# Penetration of renewable sources through solar systems: a case study Kosovo

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**Article Info**

***Article history:***

Received Feb 1, 2022
Revised Aug 31, 2022
Accepted Sep 22, 2022

***Keywords:***

Efficiency
Flat plate collector
Solar coverage
Solar energy
Solar heating system

**ABSTRACT**

This paper analyzes the potential of solar energy and the efficiency of a solar system for real measurements. During the analysis, one-year radiation measurements for the city of Pristina were used. Analyzes show a high potential for exploitation. What affects the increase of efficiency of such systems is the possibility of use throughout the year. For each respective month is shown the potential of thermal energy that can be achieved and efficiency. The paper highlights the role of solar energy in maximizing the penetration of renewable sources. The analysis shows that in August the coverage of the needs for hot sanitary water from the proposed solar system is 99% and minimally in January by 16%. Taking into account the seasonal changes that apply to the country, I consider that a possible combination of central heating systems with those of sanitary water-solar system would be an adequate solution.



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## 1. INTRODUCTION

In many countries of the world, the consumption of electricity in the construction sector represents a high value of energy consumption in the total value of energy consumption. This amount of energy is also spent on the needs of water heating for sanitary needs, which can also be done using solar energy [1]. Today, renewable sources of energy have become good solution for the problem of energy production and transmission [2]. Renewable energy as a friendly source of energy production is abundant and inexhaustible, does not create pollution, is economical and sustainable [3].

The use of solar energy depends on the available hours of sunshine, clouds and other meteorological conditions [4]. Solar thermal technologies can provide: hot water for sanitary systems and can also be used for air heating [5]. Solar collectors are the most popular devices used for heating water in solar systems based on the possibility of their use at low temperatures and their lower cost compared to other systems that use solar energy [6], [7]. It is important to reduce the cost of thermal collectors, thus increasing the possibilities of their use [8]. Depending on what performance we get from the thermal system depends on the specific place where the system is used [9]. In papers [10], [11], thermosiphon systems are studied in cold climate conditions. The possibility of using such systems in certain weather conditions.

In paper [12], the authors studied the serial and parallel connection of thermosiphon systems. Due to the reliability and simplicity of thermosiphon systems, their use increased [13]. The working medium in thermosiphon systems moves as a result of the pressure change from the heat exchanger to the tank. The operation of such systems is complex, in which the pressure in the pipes, the heat exchanger, the connection of the system, etc. must be coordinated [14], [15]. Based on the connections of the system, the placement of other equipment such as the heat exchanger and the water tank are done [16]. In the paper [17] a large number of field data of solar water heating systems have been analyzed. Errors can be derived from the meteorological data that are analyzed. The authors proposed methods for the most accurate evaluation of thermal systems. The results of the evaluation of a system in a housing complex is presented in the paper [18]. With the increase in the use of the solar system, its performance is halved compared to the design time of the system. In which the changes that occur from theory to practice are presented [19].

In this paper, we will present the design and performance of a system for heating water for domestic needs through the solar system for certain climatic conditions. This paper is organized as follows: in the first part of the paper, the data of radiation measurements for the specific location are presented, in the following, the analyzes are made regarding the possible potential of thermal energy at the output of the water heating system for the needs sanitary. Then the results are presented regarding the coverage provided by the system for each month and the corresponding efficiency of the system. The paper is very important considering the fact that we have a current energy crisis and that the energy system of the country under consideration is based entirely on coal in a fossil energy source that causes environmental pollution, with very low percentages of the use of renewable resources. What makes it more appropriate is the fact that the potential of solar energy in the studied location is high and makes the possibility of using solar energy favorable.

