

The optimal solar capture surface for building heating: method, parameters and scenarios

Suprafața optimă de captare solară pentru încălzirea clădirilor: metodă, parametrii și scenarii

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Rezumat: Lucrarea analizează dimensionarea instalațiilor solare termice utilizate pentru încălzirea clădirilor și prepararea apei calde de consum, prin introducerea unui parametru esențial de optimizare: raportul dintre capacitatea de transfer termic a clădirii și suprafața de captare solară (H/S_C). Pe baza acestui indicator, este evaluată performanța unui sistem solar instalat într-o clădire colectivă situată în Zona Climatică II (București), utilizând captatoare plane cu k_C = 3 W/m²K și un regim de temperatură scăzut (50/30°C). Studiul include determinarea parametrilor termici ai buclei solare, analiza randamentelor lunare, calculul gradului de acoperire energetică și evaluarea balanței energetice sezoniere. Rezultatele arată o contribuție solară semnificativă în perioadele de tranziție (martie–aprilie, septembrie–octombrie), cu acoperiri ce depășesc 100%, dar o eficiență redusă în sezonul rece (15–30%). Sunt analizate trei scenarii de dimensionare (H/S_C = 1.3, 11.3 și 52.2), evidențiind compromisurile dintre investiție, performanță și riscul de supraproducție. Concluzia principală este că dimensionarea optimă se obține pentru lunile de tranziție (octombrie/aprilie), în timp ce dimensionarea pentru luna critică (decembrie) devine neeconomică fără stocare sezonieră sau surse auxiliare.

***Cuvinte cheie*:** instalații solare termice, performanță energetică, sursă auxiliară

***Abstract*:** This study investigates the sizing of solar thermal systems used for space heating and domestic hot water production by introducing a key optimization parameter: the ratio between the building's thermal loss coefficient and the installed solar collector area (H/S_C). Using this indicator, the performance of a solar thermal installation serving a multi-apartment building located in Climate Zone II (Bucharest) is evaluated. The system employs flat-plate collectors with k_C = 3 W/m²K and operates under a low-temperature regime (50/30°C). The analysis includes the determination of thermal transfer modules, monthly efficiency assessment, calculation of the solar coverage factor, and evaluation of the seasonal energy balance. Results show high solar contribution during transition months (March–April, September–October), often exceeding 100%, while winter performance remains limited (15–30%). Three sizing scenarios (H/S_C = 1.3, 11.3, and 52.2) are compared, highlighting the trade-offs between investment cost, energy yield, and risk of seasonal overproduction. The study concludes that optimal sizing is achieved when the system is dimensioned for transition months (October/April), whereas sizing for the critical

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winter month (December) becomes economically inefficient without long-term thermal storage or auxiliary energy sources.

Key-words**:** solar thermal systems, energy performance, auxiliary source

Introduction

Solar thermal installation evaluation, for building heating for preparing hot water for consumption involves adopting a solar capture surface capable of ensuring an appreciable energy coverage for the consumer served, without the investment in the capture surface being excessively high. To achieve this expressed qualitatively, it is necessary to adopt a parameter built on the basis of both the size of the consumer and another parameter representative of the installed solar surface. Such a parameter can be the ratio between the heat transfer capacity of the heated building, H (W/K) and the installed solar capture surface SC (m2). In this way, the parameter H/SC (W/m2.K) is obtained, representing a kind of thermal "transmittance" of the building envelope in relation to the solar capture surface. Associating the degree of energy coverage offered by the solar installation with the value of the mentioned parameter results in an orientation regarding the value of the solar energy capture surface to be installed.

The size of the consumer is partially reflected by the heat transfer capacity H of the building envelope given that the design heat requirement of the building is $Q_{inc0} = H\cdot(t_{t0} - t_{e0})$. We leave the design temperature difference separately in the idea that an analysis can be made according to the climatic zone in which the building is located. Thus for climatic zone 1 where the design external temperature is t_{e0} = -12 ºC, we have $t_{t0} - t_{e0}$ = 32 ºC, for zone 2 we have $t_{t0} - t_{e0}$ = 35 ºC, etc. Another parameter that influences the degree of energy coverage offered by the solar installation for the building's heat requirement is the sizing of the consumer's heating installation, that is, more precisely, the design temperature couple for the heat agent, i.e. for example t_{T0}/t_{R0} = 90/70 ºC. However, the more the central heating installation is sized at lower temperature values, for example t_{T0}/t_{R0} = 80/60 ºC or t_{T0}/t_{R0} = 60/40 ºC. or even t_{T0}/t_{R0} = 50/30 ºC, the better the solar installation works, with higher yields and consequently greater contributions to the consumer's energy coverage.

Another important parameter that influences the degree of energy coverage of the solar installation is the quality of the solar collectors expressed by their heat transfer coefficient, K_C. The common range of values for this parameter is 2...3...4 $W/m^2\cdot K$. Thus, good solar collectors are characterized by values of approx. 2 $W/m^2\cdot K$ (solar collectors with evacuated tubes), or for average solar collectors values of approx. 3 $W/m^2\cdot K$ or for weaker solar collectors values of approx. 4 W/ $W/m^2\cdot K$. However, we must mention that the type of application is important in choosing solar collectors and not in every type of application it is necessary to use very high-performance solar collectors. In this paper, however, we propose to analyze an average case from the point of view of the performance of solar collectors KC = 3 $W/m^2\cdot K$. Regarding the parameter pair t_{T0}/t_{R0} for sizing the surface of the building's central heating installation, the option of low-temperature heating will be chosen, i.e. t_{T0}/t_{R0} = 50/30 ºC. This requires a favorable situation for the solar installation but also a larger surface for the central heating installation. Zone 2 characterized by a design external temperature te0 = -15 ºC will be considered as the climatic zone.

