

Contributions to the passive house concept through the usage of photovoltaic blinds

Contribuții la conceptul de casă pasivă prin utilizarea panourilor fotovoltaice

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Abstract. *The paper presents a study on the efficiency of installing photovoltaic blinds in a didactic laboratory with large glased surfaces, in order to ensure the shading of the interior spaces and to avoid the use of air conditioners during warm periods of the year, as a contribution to the passive house concept.*

Key words: photovoltaic bilds, passive house, thermal comfort, solar energy

1. Introduction

In the moment. the construction sector accounts for 35% of global energy consumption, respectively 40% , in the case of the European Union (buildings account for 80% of this consumption The European Commission, Commission Recommendation (EU) 2019/1659 of 25 September 2019 on the content of the comprehensive assessment of the potential for efficient heating and cooling under Article 14 of Directive 2012/27/EU, Official Journal of the European Union, 2019, https://eur-lex.europa.eu/legal-content]), with a corresponding share of CO2 emissions of 38%

At the national level, the final energy consumption in the construction sector their 42% of the total final energy consumption, of which 34% residential areas, and the rest (about 8%) commercial and public buildings.

The residential sector has the largest share of consumption (about 81%), while all buildings together (offices, schools, hospitals, commercial spas and other non-residential buildings) account for the remaining 19% of total energy consumption. the final. [1, 2].

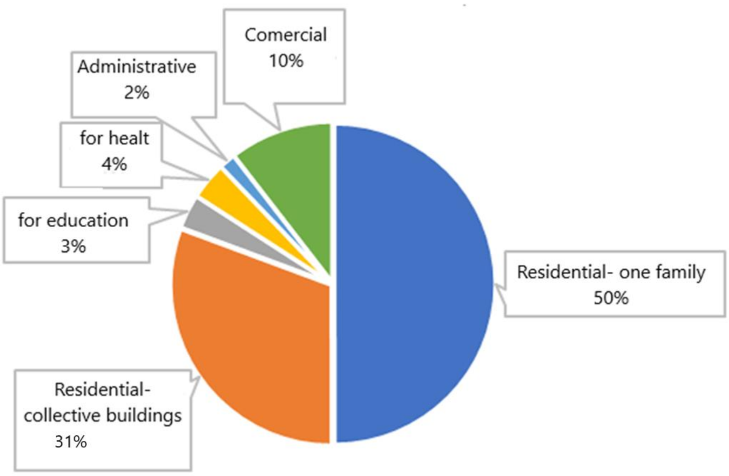

Fig. 1. Energy consumption in the residential sector [3].

The urbanization that is in continuous growth affects and modifies the ecosystems of urban areas, ultimately causing the Urban Heat Island (UHI) effect [4]. . The Urban Heating Island Effect represents the cause of the increase in soil temperature which further generates a series of ecological and environmental effects, such as: changes in soil properties, urban climates, atmospheric environment, energy metabolism that negatively affect people's health (Fig. 2).

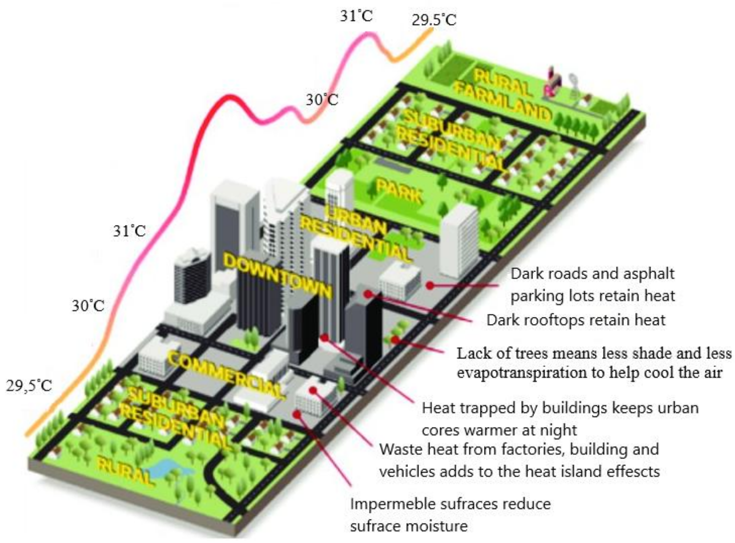

Fig. 2. Urban Heat Island Effect.[4]

The problem of global temperature increase generated by the increase in energy consumption and implicitly by the intensified urbanization, must be mitigated without having a negative impact on the general indoor comfort [5-8].