## 2. PROCEDURE SPECIFICALLY DESIGNED

### 2.1. Energy potential of solar energy utilization of Pristina

To design a system for the use of solar energy it is necessary to know a series of climatic parameters which include: The average daily radiation in solar collector planes, which is used to calculate the collector efficiency and solar energy absorbed by it; Sky temperature, which is important to know for calculating the energy calculated by the solar collector, Cold water temperature which is necessary to know to calculate the total thermal load which must be covered by the solar system [20]. The amount of solar radiation that reaches each point of the Earth's surface varies depending on these factors [21]: (i) the time during the day, (ii) season; geographical position, and (iii) geographical location and local climate conditions.

### 2.2. Solar energy potential

Solar energy data for Pristina (latitude N 42°39’46”, longitude E 21°9’55”) according to the global solar atlas database are presented in Figure 1. The climate is continental in the place analyses. While in Figure 1 are shown the average hours with radiation for each month. From the Figure 1 presented, it can be seen a high potential of solar energy which is available for use in this location. With its use, the reduction the use of the energy from fossil energy sources of energy is affected and in this way the environment is also protected. While in Figure 2 are shown the average hours with radiation for each month. As in the Figure 2, Pristina has a high potential of solar energy, seeing the many hours of solar radiation during the year. The highest temperatures are reached during the month of August, while the lowest ones are reached during the month of December and during the month of January.

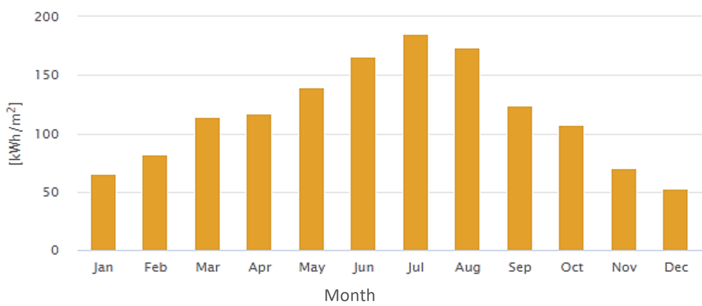


Figure 1. Monthly average direct solar irradiation

### 2.3. Average air temperatures

Factors that affect the solar collector system are related to meteorological parameters that must be taken into account from the station closest to the place where the solar collector system will be installed. Figure 3, shows the values for average monthly and annual temperatures according to the Ret Screen Expert database. The figure shows in detail the solar radiation during the months of the year for the location as well as the ambient temperature as two of the main indicators for the use of solar systems. As can be seen from the picture, there is abundant daily energy from solar energy which can be used and taking into account the air temperature, it is very convenient to use a water heating system from solar energy.

Direct normal irradiation [Wh/m$^2$]

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 1 | | | | | | | | | | | | |
| 1 - 2 | | | | | | | | | | | | |
| 2 - 3 | | | | | | | | | | | | |
| 3 - 4 | | | | | | | | | | | | |
| 4 - 5 | | | | | 15 | 34 | 23 | | | | | |
| 5 - 6 | | | | 48 | 150 | 212 | 208 | 97 | 25 | | | |
| 6 - 7 | | 12 | 101 | 209 | 259 | 314 | 342 | 306 | 213 | 100 | 12 | |
| 7 - 8 | 67 | 180 | 264 | 301 | 348 | 411 | 451 | 425 | 327 | 257 | 152 | 69 |
| 8 - 9 | 231 | 276 | 348 | 369 | 413 | 493 | 532 | 522 | 411 | 329 | 232 | 183 |
| 9 - 10 | 259 | 318 | 394 | 412 | 446 | 540 | 591 | 582 | 457 | 392 | 268 | 210 |
| 10 - 11 | 270 | 341 | 419 | 418 | 457 | 553 | 602 | 603 | 470 | 434 | 296 | 217 |
| 11 - 12 | 286 | 361 | 426 | 402 | 455 | 535 | 579 | 591 | 469 | 449 | 321 | 240 |
| 12 - 13 | 296 | 371 | 423 | 396 | 441 | 510 | 548 | 565 | 451 | 450 | 343 | 252 |
| 13 - 14 | 291 | 370 | 412 | 378 | 408 | 476 | 517 | 525 | 418 | 411 | 321 | 241 |
| 14 - 15 | 264 | 339 | 356 | 336 | 356 | 441 | 468 | 465 | 371 | 355 | 272 | 208 |
| 15 - 16 | 140 | 277 | 309 | 289 | 311 | 390 | 417 | 412 | 312 | 255 | 117 | 85 |
| 16 - 17 | | 88 | 213 | 240 | 264 | 324 | 359 | 342 | 204 | 36 | | |
| 17 - 18 | | | 17 | 102 | 166 | 246 | 274 | 177 | 17 | | | |
| 18 - 19 | | | | | 13 | 54 | 63 | 6 | | | | |
| 19 - 20 | | | | | | | | | | | | |
| 20 - 21 | | | | | | | | | | | | |
| 21 - 22 | | | | | | | | | | | | |
| 22 - 23 | | | | | | | | | | | | |
| 23 - 24 | | | | | | | | | | | | |
| Sum | 2105 | 2933 | 3682 | 3901 | 4502 | 5533 | 5973 | 5617 | 4144 | 3468 | 2335 | 1704 |

