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ANNUAL ENERGY PERFORMANCE OF SOLAR THERMAL SYSTEMS IN BRAŞOV, ROMANIA

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Abstract: *In Romania, energy for heating domestic hot water and food preparing represents about 43% of the energy provided in buildings. About 10% of the energy consumption in buildings comes from Renewable Energy Sources (RES). For this reason, energy efficiency in buildings represents a top objective at national levels. This paper presents 3 applications of solar thermal collectors (for heating and domestic hot water) and tries to determine the most efficient method considering the annual solar energy gain. TRNSYS 17 simulation software is used to simulate the building heating load and energy consumption. Real weather data are used for simulation.*

Key words: *building energy simulation, TRNSYS simulation, solar heating system.*

1. Introduction

Energy consumption in buildings represents a large share of the world's total end use of energy. Globally, buildings account for close to 40% of total end use of energy. Given the many possibilities to substantially reduce buildings' energy requirements, the potential savings of energy efficiency in the building sector would greatly contribute to a society wide reduction of energy consumption [5].

• Climatic and geographic description

Braşov has a temperate-continental climate specific to transition between oceanic and continental temperate climate. Temperature variations are large, the average temperature registered with the local Delta-T weather station, during 2006-2011, being 7.8 °C, the lowest temperature being recorded in January 2007 (−21 °C) and the maximum in August 2009 (30 °C). The Braşov basin area is characterized by thermal inversions, temperatures on the surrounding mountains being higher than those from the depression; cold air masses accumulate here because of the surrounding mountains, which prevent their movement.

The proposed study uses the weather data registered with a local Delta-T weather station. Table 1 presents the monthly values of the wind speed and wind direction for the Braşov urban area, for 2011. In the basin area the wind regime is influenced to a great extent by the surrounding mountains; in this site, recorded values of the wind speed are low with yearly means under 2 m/s.

During the six years there were only a few days with values higher than 10 m/s (the maximum values registered in 2008

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Wind profile for Braşov [*Lat. 45.39, Long. 25.35*] Table 1

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
2011												
WS	0.69	0.25	0.61	1.36	1.03	1.60	1.28	1.21	1.09	0.63	0.59	0.88
Max_WS	5.65	3.69	**25.09**	10.61	7.39	8.36	8.00	5.52	6.89	4.72	4.29	7.40
WS - wind speed [m/s]; Max_WS - maximum wind speed [m/s]												

were: 13.01 m/s in January 27, 13.26 m/s in December 4, and in March 18th 2011: 25.09 m/s).

In this section an analysis of the global solar radiation obtained in real sky conditions (real meteorological data specific to Braşov area were used) for different solar collector orientation. Thus, besides the global energy values captured by a fixed horizontal surface there are also computed:

- values of the global energy captured by a solar collector with an optimum inclination angle [1], [2];
- values of the global energy captured by a solar collector with a single axis tracking system;
- values of the global energy captured using continuous tracking (the maximum available global energy).

As seen in Figure 1, the percent of captured radiation due to tracking is considerably higher than that on a fixed horizontal surface; therefore the total energy on a fixed horizontal surface can represent 80% of the maximum available energy while using an efficient tracking system can attain 98%.

It also must be mentioned that the study is for an urban basin area and it is envisaged that, the diffuse fraction has a distribution specific to analyzed location, showing a significant influence on the radiation quantity on an absorber surface. It can be also noticed, the diffuse radiation represents, during a year, at least 27% from total radiation (this value represents the minimum value recorded in August), Figure 2.

The lower contribution of the diffuse radiation in the total radiation is also recorded during June, July, September and October (32-38%) when the clearness index has higher values.

