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AN ENERGY EFFICIENT SINGLE-FAMILY DWELLING PERFORMANCE ANALYSIS

BY

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Abstract. This study analyzes a single-family dwelling, from the energy performance point of view. The concept of the housing model took into consideration aspects related to a high degree of layout flexibility, high-energy performance, minimal impact on the environment and feasible financial investments. The analysis consists of an estimated energy performance using direct methods and numerical simulations for thermo-energetic behavior.

The evaluation using direct methods places the model as an A class energy performance building. Furthermore, an assessment for the energy performance was conducted and revealed values related to specific energy consumption for heating, domestic hot water, lighting and CO_2 emissions. Results from numerical simulations highlight that total glazing area of the building's envelope is considerable when estimating the overall heat loss balance. At the same time, the judicious orientation of the glazed areas contributes to the reduction of the heating energy demand from non-renewable resources by taking advantage of the solar gains. Conclusions of this study highlights aspects related to specific annual energy consumption, feasibility and efficiency of passive solar energy recovery systems integrated in the building's architecture.

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Keywords: energy performance dwelling; energy consumption; thermal comfort parameters; energy performance indicators; numerical simulations.

1. Introduction

This paper aims to analyze from an energy efficient point of view a single-family housing model, the Sibelius Solar House SSH, in accordance with the Romanian housing tradition, with a high degree of layout flexibility, high energy performance and minimal impact on the environment, feasible at an accessible price for different social categories.

The SSH, presented in Fig. 1, has a wooden structure and is located in the city of Suceava. The SSH single-family house, completed in 2014, has the following characteristics: category C of importance (according to GD 766/97); class III importance (according to P 100/2006); climate zone IV (see SR 10907/ 1-70) and II (STAS 6472/2-83); wind farm C (STAS 10101/20-90); snow zone D (see STAS 10101/21-92).

The layout of the premises and of the building as a whole was dictated by the proposed functions, the beneficiary's wishes and specific norms in effect. Spatial indexes account for a built area of 125.00 m^2 at ground level and a total built area of 250.00 m^2.

Fig. 1 − Facade of the SSH.

From an architectural and functional point of view, the interior spaces gather around the central green core, the greenhouse interior courtyard. At ground floor level there is the living space (living room, dining room, kitchen, fireplace area, bathroom and central heating and storage facilities) and upstairs there are two-bedrooms, two bathrooms, a dressing room and a study/library area (this is open towards the green core, visually communicating with the ground floor). The staircase is integrated into the green core.

2. Estimated Performance Energy Indicators

2.1. The Overall Thermal Insulation Coefficient, G

The Global Thermal Insulation Coefficient, *G*, is an indicator for assessing the degree of thermal insulation of buildings that includes both the energy requirement to compensate heat loss through transmission and to heat ventilated air. The value of this indicator depends on the compactness of the building (*A*/*V* ratio), the mean thermal resistance of the whole building envelope, R_M, the ventilation rate, n, and can be calculated with the following equation:

$$G = \frac{1}{R_M} \cdot \frac{A}{V} + n\rho c \ \mathrm{W/m^3K} \tag{1}$$

where: *A* is area of the building envelope, [m^2]; *V* – volume of the building, [m^3]; R_M – mean thermal resistance of the envelope elements, [m^{2}K/W]; *n* – ventilation rate, [h^{-1}]; ρc – the thermal volumetric capacity = 0.34 Wh/m^{3}k.

The average thermal resistance, R_M, is determined using the corrected thermal resistances of the envelope components and surface areas.

For the analyzed building, the data taken into account for calculating the G coefficient are presented in Table 1.

