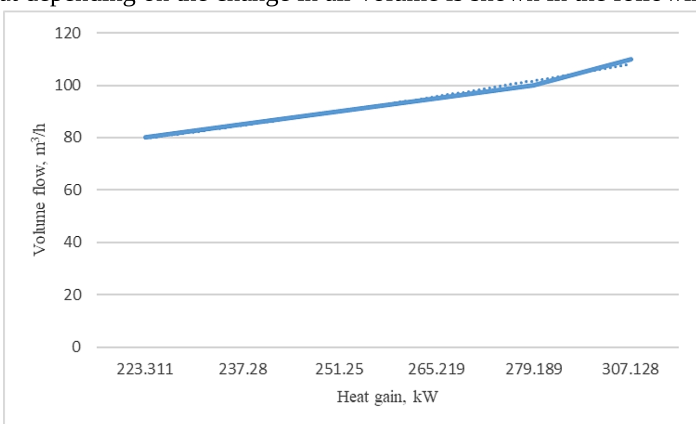

Fig 7. The change in thermal energy gained depending on the change in air volume.

5. Conclusions

Renewable energy sources are an inexhaustible source of energy, the use of which is growing more and more every day. Global warming and environmental pollution from the use of fossil energy sources has shifted the focus from the greatest use of renewable energy sources, primarily solar energy as a vital energy source. Solar energy is an inexhaustible source of energy which can be used for the production of electricity and thermal energy.
Kosovo has a high potential for the use of solar energy depending on its geographical position in which it is located. Considering the large number of sunny days during the year, it makes it a place that has the potential to use solar systems for thermal energy generation. Its small area can be seen as an obstacle to enable the greatest use of its potential in relation to this energy source.
From the energy analysis made for solar collectors with working medium water and air it is seen that there is a high potential which can be obtained from the use of these two types of collectors. Flat collectors for water heating can be used to meet the requirements for sanitary water with a good performance and high potential that can be exploited by the use of this type of collectors. Solar air heating collectors have a great potential which can be used to heat spaces to meet the needs for thermal energy. Based on the analysis made for the climatic conditions of Kosovo, the efficiency of flat plate collector with working medium water is about 50 % while the efficiency for air collectors is about 60 %.
The production of electricity for the most part from fossil fuels has affected the pollution of the environment and the increase of the air quality index in the country by aggravating the air in the country. A large part of the electricity which is used for water heating for sanitary needs and for heating in winter time can be saved by using solar collectors to cover these energy needs. Their use would have a positive impact both in terms of energy and the environment.

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