
DETERMINING THE COVERAGE LEVELS OF SOLAR INSTALLATIONS FOR ROMANIA

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ABSTRACT

The use of renewable energy, especially of solar energy, in power generation, as well as in domestic and building applications, has gained significant appreciation worldwide for meeting the goals of sustainable development and environment conservation.

This article shows the possibility and the limits of adapting a solar thermal energy supply for the energy requirement of a consumer simulated in 79 cities of Romania. The simulation carried out in this study uses the monthly method to estimate the total coverage levels of solar installations. In order to do the simulation, a consumer with a value $H=16000$ W/K for heating and $H=689$ W/K for the hot water supply is used. This corresponds to the need of energy of 80 apartments for the heating and hot water supply. The monthly intakes of solar energy were calculated and they showed the amount of renewable energy this kind of system could produce. The monthly coverage levels as well as the monthly efficiency are shown in this article in order to fully express the solar usage for the specified consumer.

Keywords: solar panels; efficiency; thermal energy; coverage levels; Romanian climate

REZUMAT

Utilizarea energiei regenerabile, în special a energiei solare, în aplicațiile pentru clădirile rezidențiale a devenit importantă la nivel mondial pentru a îndeplini obiectivele dezvoltării durabile și de conservare a mediului.

Acest articol prezintă posibilitatea și limitele adaptării unei surse de energie termică solară pentru necesarul de energie al unui consumator simulat în 79 de orașe ale României. Simularea efectuată în acest studiu utilizează metoda lunară pentru a estima nivelurile totale de acoperire a instalațiilor solare. Pentru a realiza simularea, este considerat un consumator cu o valoare $H = 16000$ W / K pentru încălzire și $H = 689$ W / K pentru alimentarea cu apă caldă. Acest lucru corespunde necesităților a 80 de apartamente pentru încălzirea și furnizarea apei calde. Aporturile lunare de energie solară au fost calculate și au arătat câtă energie regenerabilă ar putea produce acest tip de sistem. Gradele lunare de acoperire, precum și eficiența lunară sunt prezentate în acest articol pentru a exprima complet consumul solar pentru consumatorul ales.

Cuvinte cheie: panouri solare; eficiență; energie termică; grade de acoperire; clima românească

1. CONTEXT

Energy forms the basis for the economic development of any country and plays a significant role in improving the quality of life of the people living there. The importance of energy is apparent in almost every aspect of development and historical data reveals that there is a significant relation between the availability of energy and the economic activity. The use of renewable energy, especially of solar energy, in power generation, as well as in domestic and building applications, has gained significant appreciation worldwide to meet the goals of

sustainable development and environment conservation. The EU politics supports developing this area and introduces mandatory levels of renewable energy productions that rise every 10 years. As an EU member, Romania has the obligation to respect those and invest in developing this area. Increasing the overall efficiency of a solar panel system by improving energy capture but also by storing it more efficiently will result in the replacement of non-renewable energy systems with new sources.

However, at country level, there is no energy assessment that can lead to a national

assessment of the thermal potential for different thermal solar panel configurations.

In some papers on similar topics with this article (Iordache, 2018), the theoretical and practical limits of the use of thermal solar panels were shown (Iordache and Dragne, 2016). They have shown that solar panels can be used successfully in the preparation of heating energy serving a residential consumer. However, there are 5 climatic zones in Romania and the outdoor temperature and solar intensities vary from an area to another. This highlighted the need for a nationwide study that would provide an overview of the country. To the same extent, the problem of the profitability of these solar systems is compared with other systems (Iordache, 2017) using unconventional sources of energy or classic sources of fossil fuels.

This paper aims to estimate the capacity of using solar panel systems to produce the thermal energy needed by a residential consumer. From the thermal point of view, this is done by determining the coverage levels of the solar installation and of the solar energy system efficiencies (Dragne, 2019).

2. MATERIALS AND METHODS

The Romanian climate is appropriate for using the solar panels. This paper shows the possibility and the limits of adapting a solar thermal energy supply for the energy requirement of a consumer.