Table 1
Geometric and Thermo Technical Characteristics for Elements of the Building Envelope, SHH

Element	Area, [m^2]	Corrected thermal resistance, *R*', [m^{2}K/W]
Exterior walls N-W	102.6	8.799
Exterior walls S-E	98.05	8.799
Exterior walls N-E	42.50	8.799
Exterior walls S-W	44.70	8.799
Upper slab	109.90	10.082
Ground slab	136.45	9.014
Exterior joinery N-W	47.95	1.420
Exterior joinery S-E	52.50	1.420
Exterior joinery N-E	22.40	1.420
Exterior joinery S-W	29.30	1.420
Roof joinery N-W	26.55	1.420

According to updated Norm C107/1-2005, for a building to be correctly conformed considering energetic aspects, the value for the global coefficient of thermal insulation obtained through calculation, *G*, must be less than the norm value recommended by the above mentioned normative, depending however on the number of levels, *GN*.

For the analyzed building, the condition considered is met:

$$G = 0.454\ \text{kWh/m}^3\text{K} < 0.75\ \text{kWh/m}^3\text{K} = GN. \tag{2}$$

2.2. Energy Performance Certification

The MC001- 2006 Norm - methodology for calculating the energy performance of buildings - includes normative stipulations regarding the energy audit and elaboration of Energy Performance Certificate for housing buildings. The Energy Performance Certificate provides information on specific energy consumption for heating, domestic hot water, air conditioning/mechanical ventilation and lighting as well as specific CO_2 emissions. Depending on these indicators the buildings are then framed in a certain energy class.

The indicators evaluated for the SSH frames the building in the energy performance class A, as shown in Table 2.

Table 2

Energy performance indicators according to the Energy Performance Certificate

		Certified building	Reference building
Specific annual energy consumption, [kWh/m^2/an]		85.39	143.1
Equivalent emissions index [kgCO_2/m^2/an]		16.78	26.61
Specific annual energy consumption, [kWh/m^2/an] for:		Energy class	
Heating	47.67	Certified building	Reference building
Hot water/consumption	31.43	A	B
Artificial lighting	6.32	B	B
		A	A

2.3. Assessed Energy Performance by Numerical Methods

For numerical simulation regarding the thermo-energetic behavior of the analyzed building, CASANOVA program was used, a program able to model the thermo-energetic behavior of the building. As input data, geometric characteristics, material characteristics, building orientation and specific climatic data were introduced.

Among most relevant results obtained using CASANOVA program are: annual and monthly energy consumption indicators for heating/cooling, energy balance – Sankey diagram, monthly indoor temperature regime in the absence of heating sources, annual variation of solar gains, etc.

The numerical simulation for SSH provides additional data on usable solar gains that practically compensate for the heat losses occurring *via* transmission while the heating system operates only for heating the ventilated air (Fig. 2).

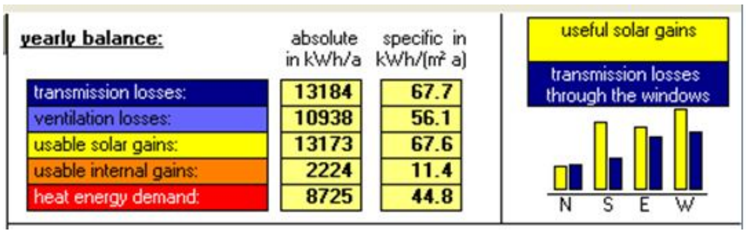

Fig. 2 – Specific heat losses, solar gains and specific energy demand for heating.

The energy balance presented as the Sankey diagram, Fig. 3, highlights the significant share of glazed surfaces in the overall heat loss balance, 72%, compared to 14% through the walls, 9% through the roof and 5% through the floor. This is explained by how important the glazed surfaces area is within the building's envelope and by the lower thermal resistance in relation to other component elements of the building's envelope.

