ENERGY EFFICIENCY FUNCTION OF INTEGRATED PHOTOVOLTAIC MODULES INTO FAÇADE AT PUBLIC ADMINISTRATION BUILDINGS

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ABSTRACT

Application of integrated photovoltaic panels at existing architecture offers the possibility to design an energy efficient and environmentally friendly building. The aim of this paper is to rebuild the existing public administration buildings in the North-western area of R. North Macedonia. The research analyses the existing public buildings fund in the R. North Macedonia. During the renovation, a double glass structure with integrated photovoltaic systems mounted in the existing structure, taking into account the need for daylight and natural ventilation. When it comes to R. North Macedonia, the integration of photovoltaic systems is not researched enough. Specifically, three public administration buildings in different municipalities of R. North Macedonia are studied. In this paper, the renovation of the existing façade of the buildings made through the installation of a double-glass facade with integrated photovoltaic systems.

The building with a newly designed envelope and its verified parameters designed as a low-energy building represents a modern way of managing existential processes based on energy efficiency and environmental protection. Optimal solution for the energy-efficient building envelope model also represents the new architectural identity of the building.

KEYWORDS: Energy saving, photovoltaic systems, double facades, integration of photovoltaic panels, energy efficiency, low energy building model, environmental protection

INTRODUCTION

The building envelope is the main element responsible for the energy needs of the building. There are many types of envelope that improve the thermal and energy performance of the building. Among the most complex and commonly referred to are double facades.

In this paper will be explored integrated photovoltaic systems as part of a double facade with the function of energy efficiency. The facade implementation includes a vertical suspended facade and a serrated folded facade. According to *Hachem* et al., (2012.) "Geometry of the building and the urban context in which it is located directly influences the availability of solar radiation ".

CONCEPTS OF SOLAR RECONSTRUCTIONS IN MACEDONIA

Although North Macedonia has a small area (25,713 km^2), it has a very diverse climate with eight climatic regions. The Energy Status Rulebook lists three climatic zones that vary by days and degrees/days with different temperature values. The data on the three zones are shown in Table 1.

Table 1: Data on climate zones of the Republic of Macedonia (Magyar et al., 2015)

Climate zone:	**1**	**2**	**3**
Average outdoor temperature in January (°C):	-1	-1,1	-2,3
Average outdoor temperature in August (°C):	25,5	24,6	23
Average global horizontal radiation (kWh/m2 y):	1478	1482	1383
Number of suny days per year (°C d/god.):	1900 - 2400	2401 - 2650	>2650

Climate conditions allow North Macedonia to build buildings known as Plus Energy Buildings. The territory of Macedonia is rich in solar radiation. The estimation of the insolation and reception of solar radiation on differently oriented surfaces shows that the use of

photovoltaic modules for electricity generation in North Macedonia is promising. The optimal tilt of the module is 42° - 57°. According to (*Aronova* et al., 2015) the building module's power rating estimates that even in the worst period of solar radiation, in December, solar modules will not produce less than 17 kWh of daily electricity consumption.

Double glazed facade

Double glazed facade means technological advancement in architecture. The double-glazed facade is extremely suitable for photovoltaic lighting integration because it consists of a closed surface, and the modules can provide a sun shelter.

Facades with integrated photovoltaic system

Photovoltaic system can be integrated in the building either by means of its deposit (wherein the system is laid on the existing building envelope) or by incorporation (integration), wherein the system forms a part of the building envelope. The photovoltaic system is used as an architectural element and a device for generating energy. Transparent and semi-transparent photovoltaic modules have been developed, and they are used as suspended facades to control the light output along with energy production. Semi-transparent glazing prevents sun rays from entering the building, which reduces the load for cooling and shining. Facades offer a great space for the integration of photovoltaic modules, which, besides generating electricity and looking attractive, they protect the building from the climate conditions. In order to achieve a multi-purpose benefit, systems that are unable to light and shade can be integrated.

Plus, energy buildings

Plus, energy building is defined as follows: "Plus an energy building is a building that produces energy from renewable sources to meet the total annual primary energy needs for heating, cooling, ventilation, lighting, transportation and all electrical appliances used in the facility itself, as shown by Leeb et al. (2011)".

Primary energy demand for energy production includes all factors of primary energy production with upstream processes, transport and distribution of energy sources.

ANALYSIS OF SELECTED BUILDINGS

While selecting a category of buildings in the Republic of North Macedonia, Public Administration buildings will be considered. The research covers three buildings in different municipalities in north-western North Macedonia.

Three buildings which belong to the subcategory Regional and Local Government in the different municipalities of north-western Macedonia have been selected in the category of Public Administration Buildings. The buildings are located in three different municipalities such as Gostivar, Tearce and Zhelino.