From the point of view of indoor thermal comfort, it was found that the energy demand for cooling in very hot and arid areas, but also in those with a temperate-continental climate with hot summers, has increased considerably, especially in the case of buildings with very large glazed areas [9].

The Urban Heating Island Effect could be significantly mitigated by several methods including: the construction of green roofs, the use of materials with high reflectivity, the cultivation of green land, the efficiency of the urban landscape and of course the improvement of the energy efficiency of buildings, which corresponds, at least, to the concept of passive house (Fig. 3) [10-11].

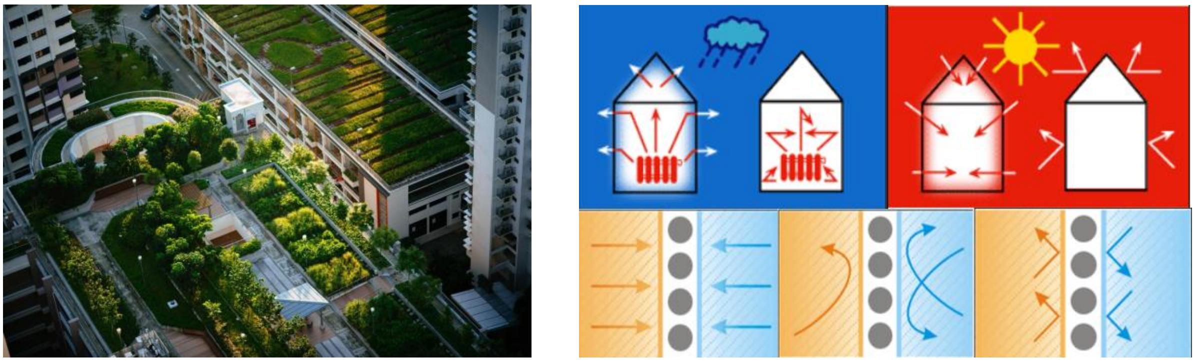

Fig. 2. Pssive green house.[4]

Recent scientific research proposes as measures to solve these problems, on the one hand, the adoption of energy-efficient materials and systems, which implies the transition from fossil fuels to renewable sources, and on the other hand, the design of buildings in house concepts passive or nZEB (netzero-energy) [12].

The Passive House concept is clearly defined and is applicable to all types of buildings and all climate zones, having as a common point the high level of comfort and energy efficiency.

The passive house standard brings to attention the increase in health and well-being of the building's occupants, thermal comfort at the same time as increasing indoor air quality. Limitation of the building heating requirement and the total demand for primary energy was also taken into account. [13-15].

The passive house is defined in terms of five criteria: airtightness, thermal insulation, elimination of thermal bridges, ventilation with heat recovery and windows with reduced heat loss (Fig. 4) [16].

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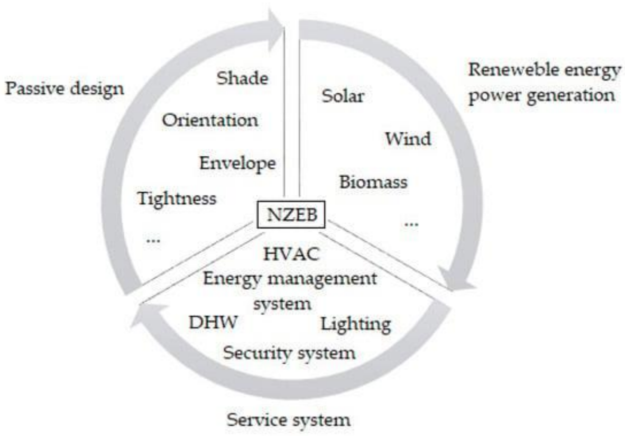


Fig. 4. Urban Heat Island Effect [16]

The article makes a study of these aspects as a contribution to the passive house concept, addressing in parallel the effects on the natural lighting of buildings which, concretely, represents a passive strategy for reducing energy consumption in buildings.