Figure 2. Hourly solar direct irradiance for every month

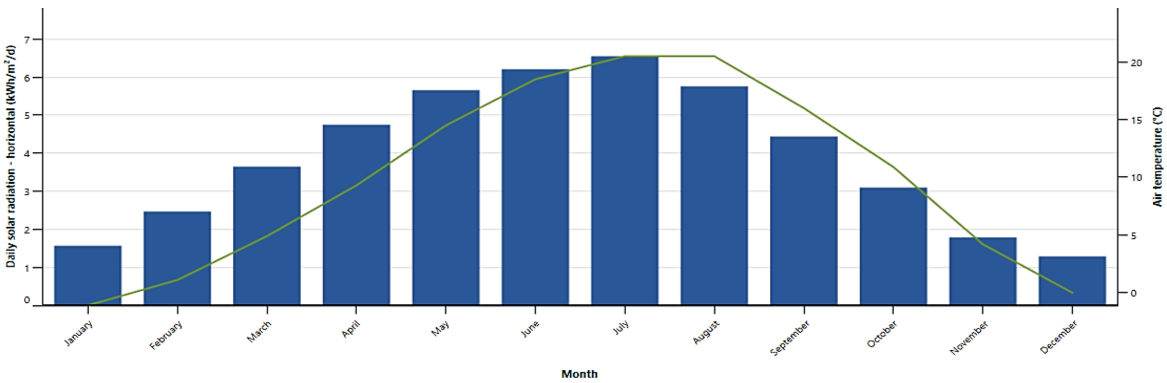


Figure 3. Solar radiation per hour and ambient temperature

## 3. METHOD

Since the middle of the 19th century, the use of solar systems for heating water has begun. Although the systems of that time were simple, their principle was the same as the systems of modern times. Over time, these systems have improved in their performance [22]. The main principle of solar thermal systems is the conversion of solar energy into useful energy using thermal collectors [23]. In most cases solar water heating systems are connected to the existing home water heating system using the capacity of the existing boiler in the system [24]. There are systems that have a low hot water storage performance [25]. To meet the requirements for hot water, water heating systems are used which use solar energy for water heating. These systems are most often used for home use based on the natural circulation flow or, as they are known with the so-called thermosyphon principle. Figure 4 presents the elements contained in such a system for water heating.

