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The efficiency of harnessing thermal-solar energy in existing buildings connected to the district heating system*

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Rezumat. *Valorificarea surselor regenerabile de energie (SRE) în scopul acoperirii cererii de energie pentru încălzirea clădirilor și prepararea apei calde menajere reprezintă una dintre soluțiile majore de reducere a consumurilor de combustibili fosili respectiv a emisiilor asociate de CO_2 și a creșterii securității în domeniul energetic. În această direcție, eficiența de utilizare SRE constituie unul dintre cele mai importante obiective în contextul energetic actual internațional. Pornind de la considerentul că energia termosolară (SRE-S) reprezintă forma de energie cea mai răspândită, curată și ușor valorificabilă, în concluzie cea mai reprezentativă formă de energie cu potențial scăzut de temperatură convertibilă în energie termică, obiectivul acestei lucrări este de a evidenția importanța creării premiselor în vederea integrării eficiente a acesteia în clădirile existente racordate la sistemul districtual de încălzire (DH). În acest sens, au fost efectuate un set de simulări operaționale pe clădirea de referință, pe parcursul unui an de operare, pentru diferite scenarii de anvelopare, în scopul de a evalua impactul configurației consumatorului asupra eficienței de utilizare SRE-S în clădiri.*

Cuvinte cheie: surse regenerabile, energie termosolară, eficiență energetică, clădiri

Abstract. *Using renewable energy sources (RES) in order to cover heat demands for space heating and domestic hot water preparation represents one of all major reduction solutions for diminishing the consumption of fossil fuels, lowering the quantities of CO_2 associate emissions and increasing the energy security in this field. In this direction, the efficient use of the RES is one of the most important goals in the nowadays international energy context. Starting from the premise that solar energy (RES-S) represents the most widespread, the most representative and the most reachable form of renewable energy with lower potential that can be converted into thermal energy, the aim of the case-study is to highlight the importance of creating the optimal premises in order to effciently integrate it, into existing buildings connected to the district heating (DH) system. In this regard, a set of operating simulations were carried out on the targeted building, during one year of operation, for different types of configuration, in order to evaluate the impact of their performances on the solar-thermal using efficiency.*

Key words: renewable sources, thermal solar energy, efficiency, buildings

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1. Introduction

In the actual context, to a global level in the field of energy consumption and harnessing the energy resources, there is a multitude of ways to answer the challenge of sustainable development. An essential objective is to optimize the use of energy and the energy resources, focusing on the percentage increase in harnessing renewable and clean sources. Optimizing the energy balance in the urban area meets these goals. In Europe, 72% of its population lives in urban areas, percentage that will continue to grow until 2050 till 84% (United Nations estimation, 2008).

Identifying the issues that set the grounds for the energy performances reduction of the existing buildings connected to the district heating system represents the first step in increasing the energy efficiency of the thermal system in both stages - rehabilitating, in order to achieve the initial performances set during the design stage and the technological modernization stage. It is essential to significantly reduce energy losses throughout the lifetime of buildings. The energy loss in buildings is mainly due to the inadequate energy characteristics of the envelope (walls, floors, roofs, doors, windows, etc). The exterior walls of the buildings represent a major source of heat loss mainly through transmission in relation to the other elements part of the envelope. The percentage rises to a share of 30-40% in the composition of heat losses. The materials used in the structure of the exterior walls have considerably diversified from both, the technological applied and the accomplished energy performance point of view, allowing the configuration of a great number of scenarios of energy optimization.

As the thermal solar energy is still considered economically uncompetitive in relation to the classical thermal sources that use fossil fuels, in case of significant expansion of the district heating systems, as a result of the intensive urban development, the integration of the thermal-solar energy becomes the main clean competitive technology [1,2].

Modifying in time the thermoenergetic characteristics of the existing building's envelopes, (ex. caused by the gradual thermal enveloping, etc.), generates important variations in the heating systems' operating parametric having a great impact on the systemical efficiency of using energy resources, harnessing renewable energy resources respectively. In this context, the biggest challenge is to efficiently combine from an energy point of view, two complementary concepts, the buildings' energy efficiency and the efficiency in using RES in buildings.

In this regard, a number of operational simulations were carried out on the reference building during one year of operation, for different scenarios of gradual enveloping, in order to quantitatively and qualitatively assess the impact of the consumer's configuration on the efficiency of active use of the energy resources with low thermal potential, particularly the thermal-solar energy (RES-S) in buildings.

2. Case Study

The consumer's profile.