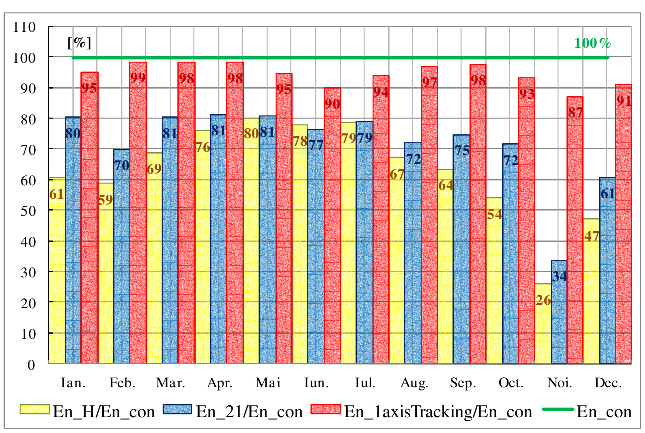

Fig. 1. *The capturing efficiency of global radiation for a fixed horizontal surface and a surface with single axis tracking*

The highest values of the ratio *En_diff/En_g* are recorded during December and January-February (over 60%) when the clearness index records the minimum values.

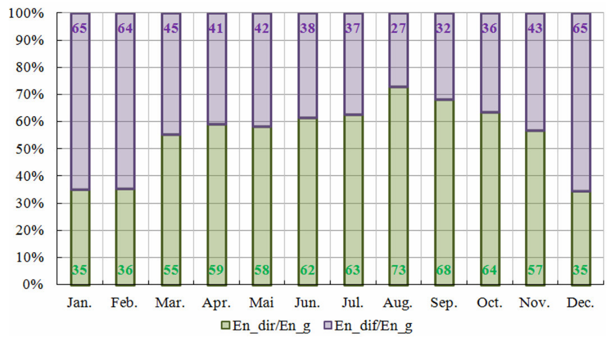

Fig. 2. *Direct and diffuse share of total radiation*

The monthly mean temperatures are presented in Figure 3. The minimum temperature was registered in January (−16.96 °C) and the maximum in August (31.39 °C). Braşov is characterized by long winters with low temperatures that lead to an extended period that requires space heating.

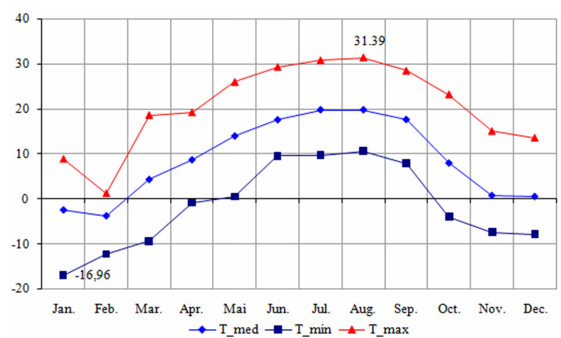

Fig. 3. *Monthly temperature distribution (min, max, medium)*

- **Building design**

The analyzed building is used as an office space with a total area of 260 m^2. The two floors of building provide thermal comfort by using radiant under floor heating. The building has an optimized architectural floor that allows the natural circulation of air flow through natural ventilation. The second floor walls are made of glass that allows daylight to pass through and benefit of the natural lighting when possible.

The building benefits from thermal insulation having a 10 cm layer of expanded polystyrene on the external walls and low-E glass windows, assuring a satisfactory lever of thermal comfort with minimum thermal losses. In the next stage, TRNSYS 17 simulation software is used to calculate space heating and cooling loads and also energy consumption in the proposed building [3], [4]. Using Trnsys3D plug-in, the 3D model of the building (Figure 4) was created and imported in TRNSYS simulation environment. Using

TRNBuild, the building was defined in detail e.g. the structure of the walls, windows, doors, the thermal behaviour, the adjacencies between zones etc.

The main input data necessary for simulation are:

- the climatic parameters of the building location;
- architectural elements of the building (walls, windows etc.);
- characteristic of the building envelope;
- equipment and occupants working scenarios;
- internal energy gains;
- heating, cooling and ventilation schedules.