Analysis of the existing building of Regional and Local Government located in Gostivar

The building is located in the town of Gostivar, at Braća Ginovski no. 61, and belongs to the earlier historical period of construction. It was built in 1975, the architect of the building is K. Muratovski and so far, there is no renovation project for the building's envelope. The Conservation Center of the City of Gostivar did not protect the Regional and Local Administration of the City of Gostivar, which means that there are no restrictions in terms of changing the design concept of the existing building.

Figure 1: Regional and Local Administration Building located in Gostivar, west façade (photographed: 08.08.2017.)

Analysis of the existing Regional and Local Administration Building located in Tearce Municipality

The Regional and Local Administration Building of the Municipality of Tearce is located in the central part of the Municipality of Tearce. The architect of the building was D. Rafajlovski and was built in 2004. The Tearce Regional and Local Administration Building is not protected by the Tetovo Conservation Center, meaning there are no limitations in terms of changing the design concept of the existing building during the renovation of the envelope foreseen in this paper.

Figure 2: Regional and Local Administration Building located in Tearce, south façade (photographed: 08.08.2017.)

Analysis of the existing Regional and Local Administration Building located in Municipality of Zhelino

Regional and Local Administration Building is located on the territory of the Municipality of Zhelino. The architect of the building was A. Hazari and was built in 2007. During the planned reconstruction of the building there are no limitations on the design and visual concept, because the building is not protected by the Tetovo Conservation Center.

Figure 3: Regional and Local Administration Building located in Zhelino, north façade (photographed: 08.08.2017.)

DETERMINING TYPES FOR SOFWERE ANALYSIS

Two different double-glazed facade systems that will be explored are different at the position of photovoltaic modules in relation to the building envelope. Photovoltaic systems are such as:

- System A: Vertical walls with integrated photovoltaic modules
- System B: Vertically - toothed walls with integrated photovoltaic modules

Determination of types according to system A

During the integration of photovoltaic modules into vertical walls (system A) it is possible to determine some variations regard to the building category. Different categories of objects will be considered as types:

- Tip A1: Vertical wall with integrated photovoltaic modules at Regional and Local Administration Building located in Gostivar

Figure 4: Appearance of the west facade of Regional and Local Administration Building located in Gostivar: provided (partly coated) double facade panels with integrated photovoltaic system A

• Type A2: Vertical wall with integrated photovoltaic modules at, Regional and Local Administration Building located in Tearce;

Figure 5: Appearance of the southern façade of the Regional and Local Administration Building located in Tearce: provided (partially coated) double facade with integrated photovoltaic panels of system A

• Type A3: Vertical wall with Integrated photovoltaic modules at Regional and Local Administration Building located in Zhelino

Figure 6: Appearance of the North Facade of the Regional and Local Administration Building located in Zhelino: a partially coated double facade with integrated photovoltaic panels of system A

Determination of types according to system B

Depending on the category of buildings, while integrating photovoltaic modules into vertically toothed walls, variations are the following types:

• Type B1: Vertically toothed walls with integrated photovoltaic modules at Regional and Local Administration Building located in Gostivar

Figure 7: Appearance of the west facade of Regional and Local Administration Building located in Gostivar: provided (partly coated) double facade panels with integrated photovoltaic system B

• Type B2: Vertically toothed walls with integrated photovoltaic modules at Regional and Local Administration Building located in Tearce;

Figure 8: Appearance of the southern façade of the Regional and Local Administration Building located in Tearce: provided (partially coated) double facade with integrated photovoltaic panels of system B

• Type B3: Vertically toothed walls with integrated photovoltaic modules at Regional and Local Administration Building located in Zhelino

Figure 9: Appearance of the North Facade of the Regional and Local Administration Building located in Zhelino: a partially coated double facade with integrated photovoltaic panels of system B

DATA ANALYSIS AND RESULTS

The method of interviewing the building user enabled the calculation of the total needs of the electricity user.

Computer Software PVSYST is a software for analysis, formatting, dimensioning and data analysis of photovoltaic systems. The PVSYST 6.4.3 program provides a tabular representation of the data obtained for a one-year period.

Results at Regional and Local Administration Building, Gostivar

The values shown in Figure 10 clearly show the ratio of output and electricity required for different types of newly designed double facades at Regional and Local Administration Building, Gostivar the amount of electricity produced meets the needs of the user. The energy surplus is 55.60 – 73.80 MWh.

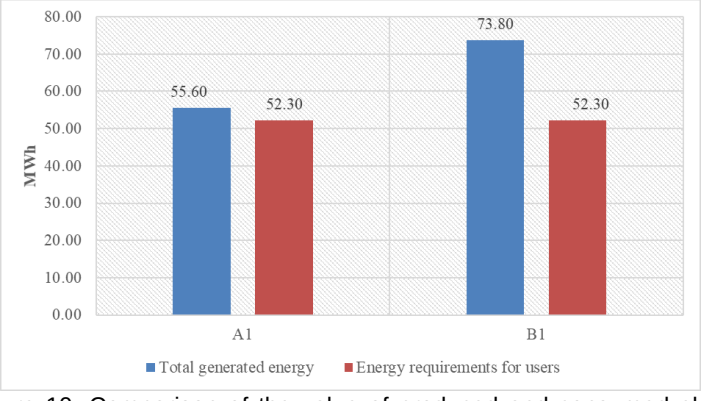

Figure 10: Comparison of the value of produced and consumed electricity at Regional and Local Administration Building, Gostivar

Results at Regional and Local Administration Building located in Tearce

Figure 11 shows the electricity values produced according to the needs of Regional and Local Administration Building located in Tearce. For type A2 there is not a quantity that meets the needs of the user. The total generated energy does not meet the requirements for users.