The national technical regulations and the European standards that use the solar energy for solar thermal panels are the following:

- SR EN 15316 / 4-3 - *Energy performance of buildings - Method of calculating energy requirements and system efficiency* - Part 4-3: Heat generation systems, solar thermal systems and photovoltaic systems Module M3-8-3, M8- 8-3, M11-8-3;
- SR EN 15316 / 6-6 - *Energy performance of buildings - Method of calculating system energy performance and system efficiency* - Part 6-6: Explanation and justification EN 15316-4-3 Module M3-8-3 M8-8- 3;

- MC 001/2006 - *Methodology of Energy Performance Calculation*.

To determine the climatic parameters and evaluate the heating period, we used:

- SR 4839 / 2014- *Heating installations, Annual number of degrees-days*;
- Annexes MC 001/2006 - *Energy Performance Calculation Methodology*.

In this paper, a new MC-001 proposal for the determination of solar systems was used for energy determinations (Iordache, 2008).

The calculation method used applies to residential or non-residential buildings fitted with solar energy storage and that use facilities for space heating and hot water.

The simulation done in this study uses the monthly method to estimate the total coverage levels of solar installations. In order to perform the simulation, a consumer with a value $H=16000$ W/K for heating and $H=689$ W/K for the hot water supply was considered. This corresponds to the need of energy of 80 apartments for the heating and hot water supply. The monthly intakes of solar energy were calculated, showing the amount of renewable energy this kind of system could produce. The monthly coverage levels as well as the monthly efficiency are shown in the following, in order to fully express the solar usage for the specific consumer. This study used a value $k_c=3$ for thermal solar panels and the following characteristics: $F' = 0.9$; $\alpha = 0.9$; $\tau = 0.85$; $G_C = 50$ l/m²h; $v = V/S_C = 50$ l/m². For the heat exchange the following values were used: $S_S = 0,1 \cdot S_C$ and $k_S = 600$ W/m²K.

Nominal heat temperatures for the heating system are as follows, $t_{T0} = 50$ °C and $t_{R0} = 30$ °C for one case, $t_{T0} = 70$ °C and $t_{R0} = 50$ °C for the second case; the hot water temperature was 60°C for one case and 50°C for the second case, while the cold water temperature was considered as constant throughout the year at a temperature of 15°C.

For 27 cities, the monthly averages of solar radiation intensities were computed for a horizontal capture area, IO, for all months of the year, according to the Mc001 methodology. For the remaining 52 cities, the values were calculated taking into account the mean radiations weighted with the inverse of

the distances from the nearest 3 cities for which the data were known.

The average monthly average temperatures for all months of the year according to SR 4839/2014 for 77 cities and for cities with no congested values were calculated taking into account the weighted average of the temperatures with the inverse of the distances from the most suitable ones 3 cities for which data were known. The formulas used for this method are the following:

$$t_0 = \frac{\frac{1}{d_1}t_1 + \frac{1}{d_2}t_2 + \frac{1}{d_3}t_3}{\frac{1}{d_1} + \frac{1}{d_2} + \frac{1}{d_3}} \quad (1)$$

$$I_0 = \frac{\frac{1}{d_1}I_1 + \frac{1}{d_2}I_2 + \frac{1}{d_3}I_3}{\frac{1}{d_1} + \frac{1}{d_2} + \frac{1}{d_3}} \quad (2)$$

The choice of the $H / (k_c \cdot S_c)$ report was done to represent as realistic as possible a solar investment for the chosen objective (residential building with 80 apartments). Thus, for heating, due to very large capture surfaces, a higher ratio values were chosen (Dragne, 2019), which implies a lower degree of coverage. For domestic hot water, lower values (Iordache, 2008) were chosen to provide a higher degree of coverage.

The cities used in the study are the following:

Zone 1: Calafat, Constanța, Drobeta Turnu Severin, Gura Portiței, Lugoj, Mangalia Moldova Veche, Reșița, Sânnicolau Mare, Sfântu Gheorghe (Deltă), Sulina;

Zone 2: Alexandria, Arad, Brăila, Bucharest, Buzău, Caransebeș, Călărași, Câmpina, Craiova, Curtea de Argeș, Deva, Drăgășani, Giurgiu, Gorgova, Grivița, Medgidia, Oradea, Pitești, Ploiești, Râmnicu Sărat, Râmnicu Vâlcea, Roșiori De Vede, Slatina, Slobozia, Târgoviște, Târgu Jiu, Timișoara, Titu, Tulcea, Turnu Măgurele, Urziceni, Videle, Zalău;