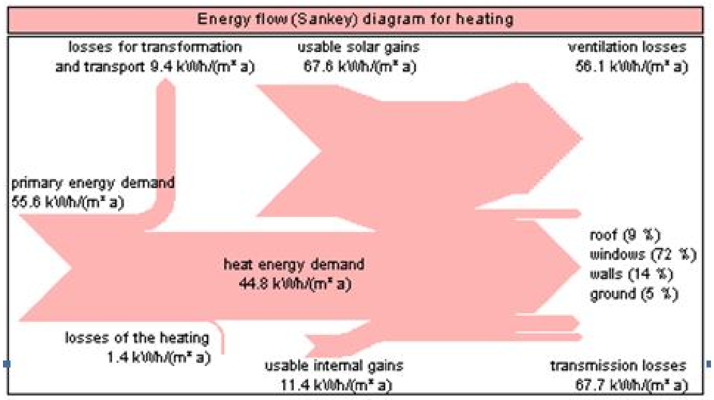

Fig. 3 – Energy flow - Sankey diagram

Monthly distribution of the heating energy demand indicates maximum values for December-January and minimum values for April-September, delimiting thus the heating season (Fig. 4).

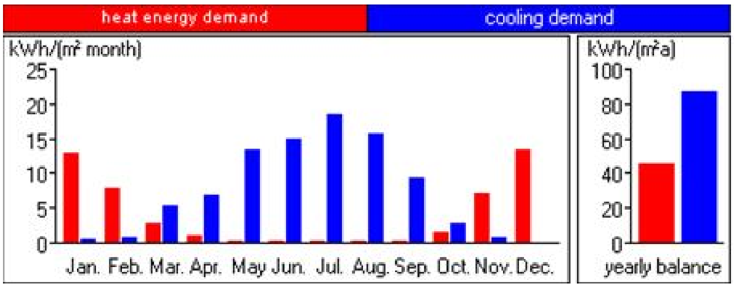

Fig. 4 − Annual energy demand variation for heating/cooling.

3. Conclusions

The analyzed building is characterized by a high level of energy performance, because according to the assessments made on the basis of the MC001-2006 code, it is placed in the A performance class. This level is the result of: the volumetric conformation, the high degree of thermal insulation and the use of the passive solar systems.

Numerical simulation regarding energy behavior pattern of the building demonstrates the efficiency of passive solar energy recovery systems, integrated in the building's architecture, with more than 50% of the heat loss compensated through solar intake.

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REFERENCES

* * * *Metodologie de calcul a performanței energetice a clădirilor*, Normativul M C001 - 2006.

* * * *Normativ privind calculul termotehnic al elementelor de construcție ale clădirilor*, Normativul C107/ 1-2005.

LOCUINȚĂ UNIFAMILIALĂ EFICIENTĂ ENERGETIC
Analiză de performanță energetică

(Rezumat)

Studiul analizează un model de locuință unifamilială eficientă din punct de vedere energetic. Conceptul modelului de locuință unifamilială a avut în vedere aspecte legate de performanță energetică ridicată, grad înalt de flexibilitate a structurii, impact

minim asupra mediului şi investiții financiare fezabile. Analiza de performanță energetică a fost realizată utilizând metode directe de calcul şi simulări numerice pentru comportamentul termo-energetic.

Rezultatele evaluării prin metode directe încadrează modelul de locuință în clasa A de performanță energetică a clădirilor. Rezultatele evaluării performanței energetice prezintă valori legate de consumul specific de energie pentru încălzire, apă caldă menajeră, iluminat şi emisii de CO_2. Aceste rezultate, obținute prin simulări numerice, evidențiază faptul că suprafața vitrată a anvelopei clădirii intervine semnificativ în volumul total al pierderilor de căldură. În acelaşi timp, orientarea judicioasă a suprafețelor vitrate contribuie esențial la reducerea necesarului de energie pentru încălzire din surse neregenerabile prin valorificarea aporturilor solare.

Concluziile acestui studiu evidențiază aspecte legate de consumul specific anual de energie, fezabilitatea şi eficiența sistemelor pasive de recuperare a energiei solare integrate în arhitectura clădirii.