
IMPROVING THE ESTIMATION OF ENERGY PRODUCED BY SOLAR THERMAL SYSTEMS

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ABSTRACT

In the context of the growing demand for energy from renewable resources, there has been a lot of interest in the use of systems that use solar energy. The basic principles for determining the performance of solar panels have been established since the 1980s, but the accuracy of these determinations has improved over the years. This paper presents the evolution of estimation methods of solar thermal systems in Romania in recent years and shows the qualitative evolution of these estimates, with obtained values much closer to reality.

Keywords: research; solar panels; residential buildings; renewable energies.

REZUMAT

În contextul creșterii cererii de energie provenită din resurse regenerabile, a crescut foarte mult interesul în utilizarea sistemelor ce folosesc energia solară. Principiile de bază de determinare a performanțelor panourilor solare au fost stabilite încă din anii '80, dar precizia acestor determinări a fost îmbunătățită pe parcursul anilor. Această lucrare prezintă evoluția metodelor de estimare ale sistemelor solare termice din România în ultimii ani și arată evoluția calitativă a acestor estimări, prin valori obținute mult mai apropiate de realitate.

Cuvinte cheie: cercetare; panouri solare; clădiri rezidențiale; energii regenerabile.

1. INTRODUCTION

Solar energy currently provides more than 6% of the total heating and cooling demand in the European Union (6). About 174 petawatt (PW) of solar energy reaches our atmosphere in a year. About one third of them are reflected back into space. The rest, 3,850,000 Exa-Joules (EJ) per year, are absorbed by the atmosphere, oceans and land surface, with a single hour of capture being equivalent to the total global energy consumption for a year, with solar energy being the largest available energy source, on the planet. This potential differs depending on latitude, being more important at the equator and lower at the two poles, as can be seen in (7). In most European countries, the average use of solar radiation intensity is 150 to 300 W / m². In other words, the potential of solar energy is huge and can be harnessed, providing much of the energy needed for heating and preparing hot water (2).

To use this resources (4), Romanian solar methodologies have evolved over the years, estimating even better the energy produced by

thermal solar panels for residential buildings (3).

2. CALCULATION ASSUMPTIONS

The next study aims to achieve a qualitative improvement of the current calculation methodology MC001 (2021 version) from the improved version of MC001 from 2018 (proposal), for the situation of the preparation of thermal agent for heating in residential buildings (1).

The values of the parameters used in the calculations conducted in this study were the following:

- a. The ratio $H / (k_c \cdot S_c) = 3, 5 \text{ or } 7$;
- b. The geometric correction factor of the captured heat flux, $F' = 0.9$;
- c. Global heat transfer coefficient of solar collectors, $k_c = 2, 3 \text{ or } 4 \text{ W / m}^2\text{K}$;
- d. Absorption coefficient of the collecting plate, $\alpha = 0.9$;
- e. Transparency coefficient of the glazed element of the collectors, $\tau = 0.85$;
- f. Angle of inclination to the horizontal plane of the sensors, $\varphi_i = 45^\circ$;

g. Angle of deviation of the catchment area from the SOUTH, $\varphi_a = 0^\circ$ (South);

h. The surface of the heat exchanger within the solar loop, $S_s = 0.1 \cdot S_c$;

i. The volume of the accumulation tank, $V_a = V / S_c = 50 \text{ l} / \text{m}^2$;

j. Global heat transfer coefficient of the heat exchanger within the solar loop, $k_s = 600 \text{ W} / \text{m}^2\text{K}$;

k. Flow of thermal agent circulated in the solar loop, $G_c = 50 \text{ l} / \text{m}^2\text{h}$;

l. The surface of the consumer central heating installation, S_{INC} -corresponding to 80 apartments;

m. Nominal temperatures of the heating medium when sizing the installation, $t_{T0}=50^\circ\text{C}$, $t_{R0} = 30^\circ\text{C}$;

n. Average solar radiation intensities, monthly averages, for a horizontal capture area, I_o , for all months of the year, according to the Mc001 methodology from 2006;

o. Average monthly outdoor temperatures for all months of the year, according to SR 4839/2014;

This building has a $H_{\text{inc}} = 16000 \text{ W} / \text{K}$ corresponding to heating of the 80 apartments chosen. The exterior climate was chosen to represent each calculation climate zone, represented by the following cities: Constanța (zone 1), Bucharest (zone 2), Cluj-Napoca (zone 3), Predeal (zone 4), Târgul Secuiesc (zone 5).