A collective building of approximately 100 apartments will be considered, characterized by a heat transfer capacity of approximately 14200 W/K.

Methodology adopted

The working procedure involves calculating the thermal transfer modules for the solar collection surface and for the surface of the heat exchanger immersed in the storage tank. Thus for the solar collection surface:

$$E_C = exp\left(-\frac{F' \cdot k_C \cdot S_C}{1.163 \cdot G_C}\right) = exp\left(-\frac{F' \cdot k_C}{1.163 \cdot a_C}\right)$$
$$where:$$
$$F' = 0.95;\ k_C = 3\frac{W}{m^2 \cdot K};\ a_C = 50\frac{L}{h \cdot m^2} \qquad (1)$$
$$E_C = exp\left(-\frac{F' \cdot k_C}{1.163 \cdot a_C}\right) = 0.9522$$

For the heat exchanger immersed in the storage tank:

$$E_S = exp\left(-\frac{k_S \cdot S_S}{1.163 \cdot G_C}\right) = exp\left(-\frac{k_C}{1.163 \cdot a_C} \cdot \frac{S_S}{S_C}\right)$$
$$where:$$
$$k_S = 800\frac{W}{m^2 \cdot K};\ \frac{S_S}{S_C} = 0.067 \qquad (2)$$
$$E_S = exp\left(-\frac{k_S}{1.163 \cdot a_C} \cdot \frac{S_S}{S_C}\right) = 0.5621$$

For the thermal transfer module of the solar loop, it results:

$$E_{CS} = \frac{E_C \cdot (1 - E_S) + E_S \cdot (1 - E_C)}{1 - E_C \cdot E_S}$$
$$where: \qquad (3)$$
$$E_C = 0.9552;\ E_S = 0.5621$$
$$E_{CS} = 0.9549$$

Solar loop correction factor:

$$F_R{}^B = \frac{1.163 \cdot G_C}{k_C \cdot S_C} \cdot (1 - E_{CS}) = \frac{1.163 \cdot a_C}{k_C} \cdot (1 - E_{CS}) = 0.8735 \qquad (4)$$

Factorul de corectie al buclei instalatiei de incalzire a consumatorului :

$$F_R{}^C = 2 \cdot \frac{H}{k_C \cdot S_C} \cdot \frac{t_{i0} - t_{e0}}{t_{T0} - t_{R0}} = \frac{2}{3} \cdot \frac{H}{S_C} \cdot \frac{20 - (-15)}{50 - 30} = 1.167 \cdot \frac{H}{S_C} \quad (5)$$

Correction factor of the installation as a whole:

$$F_R{}^{BC} = \left(\frac{1}{F_R{}^B} + \frac{1}{F_R{}^C} \right)^{-1} \quad (6)$$

Finc factor:

$$F_{INC} = \frac{t_{R0} - t_{e0}}{t_{i0} - t_{e0}} = \frac{30 - (-15)}{20 - (-15)} = 1.286 \quad (7)$$

$$f_u = 0.35 + 0.71836 \cdot exp\left[-0.1/\left(\frac{V_a}{75 \cdot S_C}\right)\right]$$
$$\frac{V_a}{S_C} = 75;\ f_u = 1 \quad (8)$$

with $\alpha \cdot \tau = 0.9 \cdot 0.85 = 0.765$

$$\beta_{REF} = \frac{t_{i0} - t_e}{f_S \cdot I} \ \ unde\ I = f_{cap} \cdot I_O \quad (9)$$

Efficiency will be :

$$\eta_{BC} = F_R{}^{BC} \cdot \left[0.81 - 3 \cdot 1.286 \cdot \beta_{REF}\right] = \\ = F_R{}^{BC} \cdot \left[0.81 - 3.858 \cdot \beta_{REF}\right] \quad (10)$$

knowing :

Incident Thermal Power :

$$P_I = S_C \cdot I \quad (11)$$

And total income in the system:

$$P_{CP} = \eta_{BC} \cdot f_u \cdot P_I = \eta_{BC} \cdot P \quad (12)$$

Having building demand :

$$P_{CONS} = H \cdot \left(t_{i0} - t_e\right) \quad (13)$$

Than, solar coverage is :

$$G_{AE} = \frac{P_{CP}}{P_{CONS}} = \frac{\eta_{BC} \cdot f_u \cdot S_C \cdot I}{H \cdot (t_{i0} - t_e)} = \frac{\eta_{BC} \cdot I}{(t_{i0} - t_e)} \cdot \frac{1}{\frac{H}{S_C}} \quad (14)$$

The evaluation of the thermal energy contributions of the solar installation is in this situation dependent on a single parameter, namely the H/S_C ratio. A test of this parameter was carried out in the range H/SC = 4…16 W/m^2.K. Thus, the H/S_C value was fixed and first the value of the correction factor F_R^C was established, then the correction factor F_R^{BC}. Next, from Mc001-revised, for each month of the year, the intensities of solar radiation on the horizontal plane, IO, were established and based on the orientation factors of the solar collectors, fcap, the effective values of the solar radiation intensity for the inclination angle of 45° and oriented towards the south resulted. Also for each month, the average monthly outdoor temperatures were established and the evaluation of the REF values and the efficiency of the solar collectors η_{BC} was carried out. Based on these, the thermal powers captured by the solar installation P_{CP} and the thermal powers required by the consumer, P_{CONS}, were calculated. The degree of energy coverage of the solar installation, G_{AE} and the related monthly energy were immediately apparent.