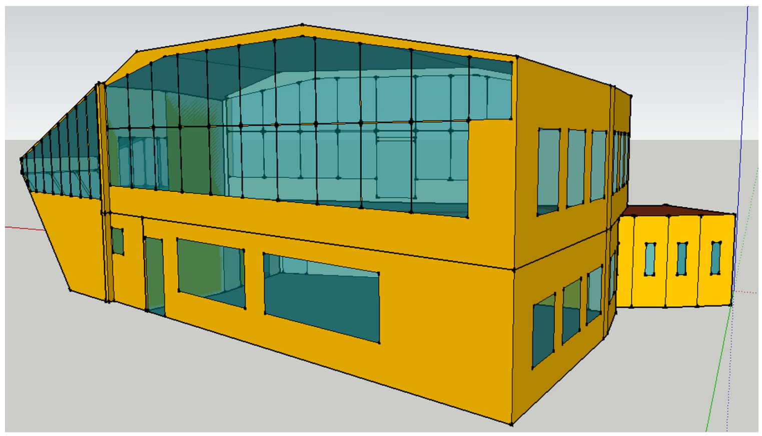

Fig. 4. *Trnsys3D model of the building*

2. Method Used

Compared with traditional methods of calculating energy consumption, Trnsys enables more accurate and lifelike energy calculations.

The system is defined by a set of interconnected components with purpose to solve a certain task. Trnsys has a modular approach of building energy simulation problem that gives flexibility in modelling a variety of energy systems with different degrees of complexity.

In order to have a real simulation environment, the Type 99 data reader and processor was used.

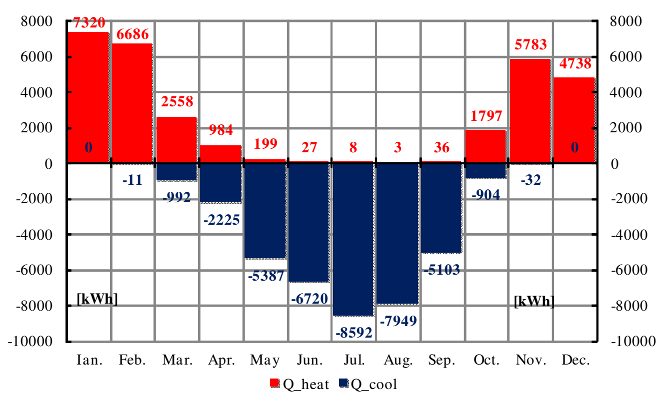

Fig. 5. *Cooling and heating load*

This type serves the main purpose of reading weather data in user format at regular time intervals from a data file, converting it to a desired system of units and processing the solar radiation data to obtain tilted surface radiation and angle of incidence for an arbitrary number of surfaces [3], [6], [7]. A typical meteorological year was created, in order to provide hourly weather data for easy input and reading of real values for solar radiation, wind speed and direction, temperature and relative humidity [1], [2].

A 0.125 h time step simulation was realized in order to calculate the yearly heating and cooling load for the building. The heating temperature was set for 21 degrees and the cooling temperature for 24 degrees Celsius. The occupation schedule and the internal gains from people, computers and other gains were established. In Figure 5 the yearly cooling and heating load are presented. It can be noticed, because the temperature variation in a day is considerable for the basin area of Braşov, in some nights of summer the temperature can drop below 20°C, thus making necessary to use the heating system.

The total space heating load is equal to 31138 kWh, corresponding to 150 kWh/m^2 of heated floor area.

Because the analyzed building is an office building, the domestic hot water need is low therefore the energy required for heating is primary.

3. Results and Discussions

During the cold period (October-March), because the intensity of the solar radiation is low, the auxiliary heater will take over the domestic hot water preparation and the heating of the building. In the summer (April-September) the solar collectors will be mainly used for DHW preparation. The system produces domestic hot water stored in a heat exchanger of the tank and water for space heating stored in tank. The heated water in the tank goes to the two low temperature radiant floors. The heat from the solar collector is transferred to the tank through a heat exchanger placed in the bottom of the tank. DHW is prepared with a similar heat exchanger placed above the solar heat exchanger and also at the top in the area heated by the auxiliary heater. During the winter the external auxiliary heater (boiler) provides the necessary heating. The Trnsys model of the system is represented in Figure 6.

