Architectural integration of photovoltaic panels on the facades of existing buildings. Case Study

Integrarea arhitecturala a panourilor fotovoltaice pe fatadele cladirilor existente. Studiu de caz

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Abstract. *Photovoltaic energy represents an outstanding solution for combating climate change and promoting sustainable development, offering benefits such as extensibility and clean energy source. Its integration into buildings as a vital component in modern architecture and sustainable construction has multiple advantages, from saving materials to generating sustainable energy and reducing dependence on fossil fuels. However, the high initial cost and dependence on sunlight are important disadvantages, but using innovative technologies and creative approaches, photovoltaic energy can play an essential role in ensuring a sustainable future and providing functional, aesthetic and sustainable building facades. The case study proposes the modernization of an existing building by installing photovoltaic panels on the western facade and on the roof, thus resulting in an annual electricity production of 16.73 MWh.*

Key words**:** *photovoltaic panels, architecture, solar energy, energetic efficiency*

1. Introduction

Photovoltaic energy is a remarkable discovery that can play a significant role in addressing climate change issues and promoting sustainable development [1]. Converting solar energy into electricity is one of the cleanest and most sustainable methods of energy production.

It is impressive to see the progress made towards zero energy buildings, and the targets set by the European Union for reducing energy consumption in buildings are an important step in the right direction. The implementation of these buildings and other

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renewable energy technologies can help reduce dependence on fossil fuels and lower greenhouse gas emissions [1,2].

It is also impressive to note how efficient a single photovoltaic cell can be, capable of producing between 1 and 2 W [1]. This underlines the enormous potential of this technology, especially when implemented on a large scale.

Therefore, the continuation of research and the implementation of photovoltaic technology is essential for ensuring a sustainable future and for combating climate change.

The benefits of photovoltaic energy are multiple [1]:

- Extensibility - the capacity of the solar panels can be easily adjusted according to the needs of the users.
- Clean and sustainable energy source - photovoltaic (PV) panels use sunlight, an inexhaustible and non-polluting source of energy, protecting the environment.
- Durability and reliability - photovoltaic systems can operate efficiently for a long time without major problems after installation, having a small number of moving parts and requiring little maintenance. This feature gives them resistance to weather conditions such as humidity, wind, snow and lightning.

However, there are also some disadvantages [1]:

- High initial cost - The initial installation of a PV system can be expensive.
- Dependence on sunlight - Electricity generation is only possible during the day, depending on the availability of sunlight, which requires adequate energy storage systems for later use.
- Reduced efficiency due to pollution - The surface of solar panels can be affected by pollution, leading to a drop in efficiency. Studies show that dirt can reduce the efficiency of panels by up to 3.5%, requiring periodic cleaning.

2. Photovoltaic panels on the building envelope

The integration of photovoltaic technology into building architecture represented a significant change in the field of sustainable construction. Buildings with extensive areas offer the opportunity to generate energy by integrating photovoltaic systems. These systems can be incorporated into building facades, roofs or can be used as shading elements to regulate natural light. Integrating these systems into the structure of buildings brings benefits in terms of saving materials, reducing electricity costs, reducing dependence on fossil fuels and adding an aesthetic dimension to the building's architecture.

Despite these advantages, photovoltaic integration in building facades plays a crucial role in shaping the urban landscape, through unaesthetics due to the visibility of the panels. Large building facades can be covered with photovoltaic panels to achieve optimal efficiency. The use of PV in facades can provide protection against excessive solar radiation and replace traditional materials, while providing an aesthetic appearance and additional protection [1].

Although the vertical orientation of facades can reduce the efficiency of photovoltaic systems, the modules can be mounted at an angle to improve the efficiency of power generation [1].

In the past, electricity generation was limited to rooftops or large open spaces, but now it can be innovatively and multifunctionally integrated into the structure of buildings, becoming an essential component of architectural projects. By emphasizing the fusion between aesthetics, functionality and energy sustainability, current models encourage a creative and non-conformist approach to traditional architecture [3].