On the other hand, the European directive on the energy performance of buildings stipulates that starting with the year 2020, all newly constructed buildings should fall within the standard of building with almost zero energy consumption (nZEB) [9, 11, 17, 18].

In this article, an analysis of the criterion referring to the glazed superface is proposed. This criterion was addressed because the problem of overheating of buildings, during the warm periods of the year, generates high energy consumption, even for passive houses. On the one hand, solar radiation is beneficial in cold periods, and on the other hand it creates problems in warm periods. So, radiation control can be a key to the optimized design virtually for any type of building, especially with regard to the glazed surface [16]. Heat loss/input through glazed surfaces is greater than through walls, so it can be said to be a critical point for any type of building. That is why, in addition to the quality of the glass and profiles, an important criterion is the establishment of the optimal dimensions in relation to the size and destination of the space, but also the orientation and the materials used for assembly and sealing. The overheating of buildings, during the warm periods of the year, generates high energy consumption, even for passive houses. The increased use of insulation and the demand for greater building air-tightness have unintentionally combined to produce a growing number of buildings that suffer from "overheating". The nZEB standard or buildings with net zero energy consumption were defined around 2010 as buildings that achieve a balance between energy consumed and delivered, also having a reduced energy requirement for the operation of HVAC (heating, ventilation, and air conditioning installations), through the integration of renewable energy sources (RES) and the use of state-of-the-art technologies in order to recover heat. [19]. Even if this goal seems far away, the progress made in the design of buildings with the aim of reducing carbon emissions or even storing carbon suggests that this building sector can become climate neutral at some point. Research shows that the key to achieving the nZEB standard is maximizing the energy efficiency of buildings, using the energy resulting from different processes to which is added the energy produced from local renewable sources. All these strategies include a variety of activities and steps to be followed as can be seen in the Fig. 5 [5. 19].

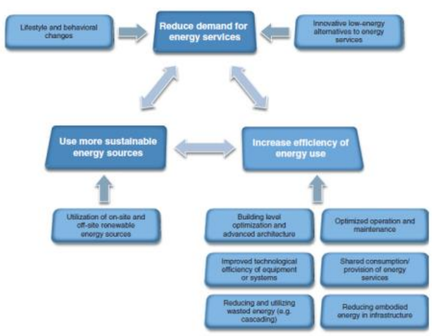


Fig. 5. Activities to achieve the objectives of the nZeb standard [5],

Although interest in residential overheating has been popular, the challenges extend across the whole built environment, including commercial and institutional buildings.

In this sense, a solution is photovoltaic blinds that exploit solar energy in both seasons (cold and warm) and provide shading of glazed surfaces in the warm season, in order to maximize energy efficiency.

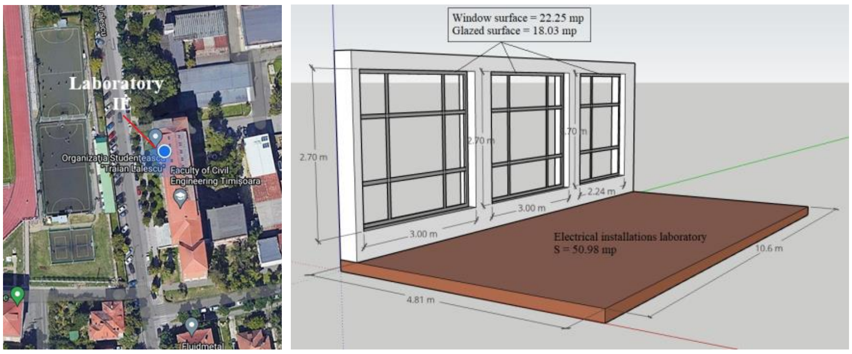
2. Background research

The interrelated effects between buildings and climate change begin to manifest once the building is in use. Buildings contribute to global warming by emitting greenhouse gases (GHG) in order to provide heat and cold. Therefore, over the lifetime of a building (which has conventional energy as its primary source of energy), the higher the outside temperature, the more energy the buildings will consume to cool the spaces, which will again contribute to GHG increase and will respectively accelerate global warming [9, 20]. For these reasons, it is estimated that the construction fund is responsible for a significant percentage of energy consumed and CO_2 emissions [19-21]. For this reason, the article addresses the context of buildings located in areas with considerable solar potential that have generous glazed surfaces. An analysis of the efficiency of the installation of photovoltaic blinds in a laboratory of the Faculty of Construction in Timisoara is proposed in order to ensure the shading of the interior space and to avoid the use of air conditioners during the warm period of the year.