The difference between the two methods used for calculations (2018 proposal and 2021 version) is mostly because of the change with β_{ref} calculation because the 2021 version uses a new f_s factor that is added to I and represents the full sunrise hours. The values obtained by using a closer to reality factor for I for a certain number of operating hours only in the β_{ref} calculation better estimate the actual operation of these solar installations.

Both methods used in those calculations are monthly and they are presented as yearly yields of the solar thermal systems by averaging the monthly values calculated individually. The yearly coverage levels provide insight of the percentage of the annual energy that can be produced with the solar panels.

3. RESULTS AND DISCUSSIONS

Comparing the results obtained by both methods (8), significant differences were found using the same assumptions.

By increasing the value of the solar surface, the intention was to see if the differences between the two models are the same, bigger or smaller.

As it can be seen in Fig. 1, the differences between those two methods are visually distinguished. The new method estimates an increasing in the coverage provided by solar panels over the year, which means an increase in the overall energy produced by the same systems.

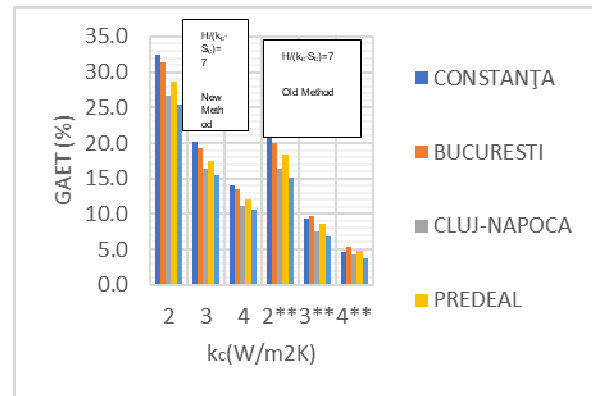


Fig. 1. Comparison of heating degrees calculated for heating, $H / k_c \cdot S_c = 7$, using a new calculation methodology and the old proposal for the MC001 methodology (case **)

In Fig. 2, the solar surface area was increased, which resulted in the decrease of the $H/(k_c \cdot S_c)$ value from 7 to 5 (due to the increase of S_c).

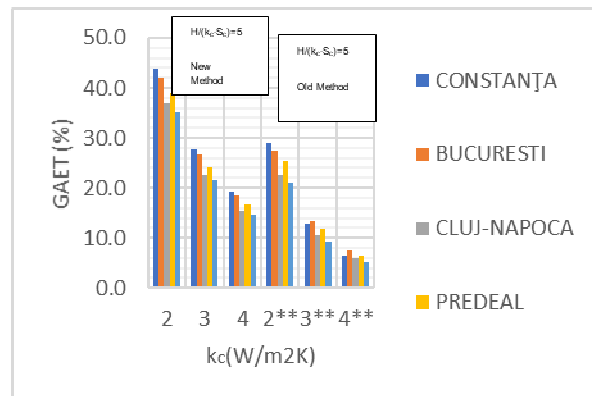


Fig. 2. Comparison of heating degrees calculated for heating, $H / k_c \cdot S_c = 5$, using a new calculation methodology and the old proposal for the MC001 methodology (case **)

The difference between the two methods used, 2021 one and 2018 one (***) is considerable, with an average 38,7% increase for the situation in Fig. 1, due of the inclusion of the sunrise factor. This was expected because raising the temperature in the boiler to a higher value and maintaining it inside the boiler is easier than raising to a lower value to more hours per day. In other words, the 2021 methodology model is more accurate and predicts the function of solar panels better than the 2018 proposal.

The difference between the models lowers in Fig. 2 to an average of 35,9% increase due to the higher capacity of the solar system. The sunrise factor is less important, because there is already a higher temperature in the boiler.

To furthermore demonstrate this aspect, the solar surface area was increased once more, with the $H/(k_c \cdot S_c)$ value decreasing from 5 to 3 (because of the increase of S_c).