Apart from traditional integration (Building Integrated Photovoltaics), modern integrated facade solutions also include elements such as fireproof and insulating materials, cladding elements and electrical components. Building facade PV integration technology has the advantage of the design freedom offered by custom solar panels that are not limited to standard shapes or sizes, ranging from 360mm to 3600mm wide, easily adapting to any architectural structure.

These solutions can adopt various typologies:

- Rain screen - recognized as one of the most effective ways to increase durability and reduce maintenance costs, this facade protects the building structure from weather phenomena such as rain and wind. In addition, the ventilation layer helps to reduce the thermal load of the building, while generating sustainable and free electricity. The ventilated solar facade allows for quick and easy installation, inspection and reuse in both new and renovated buildings.
- Curtain wall - in this scenario, solar panel systems are fully integrated into the building envelope and replace traditional support elements or glazed panels. The durable toughened glass surface, which is an integral part of the building's water- and air-tight structure, provides low-maintenance cladding and a minimal environmental footprint, while still generating electricity.
- Blinds - also known as brise soleil, are architectural elements that combine solar protection and energy production by mounting fins on the building facade, either horizontally or vertically. They thus become key components of architectural design.
- Blind systems - offer a wide variety of finishes with exclusive high-performance photovoltaic panels and discreetly and efficiently integrated. They are designed to fit perfectly into the design of the building, while respecting the specific regulations and local requirements of urban architecture.

When designing facades, a number of factors influence their design, from compositional and geographical elements to environmental considerations. Facades are an essential interface between the environment and the interior of the building, shaping its envelope and serving as a link between the exterior and interior life [4].

In this context, contemporary architecture seeks to enrich the role of facades, exploiting their potential through technological innovation. Today, technology is integrated to create more textured and expressive facades, exploring various materials and promoting circular and low-carbon architecture.

Understanding facades as the envelope of buildings and realizing the growing global demand for efficient use of resources in the built environment, there is a need to capitalize on the sunlight incident on building facades. In this sense, PV integration has become increasingly relevant in creating a new aesthetic for facades and minimizing environmental impact. These systems, with their technical capabilities and aesthetic qualities, lead to the creation of attractive, durable and resistant solar facades. They generate a positive impact on the built environment through the efficient incorporation of PV on the one hand, but also on the environment through the production of free and sustainable energy for buildings.

Solar energy can be used effectively in every season if sunlight is available. The strategic placement of solar panels on facades, instead of just being installed on roofs, allows energy to be obtained even in regions with cold climates and low solar incidence, albeit with low efficiency. This strategy extends the efficiency of solar energy use by adapting to variable climate conditions, ensuring consistent performance throughout the year.

Apart from the aesthetic advantages, the solar panels integrated on the facade are also notable for their durability and resistance to various weather conditions. Considering the need for a facade to withstand climatic conditions while maintaining structural integrity, these systems are designed to withstand difficult weather conditions, adapt to the local environment and are built from durable materials, giving them resistance to extreme temperatures (wind pressure and snow accumulation). Durability and environmental responsibility make them a practical and cost-effective solution for a wide variety of building types, whether for new construction or retrofit projects. By prototyping and developing modern models (colors that mimic a metallic or ceramic look, finishes, texture, dimensions and shape), alternatives can be explored to meet the individual needs of each project and meet specific additional standards. These designs offer an alternative to traditional cladding with strong and durable solutions without compromising quality, architectural integrity or aesthetics.

3. Case Study

The building for which the case study was carried out is located in Timișoara on Calea Șagului street (Fig. 1), 9m high, being developed on 3 levels, ground floor, respectively 1st and 2nd floor, incorporating on the ground floor of the building a commercial space intended for the sale of car parts and car accessories, and the 2 floors include block spaces. It is a building made of concrete, with the main facade facing West (Fig. 2).

Fig. 1. Location of the analyzed building

Fig. 2. The facade of the analyzed building (ProMotor from Timișoara).

This building was chosen due to its advantageous position and because it has red PVC tiles integrated on the main facade, this color being representative of the economic agent that carries out its activity in office spaces. The photovoltaic panels will be placed only on the west-facing facade because the east-facing facade includes balconies that shade the facade (Fig. 3).

We chose to replace the PVC boards with red photovoltaic panels (Fig. 3) in order to achieve an energy efficiency of the building, at the same time to offer a pleasant appearance without dissolving the original appearance imposed by the building (Fig. 4).