The Electrical Installations (IE) laboratory of the Faculty of Construction in Timisoara was chosen for the study, where teaching activities are carried out (Fig. 6) and which raises problems in terms of ensuring thermal comfort conditions during the summer.

Fig. 6. Laboratory of Electrical Installation

From the study of the specialized literature, it was concluded that large glazed surfaces facing south and small glazed surfaces facing north correspond to the passive house concept from the point of view of space heating, compared to the cooling requirement for the warm period of the year, this concept becomes unfavorable. Practically, the influence of the dimensions of the glazed surfaces, in the current conditions of the energy performance of the windows, on the heating of the spaces is not as important as in the case of their cooling. This conclusion is also valid in the case of the IE laboratory. The laboratory has a maximum capacity of 20 places, and during the warm periods of the year (June-August) the indoor temperature exceeded the ambient comfort limit. For this reason, two air conditioners were installed to ensure a comfortable temperature during the warm periods of the year. The laboratory has a volume of 178.45m^3, with a window area of 22.25m^2 and a glazed area of 18.08m^2 facing West (Fig. 7 b). The percentage of glazed surface in the west-facing wall is 48.6%. The entire building of the Faculty of Construction has generous glazed surfaces and spaces with the same orientation as that of the IE laboratory. It has no tall buildings in front of the west-facing facade (Fig. 7a).



a) b)

Fig. 1 Civil Engineering Faculty

a) Orientation of glazed surfaces, b) Detail of glazed surfaces

In order to facilitate the installation of photovoltaic blinds, the need for large sizes of glazed surfaces was analyzed by evaluating the luminosity coefficient. The luminance coefficient given by the glass/floor ratio for the IE laboratory is 0.355, falling into the category of laboratory-type spaces that require precision (0.25-0.5). Although the luminance coefficient of the IE room is beyond the limits required for educational spaces (0.166-0.25), it is considered correctly chosen because laboratory work is carried out in this space, which requires precision in making experimental measurements. Therefore, the surface of the existing glazing, which is currently shaded with textile blinds, is necessary. Although the west orientation of the windows is seen as an advantage because it benefits from more time of natural sunlight, in the case of the IE laboratory it creates both the effect of overheating and the appearance of unwanted reflections on the screens of measuring devices and computers. The overheating effect is accentuated by the significant increase in temperature in recent years (Fig. 8) [22].

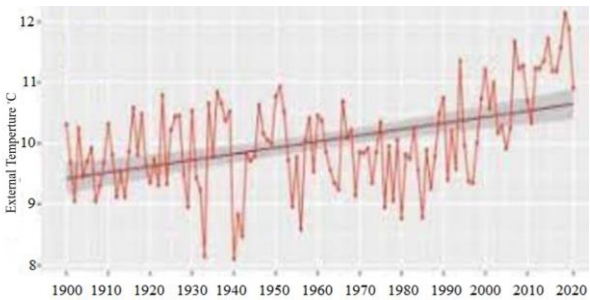


Fig. 8. Climate changes in Romania in the period 1900-2021 [12]

The overheating effect in Romania is accentuated by the significant increase in temperature in recent years (Fig. 8), a fact also confirmed in Timisoara in the period 2021-2022 (Fig. 9)

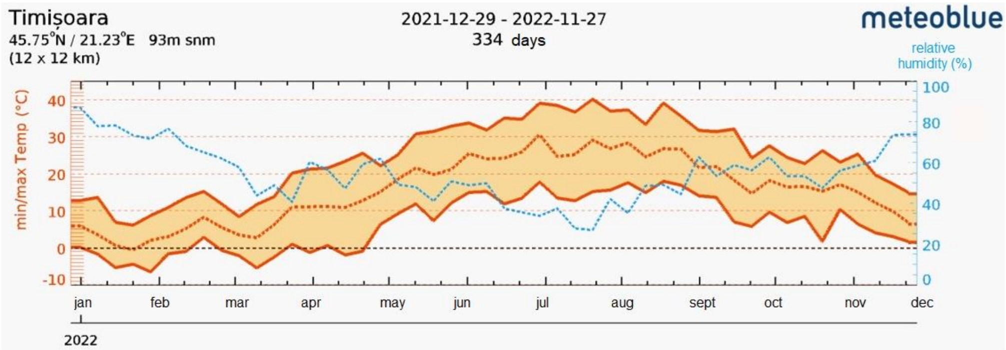


Fig. 9. Climate changes in Romania in the period 29.12.2021- 27.11.2021 [13]