The enveloping level of a building is mainly given by the typology of the elements used in the structure of the exterior walls. Several representative structures are identified in table 1 for an existing building located in urban area, height conditions Ground Floor+Attic and the frequently used rehabilitation/modernization scenarios related:

Tabel 1

Working scenarios for structural exterior walls of efficient masonry

Scen. No.	Exterior wall	Type of exterior wall	Thermal conductivity λ	Thermal transmittance U	Thermal transmittance resistance R
-	-	-	W/(mxK)	W/(m^{2}xK)	(m^{2}xK)/W
1	EW1	One-layer brick masonry 30 without EIFS*	0,228	0,725	1,38
2	EW2	One-layer brick masonry 38 without EIFS*	0,217	0,543	1,84
3	EW3	Multi-layer brick masonry 38+25 without EIFS*	0,249	0,386	2,59
4	EW4	One-layer brick masonry 30 with EIFS* (mineral wool 12 cm)	0,098	0,224	4,46
5	EW5	One-layer brick masonry 38 with EIFS (mineral wool 12 cm)	0,105	0,204	4,91
6	EW6	Multi-layer brick masonry 38+25 with EIFS* (mineral wool 12 cm)	0,135	0,176	5,67

EIFS* - Exterior Insulation and Finish System

Increasing the role of the envelope as an active interface between the outdoor and indoor environment and its capacity to adapt to the operating conditions by future incorporating the state-of-the-art materials with higher thermal insulation properties into the structures (silicates, phase change materials PCMs, vacuum material embedded), can lead to the reduction of the energy footprint of an existing building up to half of the initial value.

Next, we will refer to an annual active thermal system for space heating and domestic hot water indirect preparation for a multifamily dwelling (no absence) building, situated in East-European geographical area with a temperate moderate-to-cold climate, having the following characteristics:

- it is situated in the climatic zone II, conventional outdoor temperature for calcul in cold season is -15°C and aeolian zone IV, [3];
- it is situated in the insolation zone II, annual global solar average radiation respectively difusse radiation taking into account are 1.293,3 kWh/m^2 respectively 585,7 kWh/m^2, [4]; The annual average duration of sunshine is between 2000 - 2100 hours/year.
- the altitude and latitude are 157 m respectively 47° North;
- the total build area is 496 m^2, envelope area (heat transfer area) is 796 m^2 and interior heated volume, 1.456 m^3;
- the compactness coefficient A/V is 0,55;
- the classe of importance is III (normal), the cathegory of importance is D, (low importance).

The thermoenergetic characteristics and the heat demands of the reference consumer for the scenarios suggested in table 1 are centralized below:

Tabel 2

Thermoenergetic characteristics of the reference building

Scen. No.	Global coefficient of thermal insulation of the building G	Hourly specific space heating demand	Annual specific space heating demand	Energy classification of the building function of the annual specific heating demand*	Energy classification of the building function of the annual specific domestic hot water demand*	Integrated energy classification of the building *
-	W/(m^3 x K)	W/m^2	kWh/(m^2 x year)	-	-	-
1	0,70	111	173	D	B	C
2	0,65	105	130	C	B	C
3	0,63	99	94	B	B	B
4	0,60	93	57	A	B	B
5	0,60	92	52	A	B	B
6	0,59	90	46	A	B	B

* According to the classification system and energy certification in Romania.

The thermoenergetic characteristics of the reference building for the suggested working scenarios were established with the computing programs and thermotechnical and energetical simulations [5,6]. The calculation methodology is according with the Romanian standards [7,8].

Hybrid Thermal System Configuration. Working Method.