Energies :

$$E_{BC} = 0.024 \cdot N_{zile} \cdot P_{BC}(kWh)$$
$$E_{CONS} = 0.024 \cdot N_{zile} \cdot P_{CONS}(kWh) \qquad (15)$$

Use case example

1. general and configuration data

The study analyzes the performance of a solar thermal system used for domestic hot water preparation and heating support of a building located in Bucharest.
The solar collectors are installed with an inclination angle of 45° to the horizontal plane and are optimally oriented, with azimuth 0° (south orientation), which ensures efficient capture of solar radiation throughout the year.

The main characteristics of the collector are:
- absorption coefficient: $\alpha = 0.9$
- transparency coefficient: $\tau = 0.85$
- global loss coefficient: kC = 3 W/m²K
- geometric factor: F' = 0.95 (specific to high-performance collectors)

The heat exchanger in the solar loop has:
- global coefficient: kS = 800 W/m²K

The storage tank is sized to:
- according to a specific volume of 50–80 l/m².

The building analyzed has:
- heat transfer capacity: H = 14200 W/K
- internal design temperature: ti0 = 20°C

• external design temperature: te0 = -15°C

The temperatures of the heat transfer medium are:
• flow: 50°C
• return: 30°C

2. Evaluation of intermediate parameters

Based on the input data, the characteristic parameters of the system were determined:
• thermal module of the collector: EC ≈ 0.95
• exchanger module: ES ≈ 0.56
• solar loop module: ECS ≈ 0.95

Relevant correction factors:
• solar loop factor: FRB ≈ 0.8735
• consumer factor: FRC ≈ 13.2
• overall system factor: FRBC ≈ 0.8193

Energy utilization factor:
• fu = 1, indicating a correct dimensioning of the storage tank

Unidimensional factor of the installation:
• F_{INC} ≈ 1.28573.

Mounthly energies analyze

Tabel 1 *the values of energy parameters and external climate characteristics for the studied situation*

	Ian	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
I_{oriz}	49.6	85	124.8	167.2	205.6	233.5	200.8	233.2	175.5	114.2	54.2	41.3
t_e	-2.4	-0.2	5	11.2	16.7	20.4	22.4	21.7	17.2	11	5.3	0.3
f_{cap}	1.7609	1.4526	1.2477	1.0518	0.9425	0.8799	0.9027	1.0264	1.2205	1.4546	1.6200	1.6677
I	87.34	123.47	155.71	175.87	193.79	205.45	181.27	239.36	214.20	166.12	87.80	68.87
f_s	4.50	4.00	3.40	3.00	2.70	2.50	2.50	2.70	3.00	3.40	4.00	4.50
β_{REF}	0.0570	0.0409	0.0283	0.0167	0.0063	0.0000	0.0000	0.0000	0.0044	0.0159	0.0419	0.0636
η_{BC}	0.4835	0.5343	0.5741	0.6109	0.6437	0.0000	0.0000	0.0000	0.6498	0.6132	0.5313	0.4627

3.1 Solar radiation and the influence of positioning
The correction factor for tilt and orientation (fcap) varies between:
• **0.88** (summer) and 1.76 (winter)
This indicates that the system is optimized for the cold season, when the energy demand is higher.
The average monthly solar radiation varies between:
• **~68 W/m²** (December) and ~**239 W/m²** (August)

3.2 System efficiency

The solar loop efficiency (ηBC) has values:
• ≈ 46% – 65% in the cold season
• 0% in the summer (the system is not used for heating in the summer season)
The maximum efficiency occurs in the months of:
• May and September (~64–65%)

3.3 Thermal Power

The power required for heating (P_{CONS}) varies:
• maximum: ~318 kW (January)
• minimum: 0 kW (summer)

The captured power (PCP) reaches:
• maximum: ~174 kW (September)
• minimum: ~40 kW (December)

3.4 Energy Coverage Degree

The thermal coverage degree (G**AE**) highlights the system performance:
• winter:
o January: 16.66%
o February: 28.86%
o December: 14.29%

• spring/autumn:
o March: 52.65%
o April: 107.87%
o October: 100%

• periods of overproduction:
o May: 333.98%
o September: 439.24%
This shows that the system produces energy surplus in the intermediate periods.

3.5 Energy

Monthly energy:
• incident energy (EI):

o maximum: ~193 MWh (September)
• energy required (ECONS):

o maximum: ~236 MWh (January)
• energy captured (ECP):

o maximum: ~125 MWh (September)

3.6 Auxiliary consumption

Pump power:
• between ~1000 W and 4300 W

Monthly energy consumption:
• between ~700 kWh and 3100 kWh

This represents approximately 1–3% of the thermal energy produced.

Tabel 2 *Bucharest data*

	P_{cons}	P_i	P_{cp}	E_I	E_{cons}	E_{cp}	G_{AE}
Jul							
Aug							
Sep	39.76	268.7478	174.6429	193498.4	28627.2	125742.9	439%
Oct	127.8	208.4255	127.8161	155068.5	95083.2	95095.21	100%
Nov	208.74	110.1638	58.53196	79317.92	150292.8	42143.01	28%
Dec	279.74	86.41513	39.98505	64292.86	208126.6	29748.88	14%
Ian	318.08	109.5831	52.98016	81529.83	236651.5	39417.24	17%
Feb	286.84	154.9144	82.77618	104102.5	192756.5	55625.59	29%
Mar	213	195.3632	112.1496	145350.3	158472	83439.27	53%
Apr	124.96	220.6565	134.7975	158872.7	89971.2	97054.23	108%
May	46.86	243.1398	156.5035	180896	34863.84	116438.6	334%
Jun							