Fig. 3. Red photovoltaic panel

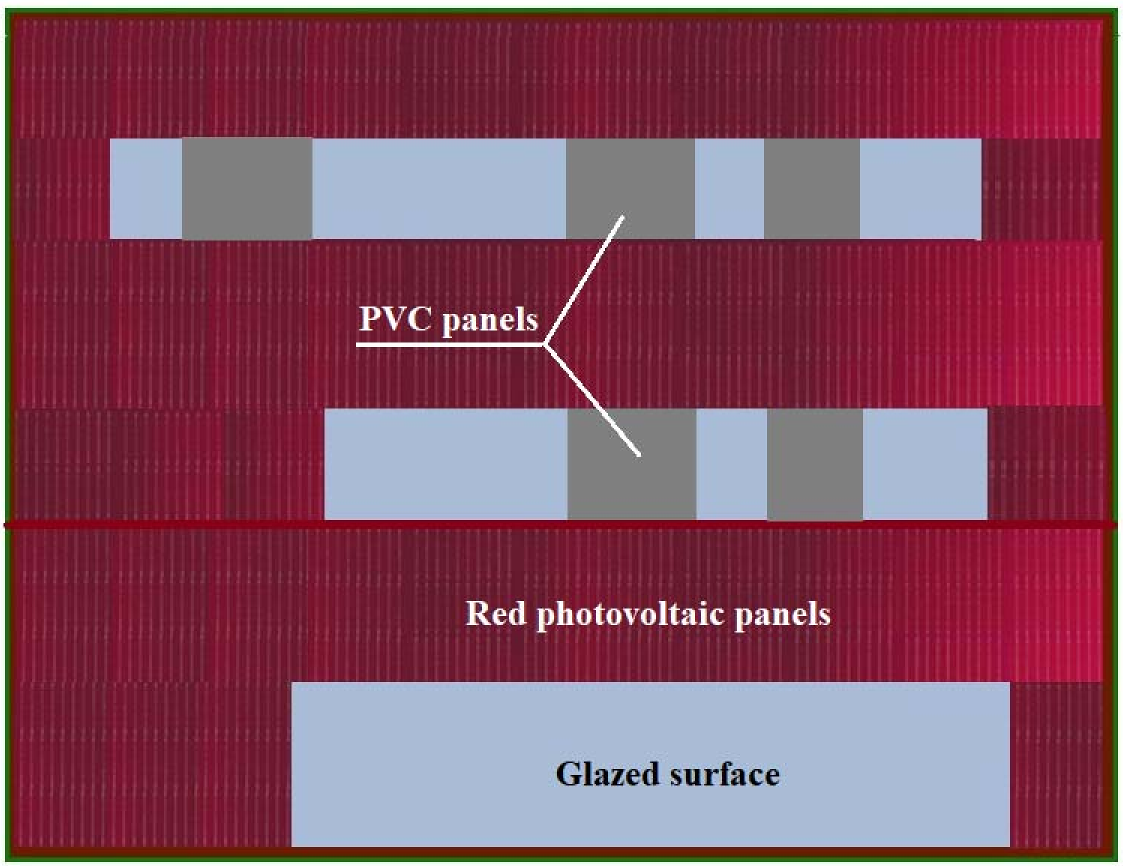

Fig. 4. the placement of photovoltaic panels on the facade of the building

The Polysun SPTX Constructor calculation program [5] was used to simulate the photovoltaic system. In order to use the existing surface potential, we proposed the placement of photovoltaic panels on the roof of the building, which is made of sheet metal. EvoCells 400 MIB type panels with a maximum production power of 400 W were placed on the roof (Fig. 4).