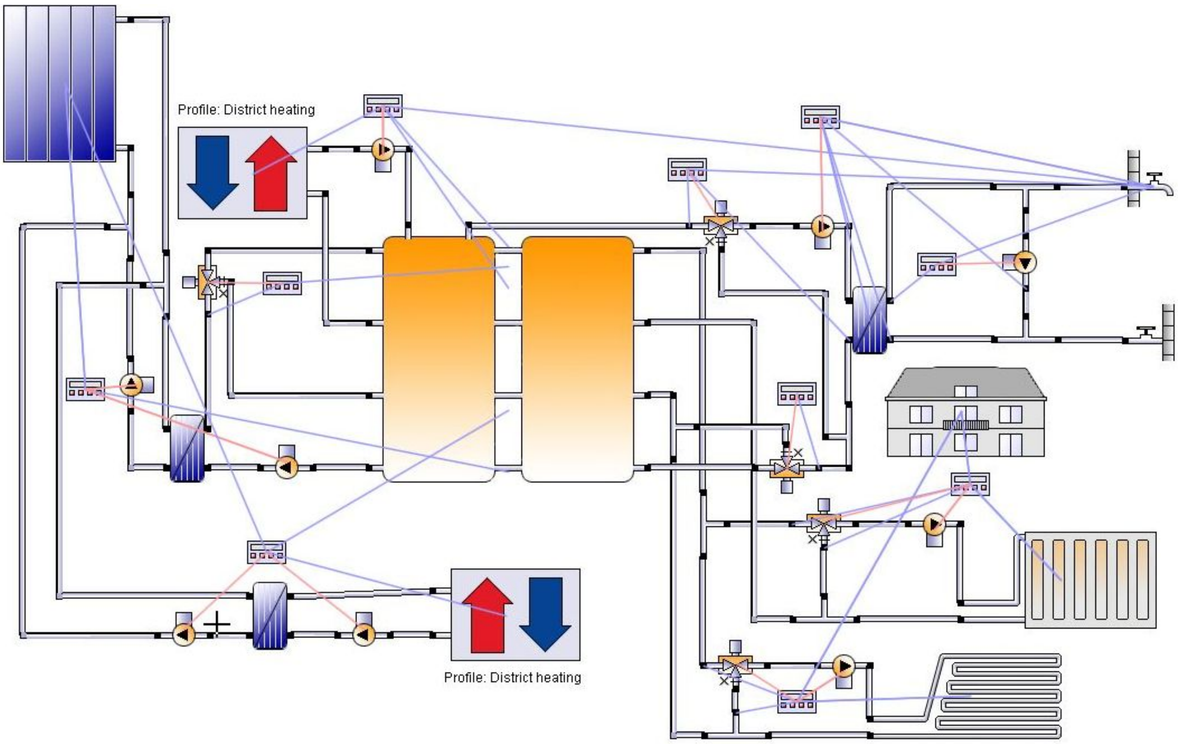


Fig. 1. Hibrid heating system - Hydronic schematic [4].

The operating regime in the hybrid thermal system is with variable flow. To ensure a constant and certain flow of the entire collecting field, (without stagnation areas of the solar agent bearing the risk of increasing the temperature in the system), the volumetric flow must be high enough. In this case, the volumetric flow is automatically adjusted function of the temperature in real time in the storage tank, the temperature of the collecting field respectively. Being a medium-sized collecting field, the thermal inertia and the generated delay in the action of control are negligible.

For a quantitative and qualitative energy assessment of the hybrid system, the following performance indicators were analyzed:
- the annual solar fraction;
- the annual solar thermal energy delivered to the system;
- the solar collector field yield;
- the annual global energy efficiency of the hybrid heating system Ef_a;

The following expression was used to calculate the annual energy efficiency of the hybrid heating system:

$$Ef_a = Q_c / (E_{aux} + E_p) \qquad (1)$$

where:

Q_c represents the annual energy, effectively consumed by the consumers, including the energy consumption for domestic hot water DHW and for space heating, in kWh;

E_{aux} - heat generator fuel and electrical energy annual consumption, in kWh;
E_p - annual electrical energy consumption of pumping system, in kWh.

Solar fraction is defined as a fraction between annual solar heat delivered in the heating system and the sum of annual auxiliary heat delivered by the auxiliary source (district heating source) to the system and the annual solar heat delivered in the heating system.

3. Results and discussions

The simulations carried out on the reference system, (computationally achieved with the help of the simulation software Polysun [4]), during one year of operation, led to the following results (the most representative are centralized in table 3):

Tabel 3

The hybrid heating system's performance indicators

Scen. No.	Annual solar fraction	Annual thermal solar energy delivered to the system	Collector field yield (related to the aperture area)	Annual energy efficiency
-	%	kWh	kWh/(m^2 x an)	-
1	13,1	59.317,7	796,3	1,32
2	16,3	58.406,4	784,1	1,13
3	20,7	57.395,3	770,5	0,94
4	28,9	56.061,5	752,6	0,73
5	30,3	55.919,6	750,7	0,70
6	32,7	55.821,1	749,4	0,66

In chart no. 2, the solar fractions obtained for the reference scenario no.1 and scenario no. 6 respectively, are presented in a comparative way:

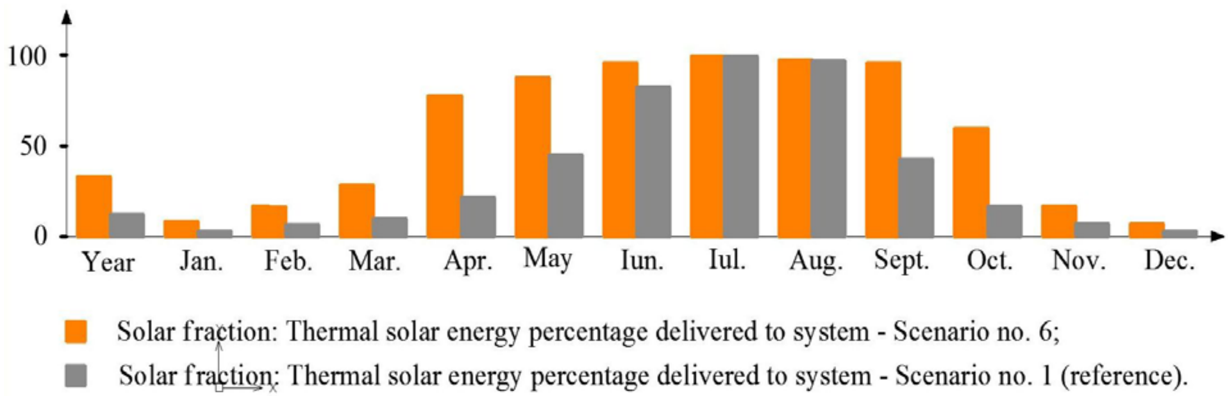
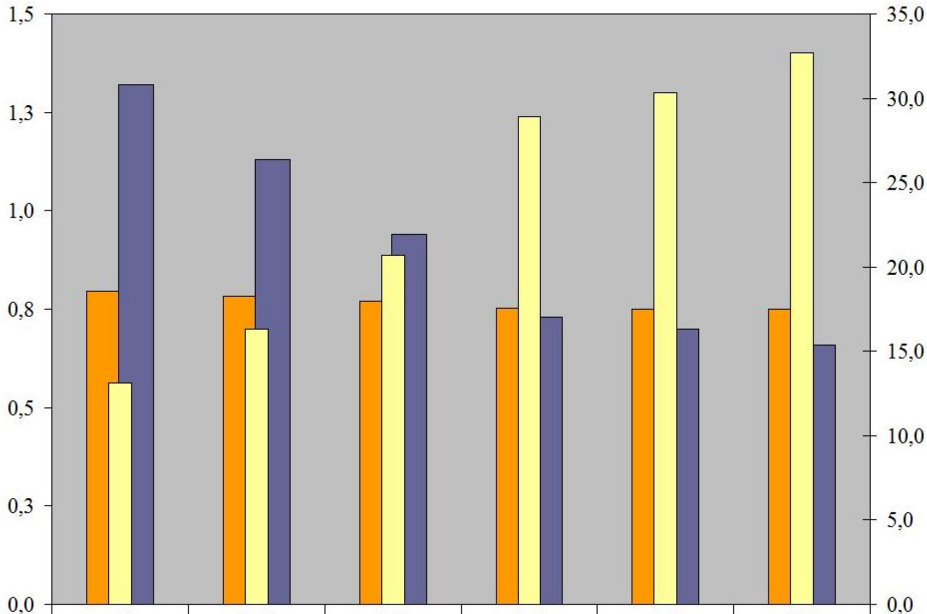


Fig. 2. Fractions of solar energy to the system.

In chart no. 3, the performance indicators achieved in the six scenarios of envelope configurations for the reference building are graphically represented:



Global coefficient of thermal insulation of the building, W/(m³xK)	0,70	0,65	0,63	0,60	0,60	0,59
Collectors field yield (MWh/m²xyear)	0,796	0,784	0,771	0,753	0,751	0,749
Annual energy efficiency	1,32	1,13	0,94	0,73	0,70	0,66
Annual solar fraction	13,1	16,3	20,7	28,9	30,3	32,7

Fig. 3. System performance indicators - Comparative chart.

The followings were observed within the simulation scenarios for the suggested thermal consumer:

- Unlike the individual thermal consumers, (equipped with its own heating and domestic hot water preparation systems), for which the solar fraction has an upper limitation due to the periods with thermal energy excess [9], in the case of integrate the thermal-solar collector fields in the district heating system in a decentralized way, the solar fraction can rise in order to cover the thermal demand, (100% DHW), without the risk of appearing heat excess in the thermal system and without enlarging the storage capacity (the excess heat being taken over by the district heating network);
- The rehabilitation/modernization of the building's envelope influences ascending the participation share of the renewable energies with low thermal potential, (particularly the solar fraction), but the effect on the thermal field yield and on the annual global energy efficiency of the hybrid thermal system, respectively, is a decreasing one;
- To avoid a negative impact of the gradual modernization of the existing buildings equipped with technologies that harness renewable energy sources with low thermal potential, a number of compensating measures in order to improve systemic overall performance (ex. long-term thermal-solar energy storage, redirecting the thermal-solar energy in the district heating network, reducing the operating temperature in the district heating system, etc. [10]).

4. Conclusions

In the actual energy context that focuses on the reduction of energy consumption as well as on increasing the energy economy in the existing buildings, the greatest challenge is to optimally combine two complementary concepts - the energy efficiency of the buildings and the efficiency in harnessing the renewable sources of energy in buildings, respectivelly.

In order to increase in terms of energy efficiency the share of renewable energies usage in buildings it is compulsory to elaborate and comparatively analyse the energy balance sheets of the heating systems. One can increase the share of RES participation in the energy mix only after the necessary premises of efficiently integrating and establishing the new optimized parametric system for the operating of heating system are ensured.

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