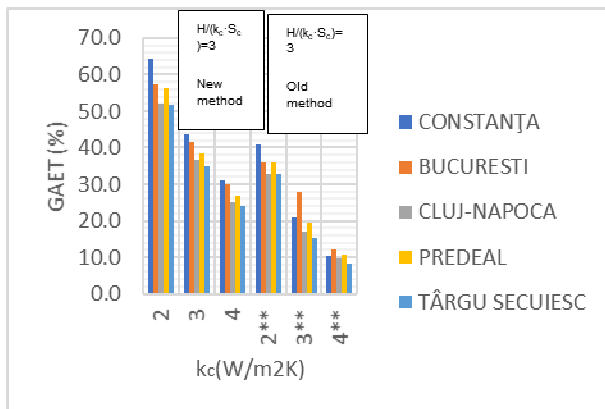


Fig. 3. Comparison of heating degrees calculated for heating, $H / k_c \cdot S_c = 3$, using a new calculation methodology and the old proposal for the MC001 methodology (case **)

The last case shows an increase of an average of 34,7%, which actually indicates that as the solar surface increases, the difference between the two models will be above 30%. In other words, the new model estimates the solar panels yields to be better with more than 30% than the old model, this value being closer to reality than older model.

Those results show how much the calculation model was improved and that is because of the observation of real time models.

Using this new and improved methodology the calculated solar yields also

show the influence of the climate factors, for example, a Constanța (Fig. 4) provides better percentages than Târgu Secuiesc (Fig. 5):

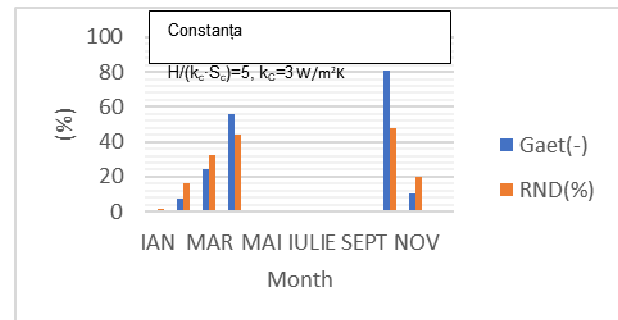


Fig. 4. Yield and degree of coverage calculated for heating, Constanța city

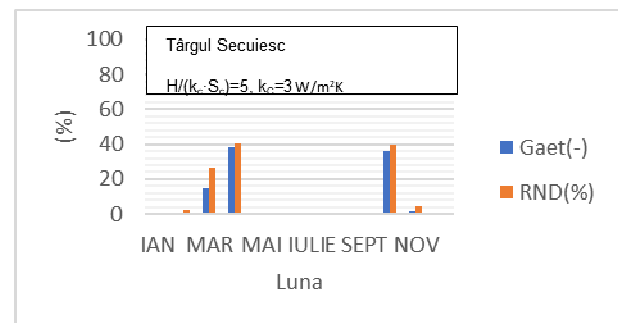


Fig. 5. Yield and degree of coverage calculated for heating, Târgu Secuiesc city

As it can be noticed from the above, the main drawback of the analyzed systems is that they do not provide much energy during winter, especially in cold climate zones, where they are useful only during spring and autumn.

4. CONCLUSIONS

This paper shows how the method of estimating the yearly solar yields has improved over the years, being more accurate into predicting the reality.

The inclusion of the f_s factor was done with the observation of the solar systems and the specific values for it have been estimated in several stages, which resulted into individual values each month. Those values can be further improved by comparing the estimations with the experimental data, which will be done by Romanian researchers in the future.

This paper also provides a solid example for five selected representative cities that show how much one can rely on current solar panels

to supply thermal energy for the heating of buildings. From the charts developed using the current methodology, it can be seen that, even with a minimum investment, as compared to the heated surface - which is specific to tall buildings - more than 10% of the energy can be provided exclusively from solar panels. Moreover, by using state-of-the-art solar panels, which are more expensive, this energy can be tripled. In other words, solar systems have become a must have component of a

system that aims to provide most of the energy for heating from renewable resources (in accordance with the current international geopolitics) and, together with other types of systems (5), they can achieve this goal.

It can be concluded that the calculation model used in the methodology is very close to the reality, the estimations providing a good insight of what can be expected from the thermal solar systems.

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