The water heating system is consisting of a flat collector, which heats the water that flows in the pipes by means of solar energy that is used in Pristina. The left and right sides of the collector are covered with stone wool. Also, collectible an aluminum frame on its three sides. The collector is made from one single glass. The water heating system is consisting of a flat solar collector, which heats the water flowing in the pipes by means of solar energy that is used to fulfill the thermal energy needs in Pristina. The left and right sides of the collector are covered with stone wool. Also, collectible an aluminum frame on its three sides. The analyzed water heating system represents a system for heating water from solar energy to fulfill the needs for thermal energy in the sanitary sector for a certain family with five members. Where the use of such a system affects the reduction of the electricity bill by providing thermal energy from solar energy. Where in the following part the capacity needed to heat, the thermal energy requirements for each person and other facts that are needed during the design of the system in order to have a higher performance of the thermal system and to have most benefit are analyzed large amount of useful energy that is used by solar energy. In this work, the analysis of the system is presented, calculating the necessary number of collectors to cover the needs for thermal energy. Analysis of the necessary energy that is sought to be obtained from solar energy for different periods of the year, the efficiency of the system and the coverage achieved by the water heating system throughout the year. Collector number calculation formula:

$$n = \frac{\frac{Q}{q \cdot \eta}}{S} = 2\ [collectors] \qquad (1)$$

The amount of heat per day is:

$$Q = G \cdot \frac{C_p(T_{max} - T_{min})}{1000} = 11.31\ \left[\frac{kWh}{day}\right] \qquad (2)$$

where:
G=250 [l] : Volume of the boiler
$T_{min} = 11$ [°C] : Temperature in the boiler entry of water supply
$T_{max} = 50$ [°C] : Temperature at the exit of the boiler
$C_p = 1.16\ [Wh/kgK]$ : Specific water thermo capacity
$\eta = 0.78$ : Utilization coefficient
$S = 1.9\ [m^2]$ : Effective area of the collector
$q = 4\ [\frac{kWh}{m^2 day}]$ : Capacity of sunlight

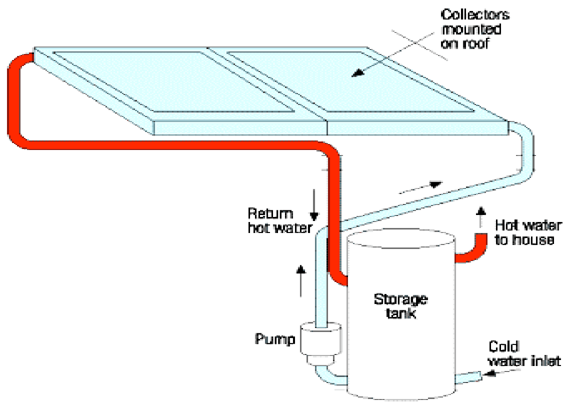

Figure 4. Solar water system [21]

The amount of energy accumulated from solar energy is:

$$Q = c \cdot m \cdot (T_{out} - T_{in}) \qquad (3)$$

where:
$Q$ : total heat absorption from solar system,
$c$ : water specific heat capacity 4.2 [kJ/kgK]
$m$ : mass flow of water [kg/s]
$T_{out}$ : export water temperature [K]
$T_{in}$ : inlet water temperature [K]
Efficiency of the collectors is determined by [26]:

$$\eta = \frac{Q}{A \cdot H} \qquad (4)$$

where:
$A$ : collector area [$m^2$] and
$H$ : solar irradiance [$W/m^2$]
The water storage tank must be well insulated in order to minimize losses with the surrounding environment. The analyzed family consists of five members (50 liters per person); the specifics of the analyzed SWH system are presented in Table 1.

Table 1. SWH system specifications [21]

| Collector type | Flat - Plate |
|---|---|
| $F_r U_L$ | 8.42 [$Wm^{-2}K$] |
| $F_r(\tau\alpha)_n$ | 0.77 |
| Collector recliner | 45° |
| Tank capacity | 250 (liter) |
| Temperature of hot water | 50 ℃ |
| Demand/day of hot water | 250 [l] (5 persons) |
| Area of the collector | 4 [$m^2$] |

The thermal efficiency is obtained by dividing Q by the energy input [27]:

$$\eta = F_r(\tau\alpha)_n - F_r U_L \left(\frac{T_{min}-T_a}{G_t}\right) \quad (5)$$

where: $T_a$ – Temperature of ambient [℃]; $G_t$ – Global solar irradiance at the collector plane, [$W/m^2$].