In the Fig.9, it can be seen that in the absence of shading and/or air conditioning systems, in the laboratory, a greenhouse effect would be produced, making teaching activity impossible.

The proposal to replace them with photovoltaic blinds will contribute, on the one hand, to the reduction of energy consumption for cooling and, on the other hand, to the integration of solar energy as an energy source for supplying consumers in the laboratory. Thus, the installation of photovoltaic blinds will contribute to the transition of existing buildings with large glazed surfaces to the passive house concept, as is also the case with the Faculty of Construction.

Two installation options are analyzed (Fig.10):

- Outside the glazed surface – solar radiation is captured before coming into contact with the glazed surfaces;

- Inside the space – solar radiation is captured after passing through the glazed surfaces;


Fig. 10. Blinds installation options

In this regard, a data acquisition station using KNX equipment was installed for the proposed study:

- outside a pyranometer (Fig. 11. a) for monitoring the intensity of solar radiation. The monitored data were stored and processed using a Logic controller (Fig. 11. b). The monitoring of the intensity of solar radiation was also carried out in order to analyze the opportunity of installing photovoltaic panels on the facade of the building, an analysis that was the subject of previous studies by the authors [23-24].

- inside (in the laboratory), a sensor for monitoring temperature and solar radiation (Fig. 11.c)

a) b) c)

Fig. 11. Acquisition station

For the experimental measurements regarding the photoelectric conversion, the following were used: MI 3109 Eurotest PV Lite, METREL, a sensor for measuring the temperature of photovoltaic cells, a probe for measuring solar radiation , a variable resistance and two multimeters for measuring voltage and current intensity DC/AC, (Fig.12).

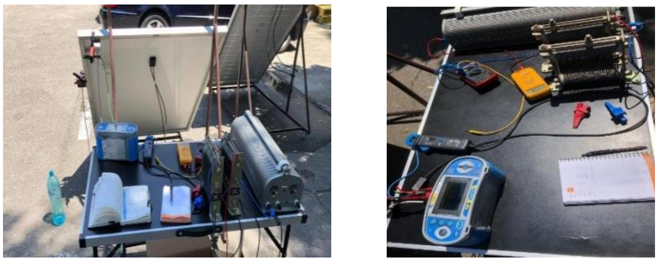


Fig. 12. Solar radiation measurement

3. Results and discutions

The study addresses three directions, namely:

- Reducing the energy needed to cool the space consumption;
- Space shading;
- Production of electricity through photovoltaic effect.

Measurements were made for short periods of time, both in the warm season (June) and in the cold season (November).

To reduce the greenhouse effect, the paper proposes the creation of a shading system with photovoltaic cells.

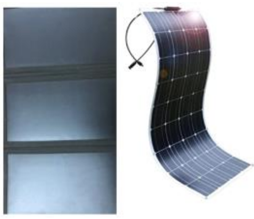


Fig. 13. Shading system with photovoltaic cells

Using PVGIS, the photovoltaic potential was evaluated for a 2KW(peak) photovoltaic system, installed vertically on the building facade. The proposed system can produce 1182 kWh/year, estimated with help of PVGIS

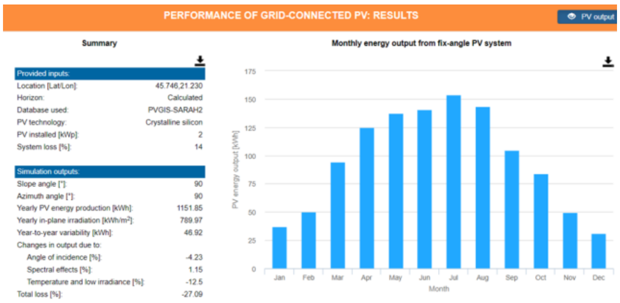


Fig. 13. Estimation of energy production with PVGIS [23]

Table 1 shows the data on energy consumption during the teaching period, for the two air conditioning units installed in the LE laboratory, and in the Fig. 14 compares the electricity consumption required for cooling with the electricity production during the absence of teaching activity.