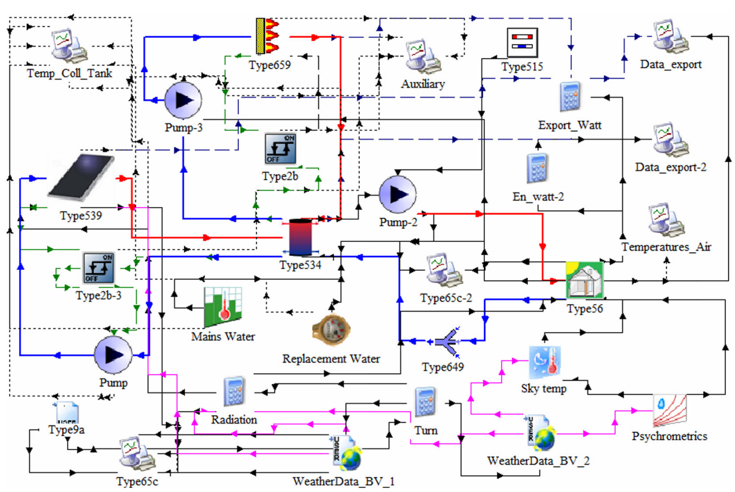

Fig. 6. *TRNSYS model*

The solar water and space heating application contains a circulation pump, solar collectors (10 m^2), solar tank and a controller that transmits a control signal to the circulating pump. The operating condition is the outlet temperature from the solar collector is higher than the temperature in the tank.

One of the many benefits of using Trnsys is the dynamic plotting where the behaviour of the system can be easily observed at a user defined time step. The simulations are performed over one year. The advantages, disadvantages or any inconsistency of the system can be detected thus eliminating time and cost expenses.

In Figure 7 the solar energy gain (Q_soll_kWh) and the auxiliary heating rate (Q_aux_kWh) can be observed during 2 weeks (one week in the spring. While approaching 12 noon, when the solar potential has maximum value, the solar collector system takes over the heating circuit and the auxiliary heater is turned off.

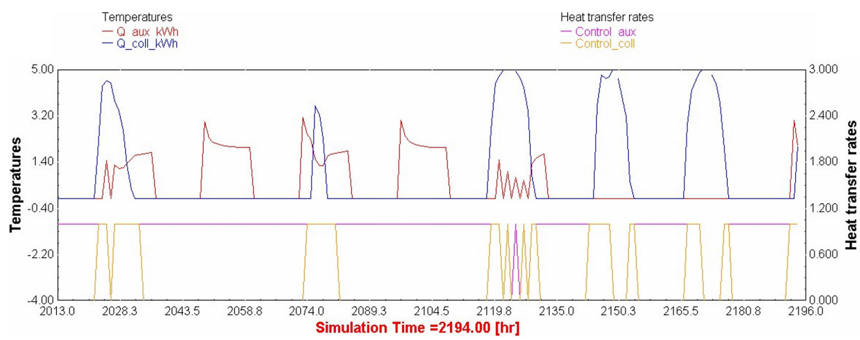

Fig. 7. *Solar gain and auxiliary heating rate during 2 weeks in March-April*

The outlet temperature of collectors is presented on a monthly diagram in Figure 8. The average temperature oscillates between 25 and 80 °C during the year.

The maximum temperature is limited to 80 °C taking into consideration that the input temperature in the active layer is limited to 35 °C and the temperature of domestic heat water is around 40 °C. The air temperature on the building varies according to a schedule. Thus during the heating season: January - the 15th April and 1st October - December the maximum temperature is fixed to 21 °C during the workday and 15 °C during the weekend and night.

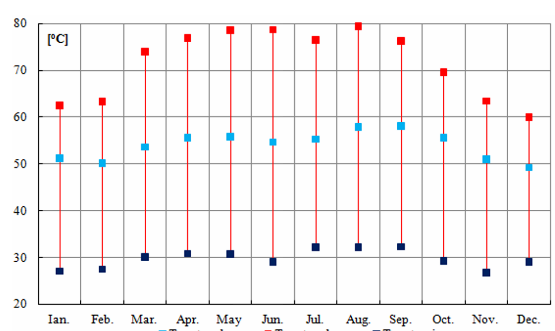

Fig. 8. *Monthly outlet temperature of collectors (south 21^o oriented)*

The temperature of water supplied to the radiant floor is limited at 35 °C. When the heating circuit is turned on, the temperature in the building rises at the set temperature (Figure 9) and remains constant until the end of the working day.