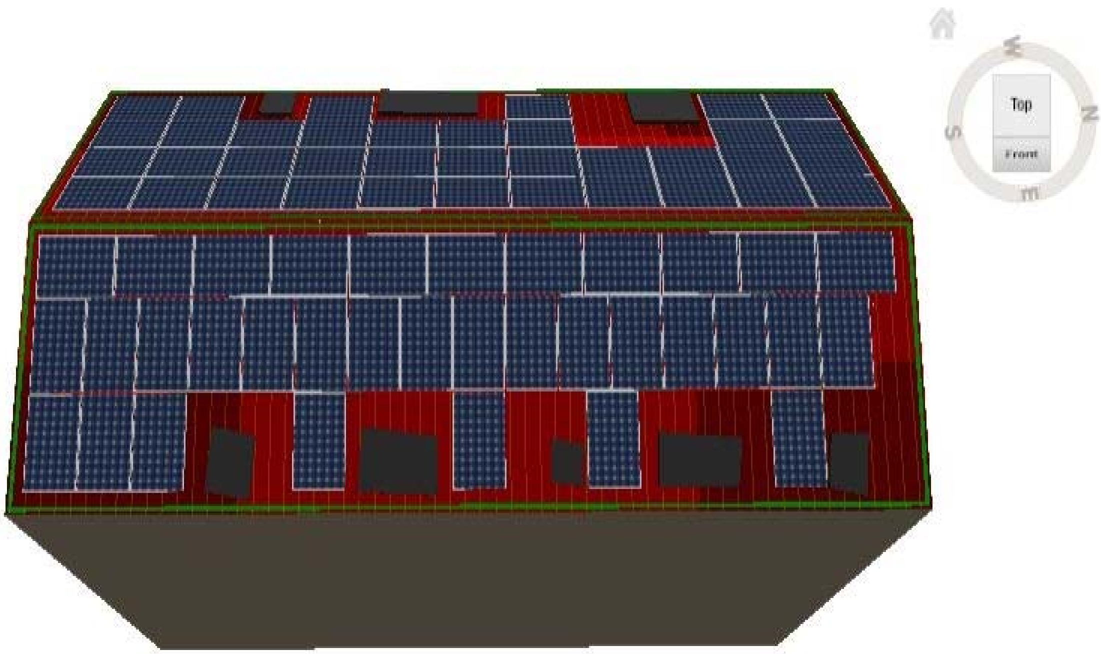

Fig. 5. Placement of photovoltaic panels on the roof of the building

The installed power of the photovoltaic system is 49.96 kW. Following the simulation, the annual production of the photovoltaic system was 16.73 MWh. The monthly electricity production can be seen in the graph in Fig. 6.

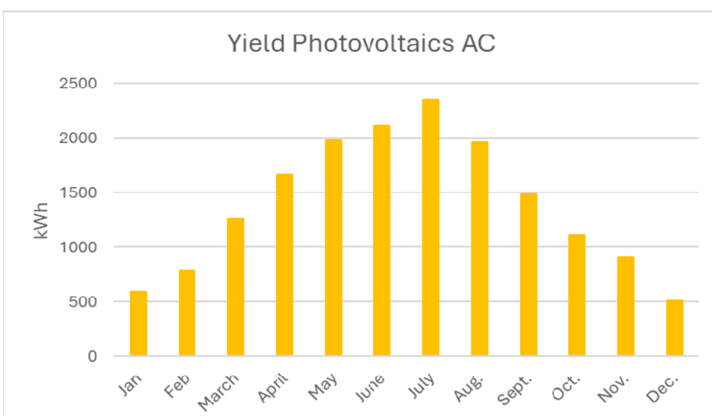

Fig. 6. Monthly electricity production

In addition to the benefit brought by the production of electricity, the use of photovoltaic panels also has the great advantage of reducing the amount of CO2 compared to the production of electricity using classic fuels. In Fig. 7 shows the amount of CO2 saved using this method of electricity production.