Zone 3: Alba Iulia, Bacău, Baia Mare, Bârlad, Botoșani, Cluj-Napoca, Dej, Dumbrăveni, Focșani, Galati, Holod, Iași, Petrani, Petroman, Piatra Neamț, Roman, Satu Mare, Sibiu, Sighetul Marmăției, Sinaia, Târgu Ocna, Tecuci, Vaslui;

Zone 4: Bistrița, Brașov, Bucin, Dorohoi, Predeal, Rădăuți, Suceava, Târgu Mureș;

Zone 5: Joseni, Miercurea Ciuc, Sf. Gheorghe (Mountain), Târgu Secuiesc.

The annual values were represented on charts, displaying distinct values for each case of heating or domestic hot water preparation.

3. RESULTS AND DISCUSSIONS

The results show that solar panels have good efficiency in Romania because of the specific climate, with warm and sunny days. Diagrams obtained for each case of heating and hot water preparation (depending on supply temperature variation) are shown in the following.

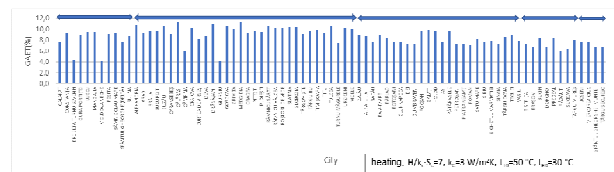


Fig. 1. Degree of coverage computed for heating, $H/k_c \cdot S_c=7$, $k_c=3 \text{ W/m}^2\text{K}$, $t_0=50 \text{ }^\circ\text{C}$, $t_{R0}=30 \text{ }^\circ\text{C}$



Fig. 2. Efficiency computed for heating, $H/k_c \cdot S_c=7$, $k_c=3 \text{ W/m}^2\text{K}$, $t_0=50 \text{ }^\circ\text{C}$, $t_{R0}=30 \text{ }^\circ\text{C}$

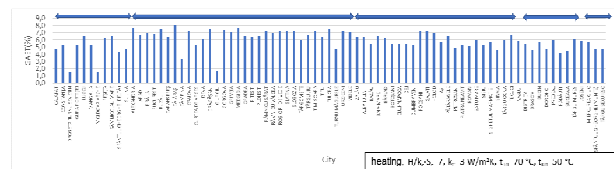


Fig. 3. Degree of coverage computed for heating, $H/k_c \cdot S_c=7$, $k_c=3 \text{ W/m}^2\text{K}$, $t_0=70 \text{ }^\circ\text{C}$, $t_{R0}=50 \text{ }^\circ\text{C}$

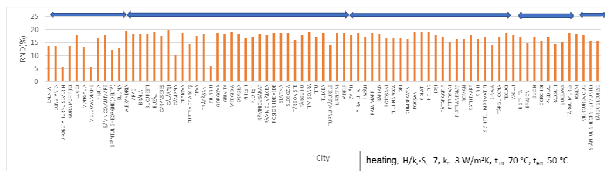


Fig. 4. Efficiency calculated for heating, $H/k_c \cdot S_c = 7$, $k_c = 3 \text{ W/m}^2\text{K}$, $t_0 = 70^\circ\text{C}$, $t_{R0} = 50^\circ\text{C}$

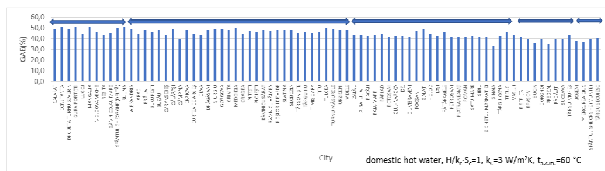


Fig. 5. Degree of coverage for domestic hot water preparation, $H/k_c \cdot S_c = 1$, $k_c = 3 \text{ W/m}^2\text{K}$, $t_{acm} = 60^\circ\text{C}$