4. Conclusions

1. The system is correctly sized, conditioned by generating the entire heating energy needed for the month of October with an optimal utilization factor (fu = 1).
2. The performance is very good in transition periods, where the system can fully cover or even exceed the need.
3. In the cold season, the contribution is significant (15–30%), reducing conventional energy consumption.
4. There is a significant energy surplus in spring and autumn, which suggests:

o the possibility of using it for domestic hot water
o or integration into a hybrid system

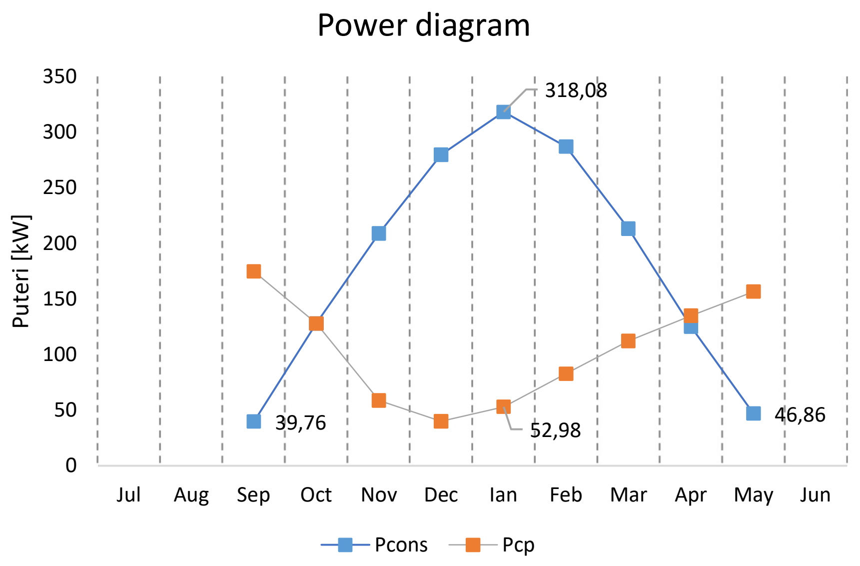

***Figure 1** Demand and delivered power*

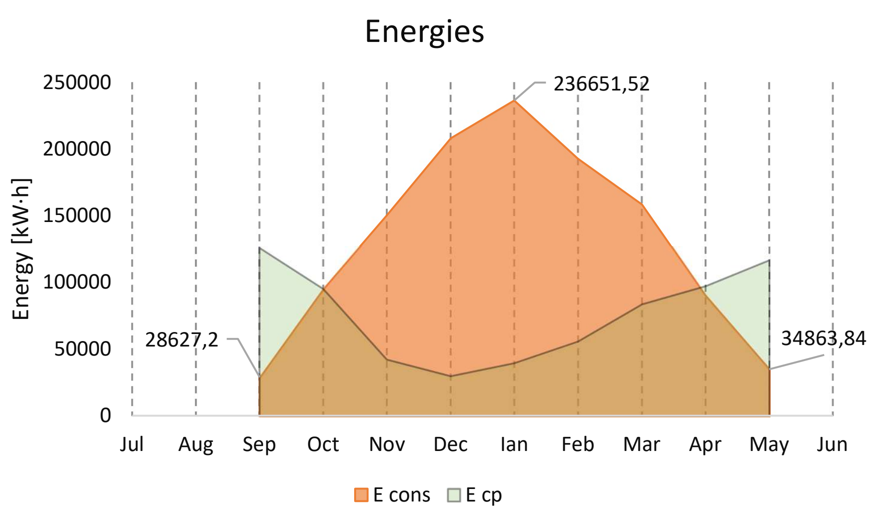

***Figure 2** Energies*

Seasonal Energy Balance Analysis

Figure 2 illustrates the monthly variation of energy consumption (ECONS) in relation to energy produced or captured (ECP), highlighting the seasonal dynamics of the analyzed system.

1. Consumption Profile (ECONS): A direct correlation is observed between energy demand and the cold period of the year. Consumption records a pronounced upward trend starting with October, reaching a peak load in January (236.65 MWh). This distribution suggests a major dependence on the heating requirement, which is

intensified in winter. Subsequently, demand progressively decreases towards May (34.864 MWh).

2. Correlation with Energy Produced (ECP): The available energy curve shows an inversely proportional behavior to that of consumption. An energy surplus is observed in the transition periods (September and May), while in the winter months (November–February) a significant energy deficit appears. The intersection points of the two curves (approximately in October and April) mark the equilibrium moments of the system, where the demand is satisfied by the solar energy capture system.

Technical Observations:

1. Seasonal discrepancy: The high amplitude of the ECONS curve in relation to the ECP indicates the need for an auxiliary energy source or a long-term storage system to cover the deficit in the period December–February.

2. System efficiency: The minimum consumption values are identified in September (28.63 MWh), reflecting the base load of the system in the absence of seasonal thermal demand.

Local conclusion: Analysis of the diagrams reveals a substantial gap between the availability of the resource and the user's demand, highlighting the challenges related to the energy self-sufficiency of the studied objective in the winter months. It should be noted that the reduction in the energy captured in the period November–January is consistent with the reduction in the incident solar radiation flux.

Aspects regarding the possible sizing of the monthly capture surface.

Figure 3 shows the variation of the capture surface required to fully ensure the energy requirement, depending on the “target month”/”pursued scenario”, highlighting an inverse correlation between the local solar potential and the thermal demand.

Identification of the Critical Month (Maximum Point):

In the climatic context of Bucharest, the month of December represents the critical moment of the system, requiring a maximum surface of 14,560.15 m². This extreme value is the result of the superposition of two unfavorable factors: the lowest incident radiant flux (short days, high cloudiness) and the highest heating requirement (minimum outdoor temperatures).