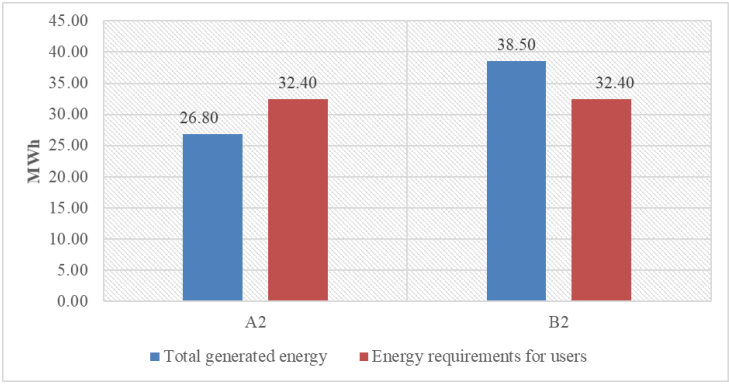

Figure 11: Comparison of the value produced and consumed energy at Regional and Local Administration Building located in Tearce

Results at Regional and Local Administration Building located in Zhelino

The value of electricity produced in accordance with the needs of the Local Administration Building located in Zhelino are shown in Figure 12. Type A3 does not meet the needs of users.

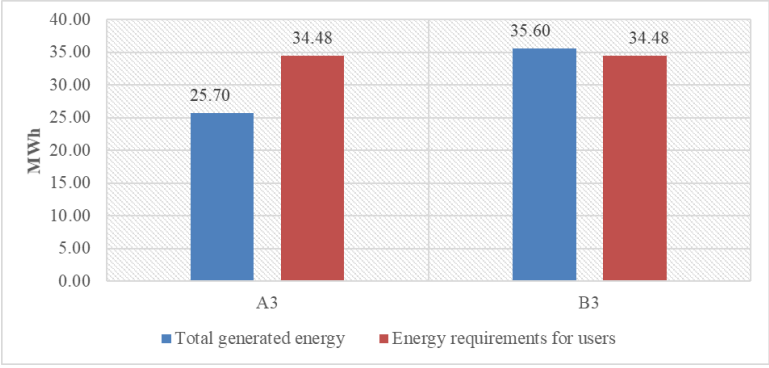

Figure 12: Comparison of the value produced and consumed energy at Regional and Local Administration Building located in Zhelino

CONCLUSION

The results obtained with graphs give a clear insight into the optimal double glassing system, vertically toothed, with integrated photovoltaic modules, a B system. This type of envelope in further consideration is the optimal solution for a low-energy building model that will serve Administration buildings that have high energy requirements when renovating the building envelope. According to

software PVSYST total assessment of the investment of a B system integrated above the entire envelope reaches a value of 222.700 EUR at RLA Zhelino, 251.100 EUR at RLA Tearce and 445.808 EUR at RLA Gostivar. The optimum solution for the model of a more energy-efficient building can be applied to many buildings but must be subjected to the renovation of the envelope according to conventional energy recovery methods. Created an optimal solution for the energy-efficient building envelope model in the form of vertically toothed walls with integrated non-transparent and semi-transparent photovoltaic modules represents the redesign of the envelope not only for energy saving but also for architectural attitude. In terms of the transformation of existing identity, the new form also represents the new architectural identity of the building.

REFERENCES

Aronova, E., Vatin, N., Murgul, V. 2015. Design Energy-Plus-House for the Climatic Conditions of Macedonia, International Scientific Conference Urban Civil Engineering and Municipal Facilities, ScienceDirect, Procedia Engineering, 117 (2015), pp. 766. - 774.

Hachem, C., Athienitis, A., Fazio, P. 2012. Design methodology of solar neighborhoods, Energy Procedia 30 (2012), pp. 1284 - 1293.

Leeb, M., Korjenic, A., Bednar, T. 2011. Peb - Marketable Energy Plus Office Building, KGH 42nd International Congress and Exhibition on Heating, Refrigeration and Air Conditioning", (2011), pp. 391. - 401.

Magyar, Z., Nemeth, G., Kontra, J. 2015. D3.3 Report on best practices and lists of technologies useful for the refurbishment of buildings with detailed national sections, D3.4 Report on proposed packages of measures, Contract N°: IEE/13/886/SI2,674899 Refurbishment of the public building stock towards NZEB acronym of the project Republic ZEB