F-chart method is the most popular method and the most used is a simple and accurate metric, which leads us to reliable conclusions [28]. The F-chard method is used at the time when the minimum energy distribution is done at temperature 20 ℃. The method represents the total load of the system and that which is covered by the solar system. When using the method, several factors are taken into account: the specific location, the collectors used, the size of the heat exchanger and the tank [29]. The method is used to calculate the availability of requests from the solar thermal system. The method determines the plannability of the system based on: solar radiation, air temperature and the necessary demand of the system. In the system of water heating from the solar system, the temperature received from the network $T_m$ and the minimum accepted temperature of the hot water $T_w$ are affected. These temperatures also affect system losses. Total monthly load f operated by the solar system and the water heating system:

$$f = 1.029 \cdot Y - 0.065 \cdot x - 0.245 \cdot Y^2 + 0.0018 \cdot X^2 + 0.0215 \cdot Y^3 \quad (6)$$

$F_i$ represents the contribution of energy in the monthly period while $L_i$ represents the monthly load for hot water [30].

$$F = \frac{\sum f_i \cdot L_i}{\sum L_i} \quad (7)$$

## 4. RESULTS AND DISCUSSION

The design of the solar water heating system will be done for a house in Pristina, (with geographic latitude indicated). The collectors used in the analysis have two covers with $F_r$ $U_L$ and $F_r$ $(\tau\alpha)_n$ as shown in Table 1. Placement of which is done at a 45° slope. The water heating load is 250 liters/day heated from 11℃ to 50℃. The tank is cylindrical in shape with a diameter of 0.50 m and a height of 1.16 m, with a loss coefficient of 0.62 [W/m2]. Calculate the fraction of the monthly heating load supplied by solar energy for this collector system is 4 $m^2$. Radiation in the collector $\overline{\overline{H_T}}$ $[\frac{kWh}{m^2}]$ and $\frac{\overline{(\tau\alpha)_n}}{(\tau\alpha)} = 0.94$. The Figure 5 shows the f factor of energy coverage from the solar water heating system. From the Figure 5 shows the highest coverage from solar energy is done in August for 99%while the lowest coverage in December for 16% in Pristina. Figure 6 shows the thermal efficiency of the analyzed system.

As shown in the Figure 6, the highest efficiency is reached in August of 88%, while the lowest efficiency in January 55%. This is due the fact that during the summer months there is greater radiation from the sun, we also have greater benefits of thermal energy compared to with the winter months where with the fall of solar radiation affects the reduction of thermal benefits from the system. Figure 7 shows the efficiency diagram of different types of collectors.


Figure 5. The fraction f of the fertility from the solar system in the total monthly loads