Seasonality and Curve Dynamics:

1. Winter Period (December – February): High values (>11,000 m²) indicate a low efficiency of solar conversion relative to the thermal load. The reduction in area from December to January suggested by the graph (from 14,560 to 11,271 m²) can be attributed, in zone II, to a possible increase in sunshine in January compared to December, although temperatures remain low.

2. Transition and Summer Period: The steep decrease towards May and the minimum value in September (271.82 m²) reflect the transition to a regime in which solar radiation is abundant and the energy requirement is probably limited only to the preparation of domestic hot water (DHW).

3. Implications for Design (Optimal Sizing): This inverse assessment demonstrates that a sizing based on the critical month (December) would lead to massive overproportionality in the rest of the year. The ratio between the area required in December and that in September is approximately 53:1, which highlights the need to adopt a compromise solution (e.g. sizing for March or October) supplemented by an auxiliary energy source.

Technical Conclusion: For climate zone II, the graph confirms that the use of solar energy as a sole source for the full coverage of residential/industrial consumption is technically feasible, but economically inefficient without an inter-seasonal storage system or an additional source, due to the order of magnitude variation in the required capture surface.

Analysis of the Dynamics of the H/SC Ratio as an Optimization Indicator

Figure 4 illustrates the monthly evolution of the critical ratio, a parameter that defines the energy self-sustaining capacity of the solar system for the analyzed location (Bucharest, Zone II).

Interpretation of the Maximum Value (September):

The maximum point recorded in September (52.24 W/m2·K) indicates the period of maximum efficiency of the building-solar system coupling. A high value of the ratio suggests that a minimum capture area is required to compensate for the building's thermal losses, due to the abundant solar radiation and the reduced indoor-outdoor thermal gradient, in other words, the higher the required/production ratio, the greater the need.

Conclusion on the consumer/producer ratio:

The variation of the H/SC ratio demonstrates that, for climate zone II, optimization should not only aim at maximizing the SC surface, but especially at reducing the H value (through energy efficiency measures). A building with a low H will shift the entire curve towards higher values, making the solar system viable for a longer period of the heating season, for the same solar capture surface.

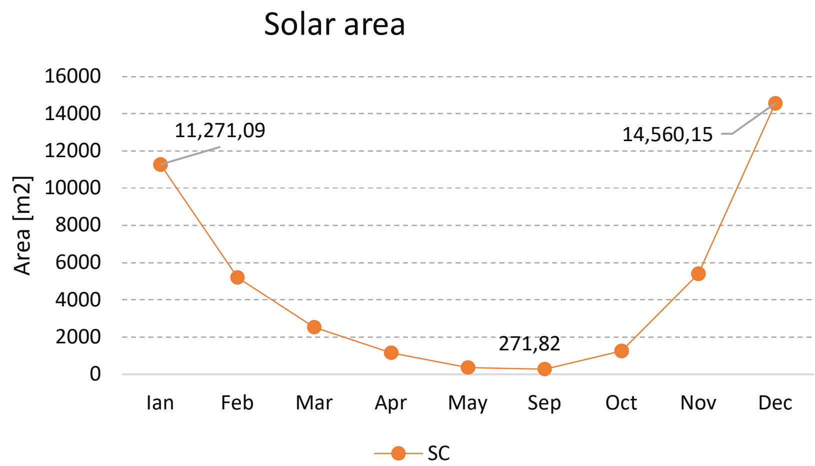

Figure 3 *The capture area required to generate the entire consumption required for each month*

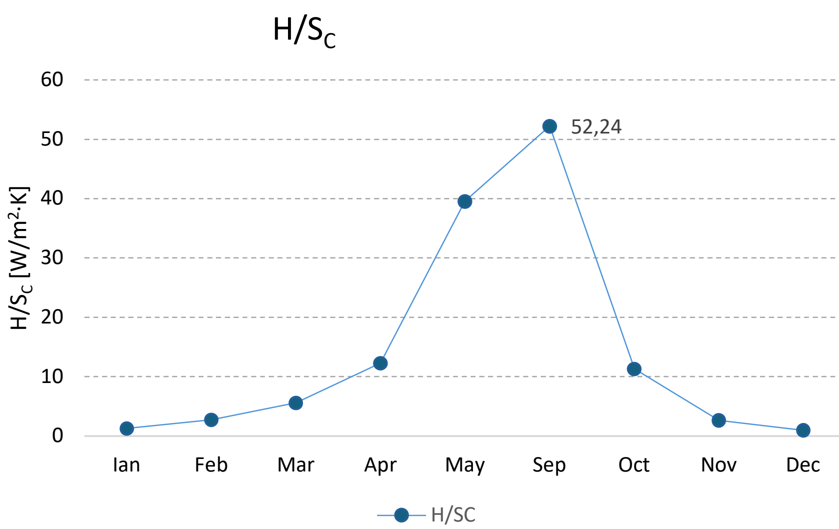

Figure 4 *H/SC ratio for generating the entire required consumption for each month*

Possible sizing scenarios and comparative analysis

The following are 3 possible scenarios to understand the dynamics of the capture system in the context of an installed consumer characterized by a global transfer coefficient with the exterior H=14200W/K. These graphs illustrate the balance between the captured energy (solar supply) and the required energy (heating demand) over a year, analyzing the impact of sizing the capture surface (SC) compared to the thermal losses of the building (H).

1. Analysis of the H/S_C=1.3 Ratio (Oversized System)

• **Figure 5** (Powers) and Figure 6 (Energies): In this case, the capture surface is very large in relation to the building losses.