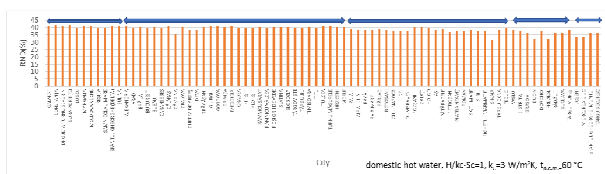


Fig. 6. Efficiency calculated for domestic hot water, $H/k_c \cdot S_c = 1$, $k_c = 3 \text{ W/m}^2\text{K}$, $t_{acm} = 60^\circ\text{C}$

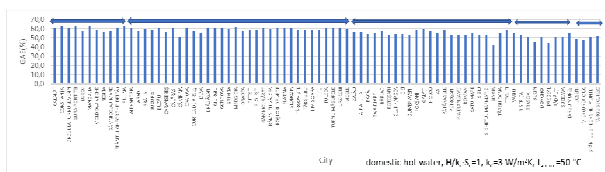


Fig. 7. Degree of coverage for domestic hot water preparation, $H/k_c \cdot S_c = 1$, $k_c = 3 \text{ W/m}^2\text{K}$, $t_{acm} = 50^\circ\text{C}$

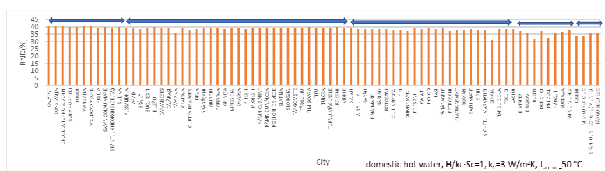


Fig. 8. Efficiency calculated for domestic hot water, $H/k_c \cdot S_c = 1$, $k_c = 3 \text{ W/m}^2\text{K}$, $t_{acm} = 50^\circ\text{C}$

The year efficiency of the system is much lower than the real efficiency of this setup because of the fact there are periods when the total power produced is much higher than the need of heating or hot water supply. In other words, for the sunny days with high temperatures the system produces thermal energy that the consumer cannot use, thus decreasing the efficiency. This matter causes some problems for the monthly input of the method used, because it limits some cities to get better results because of the lower duration

of the heating period. This can be seen in cities like Drobeta-Turnu Severin, Moldova Veche, Giurgiu and Câmpina, where this method shows lower than average results, with 5% less for both thermal indicators. If we exclude those abnormalities we can see that the average of zone 1 and 2 is higher than on the other zones, which it was expected.

Obtaining coverage levels of less than 10% (Figures 1 and 3) suggests that the solar panels can be used for heating in all regions but, with a lower investment cost, it can only sustain a fraction of the necessities of the consumer during the winter.

The general efficiency of the system for heating was over 20% (Figures 2 and 4) in all regions, but it doubles (to 40%) in the production of hot water supply. This leads to the fact that the chosen type of solar panels is recommended only for hot water supply purposes, where the system can produce 50-60% (Figures 5 and 7) of the energy required by the consumer.

On the preparation of hot water supply, due to the fact that the system works the entire year, results are very dependent on the climate factors and cities with lower temperatures (like Sinaia) get the lowest results (Figures 5 and 7). This shows that the current method is very reliable in this case. On the other hand, the results of efficiency given in Figures 2 and 4 show that this method requires using an average value for "the border cities" that have the heating period not very well estimated with the monthly method.

The difference between the coverage levels of Figures 5 and 7 show that, for 10°C more, the system loses about 10% of coverage, so we can estimate that, for various set up temperatures that are higher than 50°C , the system will lose about 1% for each 1°C . The efficiencies of both systems (Figures 6 and 8) are similar, almost independent of the temperatures used.

4. CONCLUSIONS

The results are encouraging for using a solar thermal system in Romania, especially for the preparation of hot water supply. Most

of all residential consumers would have the space needed to use solar panels for the presented cases, which determines that more than half of the energy needed for the preparation of hot water supply can be obtained using only solar collectors.

Those systems produce “free” energy, which provides an economy for the consumer for all cases presented in this paper. This aspect encourages the use of solar installations for the preparation of thermal energy in residential spaces.

The differences between the various locations chosen in similar climate regions (from 1 to 5) are relatively small, which determines that the values obtained in this study can be used for the whole Romania, depending on the climate regions. For the heating case we recommend the use of an average value for every climatic region, which would be more reliable than the use of this method for the “border cities” that may receive erroneous energy estimations. This aspect is to be discussed in future research, while trying to improve the method or to develop a better one.

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