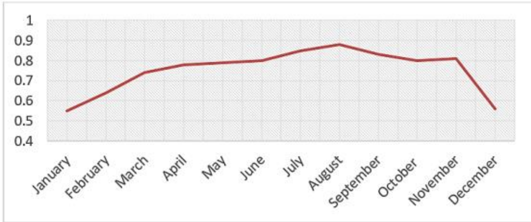


Figure 6. Solar water system efficiency

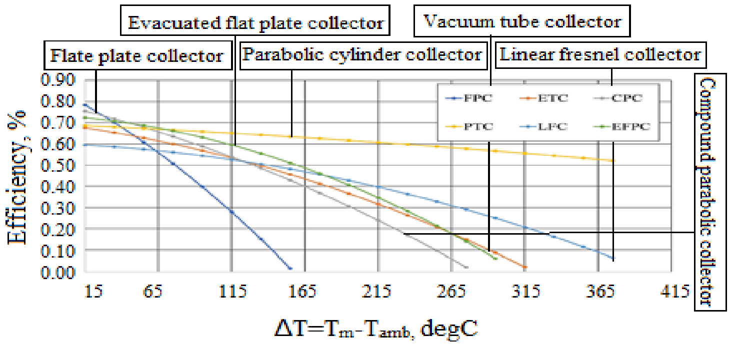


Figure 7. Comparison of the efficiency of different types of collectors, ETC-Vacuum tube collector, CPC-Compound parabolic collector, PTC-Parabolic Cylinder collector, LFC-Linear Fresnel collector and EFPC-Evacuated flat plate collector) [31]

Similar to the data presented in Figure 6 as well as from Figure 7, knowing the average temperature of the hot water and the ambient temperature, we read the efficiency of the system. For the analyzed location, the efficiency of the system in the cold period of the year is 55% with the use of solar collectors. Efficiency increases if flat collectors rated up to 68% are used for the same period of time. With the use of the most advanced collectors, it can be seen that the highest efficiency of the system is obtained and we have greater benefits from their use. Figure 8 shows the amount of heat received from the sun to cover thermal energy needs. As shown in Figure 8, the depending on the period of the year in which we are, a different thermal quantity is required that needs to be obtained from solar energy. In the warm periods of the year, when it is required to achieve a smaller change in temperatures, the amount of heat we need to get from the sun is smaller, while with the increase in the temperature change, the demand for thermal energy also increases in the cold periods of the year. Which means that the increase in the amount of the need for thermal energy from the sun's energy is proportional to the increase in the temperature change that is sought to be achieved.

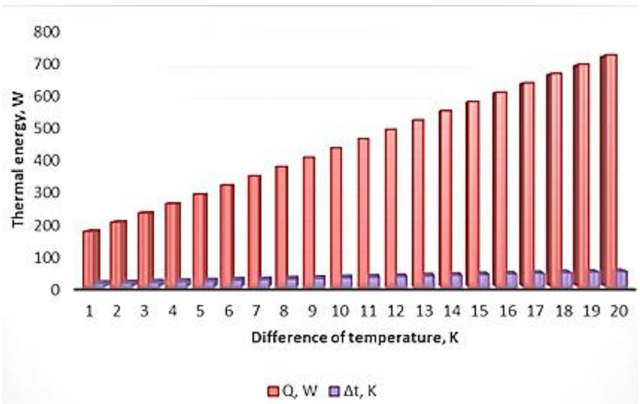


Figure 8. The necessary amount of thermal energy to be obtained from solar energy

## 5. CONCLUSION

Energy is one of the main factors in the development of a country. Energy development has a direct relationship with economic development which affects both our lives and the environment in which we live. The ever-increasing progress of human activity has affected the increasing pollution of the environment. Finding adequate ways of energy supply which are also environmentally friendly would bring about a sustainable energy supply. In this paper, we present the performance analysis of a residential system for the supply of domestic water from solar energy. The main parameters such as: solar radiation and temperature of ambient for the given location are analyzed in detail. It is also presented in detail the degree of coverage by the solar system during the months of the year and the efficiency of the system that is achieved for a certain month. From the paper, it can be seen that the degree of coverage from the solar system for domestic water is reached in August from 99 % while the lowest coverage is reached during January at 16%. While the highest utilization rate is reached in August at 88 % while the lowest in January 55%. This is because it is known that higher sunlight falls on the solar panels more in the warm summer months than in the cold months during the winter months. The analysis shows that Pristina has a high potential of solar energy that can be used for thermal energy needs based on the high degree of solar radiation and the high number of hours of solar radiation during the year. Although solar energy has a low degree of utilization in our country based on the high potential which we can easily use it can be said that in the future we will have a larger number of solar systems in use which will to have a greater production of energy from renewable sources of energy, a sustainability of energy supply and a cleaner environment.

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