• **Comment:** It is observed that the captured power (**P_{CP}**) exceeds the heating demand (**P_{CONS}**) almost throughout the year, except for the peak winter period (December-January).

• **Conclusion:** Although the system covers a high solar fraction, it generates a massive energy surplus during the transition and summer periods (the red area visibly exceeds the blue area in Fig. 6). This indicates low economic efficiency and risks of overheating of the installation.

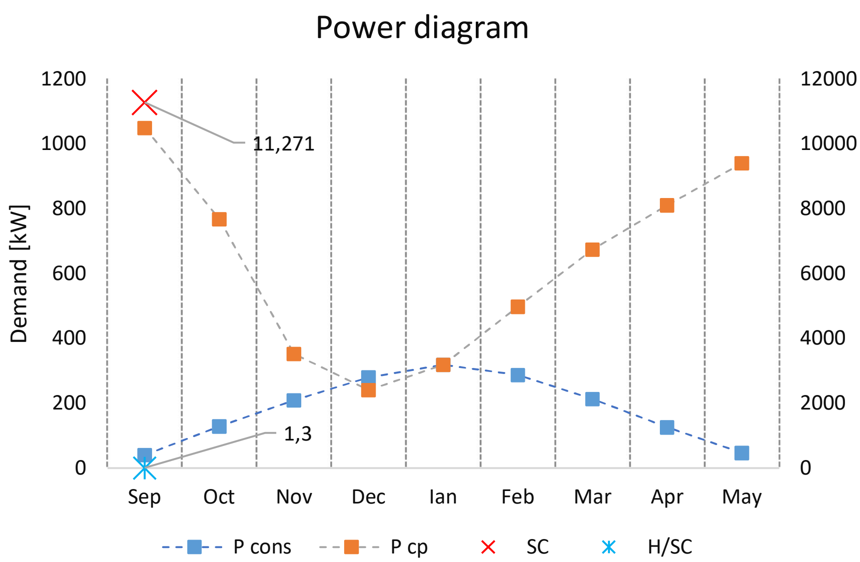

Figure 5 *Demand and delivered powers for H/S_c 1.3*

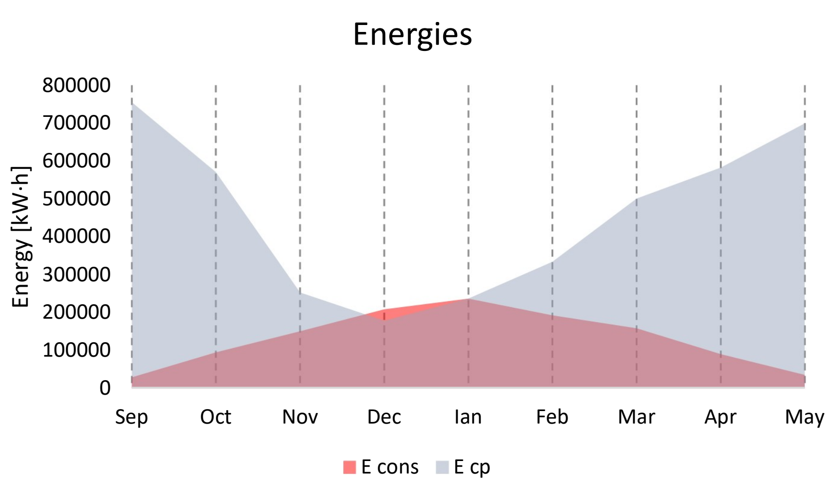

Figure 6 *Demand and delivered energies H/S_c 1.3*

2. Analysis of the Ratio H/SC = 11.3 (Optimized/Balanced System)

• Figure 7 and Figure 8: This configuration represents a compromise between investment and performance.

• Comment: The captured power curve intersects with the required one in the spring and autumn months (**March and October**). During the winter period, the energy deficit is obvious, but the solar contribution remains significant.

• Conclusion: This seems to be **the optimal sizing area**. The capture surface is used efficiently, the energy surplus (**red area over blue** in Fig. 8) being much reduced compared to the previous case, which **minimizes losses** and installation costs.