Table 1

The energy requirement for cooling the space

Month	Week	Day	Hour	Total hour/month	Consumption / unit [kW]	No unit
May	3	5	8	120	0.31	2
June	4	5	8	160		
July	25	5	8	80		
Total hour/ year				360		
Total comsumtion/ year [kWh/year]					446.4	

Estimation of the amount of energy during the period when there is no teaching activity (total shading 556 kWh/year) and consumption for cooling (223 kWh/year), resulting in a benefit of 333kW/year.

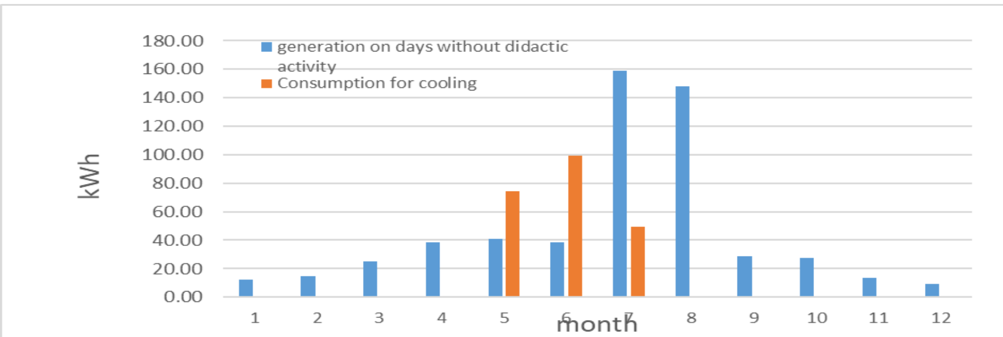


Fig. 14. Compares the electricity consumption and electricity production

4. Conclusions

Starting from the problem of the effects generated by global warming on energy consumption in buildings, especially during the warm period of the year, the luminance coefficient related to the didactic laboratory-type educational space was evaluated, which was calculated at the value of 0.355, which places the space in the category of precision laboratories. It started with this idea because during the warm period of the year the space overheats due to solar radiation and the orientation of the glazed surfaces.

The shading of the glazed surfaces with the textile blinds mounted on the inside is not sufficient, both from the point of view of overheating the space, and from the point of view of shading.

Even if there is the possibility of reducing the glazed surface needed for the natural lighting of the space, in order to maintain the luminance coefficient in the range of 0.166-0.25, it was decided to analyze the installation of photovoltaic blinds for the benefit of solar inputs during the cold period of the year.

The study was also carried out in order to make a contribution to the passive house concept, a concept that should also be adopted in existing buildings.

As solar radiation is beneficial in cold periods, but creates problems in warm periods, it can be said that a key to solving the problems of overheating of the analyzed space is radiation control. Practically, the influence of the dimensions of the glazed surfaces, in the current conditions of the energy performance of the windows, on the heating of the spaces is not as important as in the case of their cooling. For the warm period of the year, the installed air conditioners consume 0.31 kW/h/unit and it is necessary to operate during the entire period of occupation of the space.

Since solar radiation is beneficial in cold periods but creates problems in warm periods, it can be said that a key to solving the problems of overheating of the analyzed space is radiation control. Practically, the influence of the dimensions of the glazed surfaces, in the current conditions of the energy performance of the windows, on the heating of the spaces is not as important as in the case of their cooling. For the warm period of the year, the installed air conditioners consume electricity and it is necessary to operate during the entire period of occupation of the space.

The proposed installation of photovoltaic blinds will contribute, on the one hand, to the reduction of energy consumption for cooling and, on the other hand, to the integration of solar energy as an energy source for supplying consumers in the laboratory. Extrapolating, the installation of photovoltaic blinds will contribute to the transition of existing buildings with large glazed surfaces to the passive house concept.

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