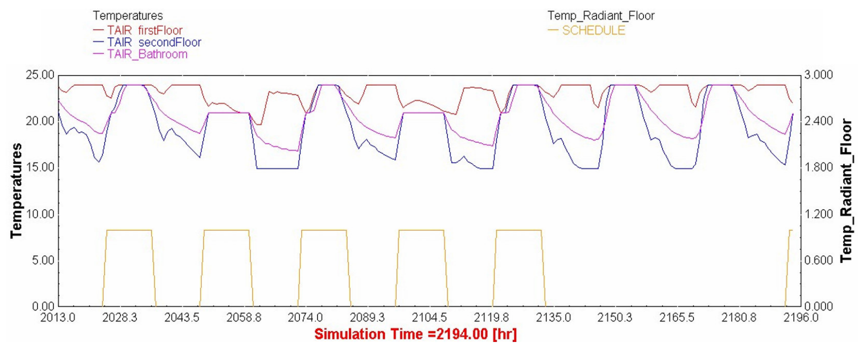

Fig. 9. *The working schedule and air temperature of building during 2 weeks March-April*

The tank temperatures are monthly represented in Figure 10. The top temperature drops during the January, February, November and December. However, the average tank temperature covers the heating demand and DHW.

In Figure 11 the solar energy gain is presented for the three different systems. The three systems were simulated at a time step of 1 hr for an entire year (8760 hr). It can be observed that the system with single axis tracking has a higher efficiency and the solar gain is greater, leading to a decrease in auxiliary energy consumption.

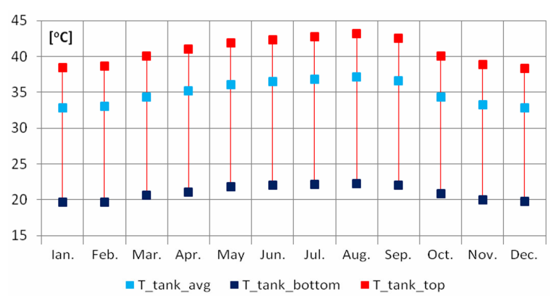

Fig. 10. *Water temperature in the storage tank*

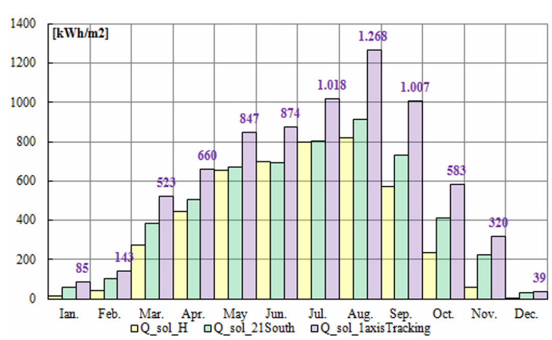

Fig. 11. *Solar energy gain for horizontal surface, 21 degrees slope and single axis tracking system*

4. Conclusions

This paper analyzes the influence of the orientation system of solar-thermal collectors on the intake of solar energy used for heating and domestic hot water preparation for an office building; the main objective was to make a calculation closer to reality that lead to the adoption of an advanced hourly method calculation simulated with Trnsys software.

All simulations are based on real weather data. In this sense a weather data base was created based on data provided by a local weather station, data that have been imported in Trnsys software to minimize the influence of external factors that could alter the results.

The study highlighted the benefits of using tracking systems for solar-thermal collectors taking into account that the global solar energy (obtained on the horizontal surface) for a basin area is reduced, respectively about 1350 kWh/m^2 compared with 1950 kWh/m^2 - the maximum available solar energy obtained by a surface with continuous orientation.

Using a south oriented surface with an inclination angle of 21 °C leads to an increase of 20% of captured solar energy comparing to a horizontal surface, respectively with 60% in the use of a single axis tracking system. Thus, the study emphasizes that using tracking systems is more efficient than using fixed solar collectors. The surface of solar collectors can be substantially reduced, lowering the investment cost.

Before implementing a system containing tracking a detailed analysis of cost should be made. Depending on the tracking solution, for some geographical areas, tracking is not a viable solution increasing the cost of production without the return of investment/investment rollback in a reasonable amount of time.

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