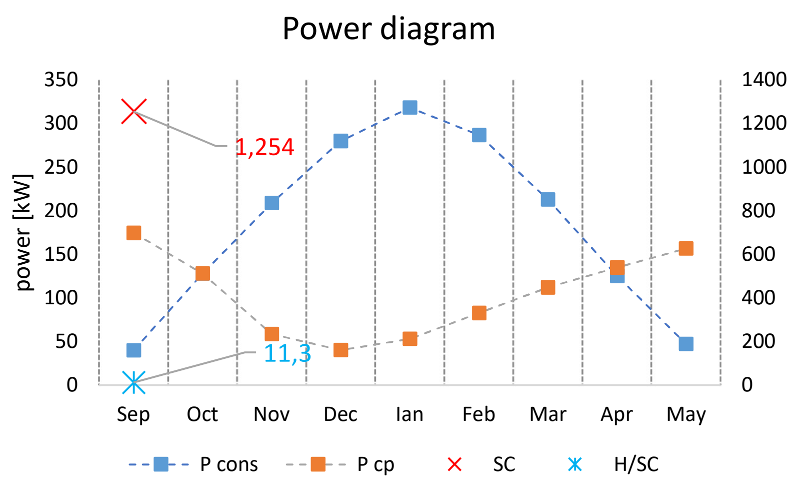

***Figure** 7 Demanded and delivered power for H/S_c 11.3*

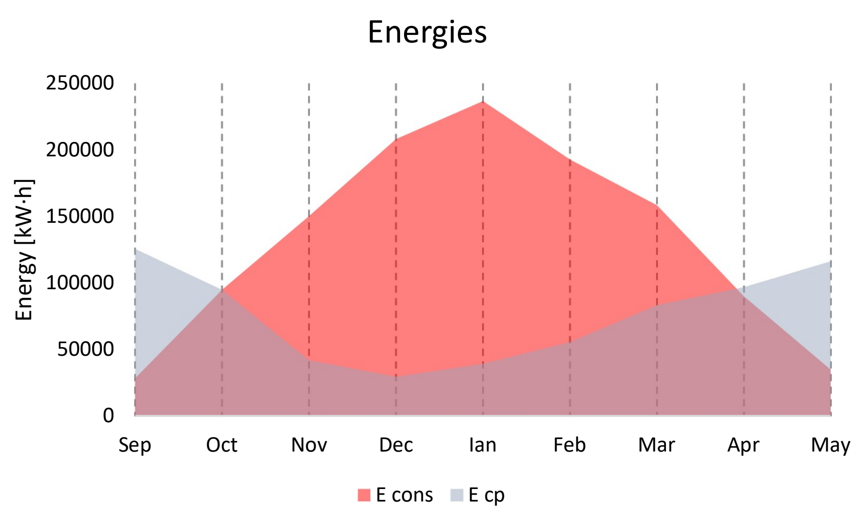

***Figure 8** Demanded and delivered energies for H/S_c 11.3*

3. Analysis of the Ratio H/SC=52.2 (Undersized System)

• **Figure 9 and Figure 10**: Here, the capture surface is too small to support the thermal load.

• **Comment:** The power supplied by the collectors (**P_{CP}**) is lower than the required (**P_{CONS}**) even during periods of favorable solar radiation. The solar fraction is minimal.

• **Conclusion:** The system is **undersized**. Although there are no risks of stagnation or overheating (the surplus is almost zero), the solar system has an insignificant impact on the reduction of conventional fuel consumption, not justifying the investment in an active capture system.

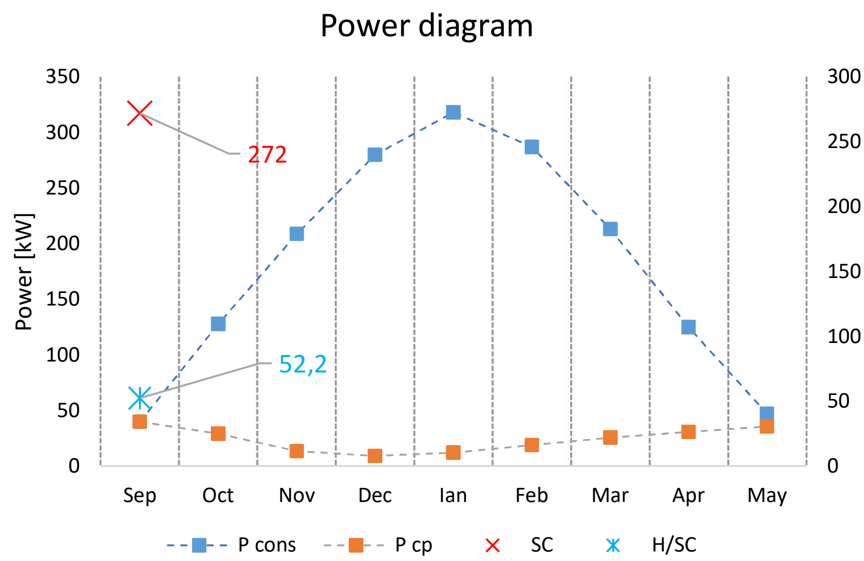

Figure 9 *Demanded and delivered Powers for H/S_c 52.2*

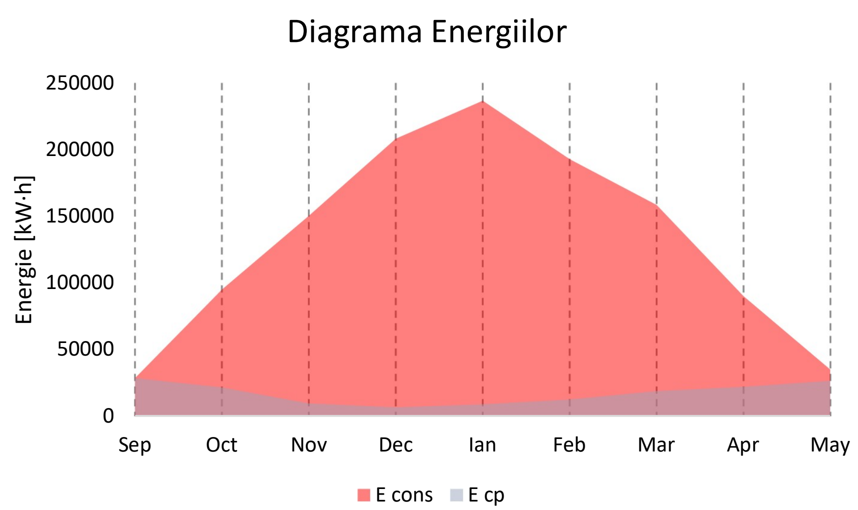

Figure 10 *Demanded and delivered energies for H/S_c 52.2*

The 3 scenarios were developed to cover the energy needs in Bucharest (Zone II) for a consumer of thermal energy for heating. The summary of the chapter, making a structural parallel between the three situations, is presented in Table 3.