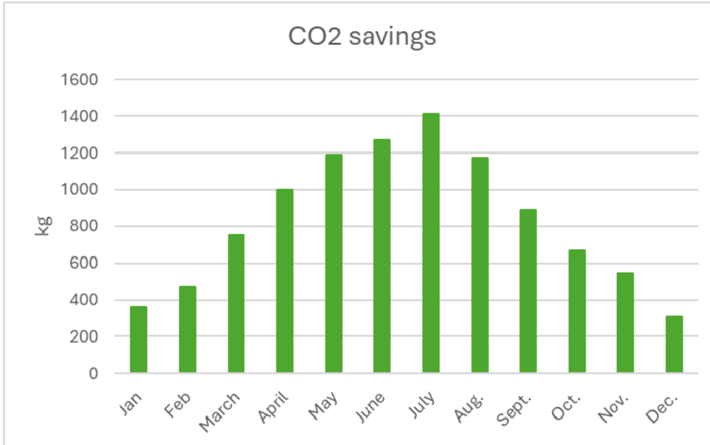

Fig. 7. CO_2 savings

It should also be emphasized that the production of electricity is significant during the summer months, when the amount of energy produced is greater than the amount consumed in the internal electrical installation, so that the surplus energy produced can be delivered to the SEN. In Fig. 8 presents the annual energy flow.

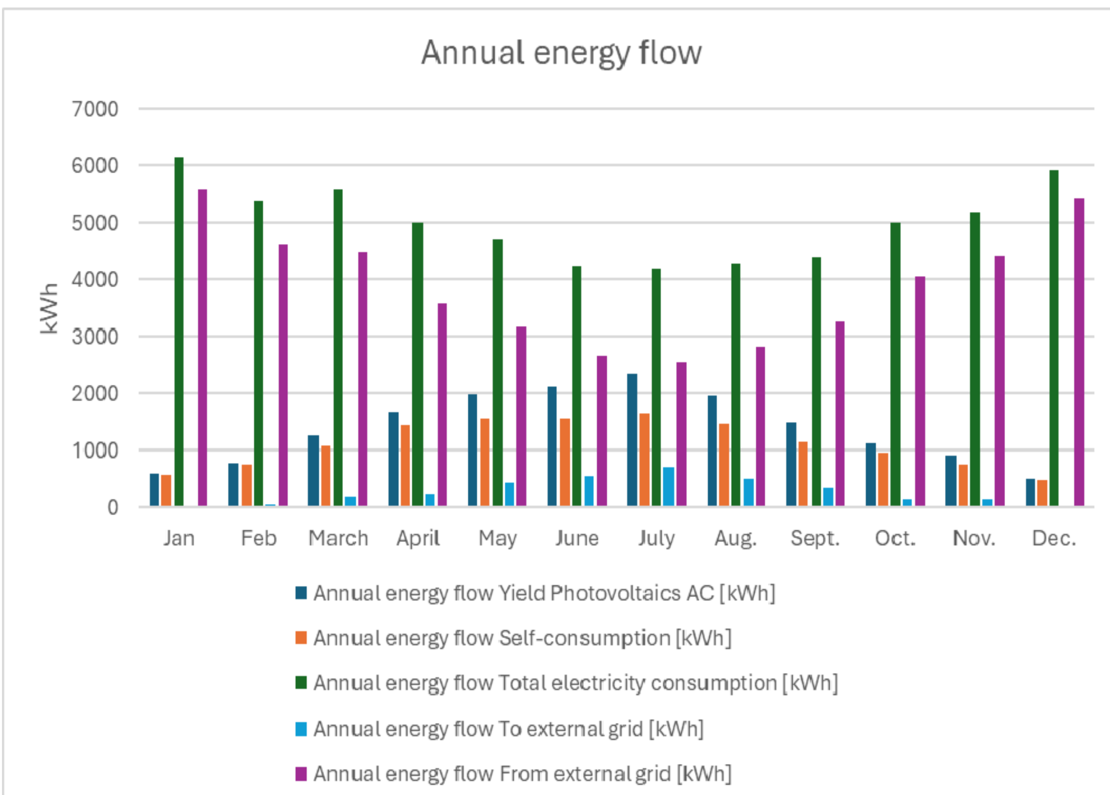

Fig. 8. Annual energy flow

6. Conclusions

In conclusion, photovoltaic energy represents a viable and promising solution for combating climate change and promoting sustainable development in the construction sector. Its integration into building facades presents significant advantages, including the generation of clean and sustainable energy, saving resources and reducing dependence on traditional energy sources. However, it is essential to further address the challenges of cost and reliance on sunlight in order to maximize the benefits of PV technology in creating a sustainable and aesthetically pleasing built environment, thereby helping to build a greener and more sustainable future.

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