Tabel 3 *Strategies and sizing overview*

Month	Rapport H/S_C	System behavior
September	**Maxim (52.3)**	**Undersized System**: The surface area is very small. It covers consumption only in the warm months, being practically irrelevant for the rest of the heating season.
January	**Unfavorable (1.3)**	**Unfavorable System**: The area increases significantly, becoming uneconomical due to the area of **11071m2**. Full coverage is obtained in January and visible support in the transition months, but the surplus in the other months is unfeasible.
October	**Optimal (11.3)**	**Optimal System:** Similar to April but calibrated for the beginning of the cold season. In the Figures for October, the equality $\mathbf{E_{CP} = E_{CONS}}$ is observed at a higher energy level than in September.

Discussions

1. **Energy Capture Translation (ECP)**: As we choose a month with a lower **H/S_C ratio** (from **September** to **October**), the energy capture (**ECP**) bars increase in height throughout the graph. This indicates that an area calculated for a colder month "**captures**" more energy throughout the rest of the year.
2. **Winter Months Problem (Dec-Jan):** Even in the **October scenario**, the deficit remains huge. Although **S_C is higher**, the **orange bar** (**E_{CONS}**) in January exceeds the **production capacity** (**E_{CP}**) by more than 5 times, confirming that in **Zone II**, solar cannot be the sole source without massive seasonal storage or other auxiliary/backup source.
3. **Surplus Occurrence**: In the **January scenario**, we observe a new phenomenon: in the other months, the **energy captured** (**E_{CP}**) considerably exceeds the need (**E_{CONS}**). This energy surplus must be managed (through thermal discharge or storage or temporary shutdowns of the installation) to avoid system overheating, thus avoiding.

General conclusion:

The overview demonstrates that sizing for **October/April** represents the technical threshold from which the solar system begins to have a real impact on primary energy savings, while sizing for September remains only a symbolic solution, limited to the preparation of domestic hot water.

Symbols

φ_I	the angle of inclination of the solar collectors to the horizontal plane, ^{o};
φ_A	the azimuth angle – the angle between the cardinal orientation of the solar collector to the south orientation, ^{o};
α	the absorption coefficient of the collector plate, -;
τ	the transparency coefficient of the collector's glazed element, -;
S_C	the total surface area of the solar collectors used by the system, m2;
k_C	the global heat transfer coefficient of the solar collectors, W/m2·K;
F'	the geometric correction factor of the solar collector's performance, -;

S_S	the surface area of the heat exchanger within the solar loop, m2;
k_S	the global heat transfer coefficient of the heat exchanger of the solar loop, W/m2.K;
G_C	the flow rate of the heat agent circulated in the solar loop, l/h;
V_a	the volume of the storage tank, l;
G_{CONS}	the average daily hourly flow rate of hot water consumption, l/h;
S_{INC}	the surface area of the consumer's central heating installation, m2;
G_{INC}	flow rate of the heat agent circulated in the heating system, l/h;
t_r	cold water temperature, oC;
t_c	hot water temperature for consumption oC;
t_{T0}	nominal temperature of the heat agent at the entrance to the consumer's central heating system, oC;
t_{R0}	nominal temperature of the heat agent at the exit from the consumer's central heating system, oC;
t_{i0}	standard indoor temperature, oC;
t_{m0}	average nominal temperatures of the heat agent in the consumer's heating system, oC;
t_T	temperature of the heat agent at the entrance to the consumer's central heating system, oC;
t_R	temperature of the heat agent at the exit from the consumer's central heating system, oC;
t_m	average temperatures of the heat agent in the consumer's heating system, oC;
t_{e0}	nominal outdoor temperature, oC;
t_e	outdoor temperature, oC;
t_{em}	average monthly outdoor temperatures, oC;
I	global intensity of solar radiation on the plane of the collection surface, W/m2;
I_O	global intensity of solar radiation for a horizontal plane W/m2, W/m2;
a_c	specific flow rate of heat agent in the solar loop, l/h m2;
F_C	characteristic factor of inputs-losses of the solar collector, K m2/W;
F_R^B	correction factor of the heat flux captured by the solar loop, -;
F_R^C	correction factor of the heat flux captured due to the consumer, -;
f_{cap}	correction factor of the global intensity of solar radiation due to the inclination angle of the solar collectors and the angle of deviation from the SOUTH orientation of the solar collectors, -;
F_R^{BC}	correction factor of the heat flux captured by the system composed of the solar loop and the consumer, -;

β_{REF}	synthetic thermal parameter to which the assembly composed of the solar loop of collection and the consumer is subjected, K m2/W;
η_{BC}	efficiency of the solar collection loop, -;
f_U	utilization factor of the captured energy, -;
G_{AET}	thermal energy coverage degree of the solar loop, %;
G_{AE}	solar loop energy coverage degree, %;
RND	system capture efficiency, %;
P_{CP}	thermal power captured and delivered to the consumer, W;
P_{CONS}	thermal power requested by the consumer, W;
E_I	solar energy incident on the capture surface, kWh;
E_{CP}	thermal energy captured by the solar loop, kWh;
E_{CONS}	energy requested by the consumer, kWh;
Φ_{NEC0}	calculated heat demand of the consumer's building, W;
Nzl	number of days in the month, day/month;
P_P	solar loop pump power, W;
P_{EL}	average daily solar loop pump power, W;
R_{INC}	thermal resistance of the consumer's heating installation, K m2/W; is the inverse of the global heat transfer coefficient related to the surface of the consumer's heating installation;
F_{INC}	dimensionless correction factor;
H	building heat transfer capacity, W/K.
H/S_C	the ratio between the transfer capacity and the surface area of the solar collectors H/S_C
City	the city for which the calculation is made
I_{up}	Index of the positioning angle relative to the Horizontal and Azimuth

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