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Original Scientific Paper

HOW TO RENEW THE FAÇADE OF EDUCATIONAL BUILDINGS BY USING SOLAR ENERGY?

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Abstract

Integration of photovoltaic modules at existing architecture offers the possibility to design an energy efficient and environmentally friendly building. When it comes to R. N. Macedonia, the integration of photovoltaic systems isn't researched enough. In older building energy consumption can be reduced significantly by renovating the building shell. The remaining energy demand should be covered by active systems that use energy from a renewable source. This paper aims to step towards renovation of existing educational buildings in the Northwestern area of R. N. Macedonia using solar energy. Research analyses the existing educational buildings fund in the R. N. Macedonia. Renovation of façade of buildings is made by double glass structure with integrated photovoltaic systems mounted in the existing structure, taking into account the need for daylight and natural ventilation. Specifically, three educational buildings in different municipalities of R. N. Macedonia are studied. The building with a newly designed envelope and it`s 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: Solar energy, integrated photovoltaic modules, energy efficiency, educational buildings, double glass structure

1. Introduction

The traditional way to improve a facade that is worsened is to apply a new cladding, often together with additional opaque insulation. Solar alternatives consist of different types of solar walls from simple unventilated solar walls (glazing) to more advanced solar walls like 'Tomb walls'. According to (Dalenbiick 1996), the solar walls, like the traditional wall renovation, protect the old wall (damaged concrete or plaster) and reduce the coefficient of thermal transmittance (*U* value).

To apply glazing as a double façade can also be an interesting alternative that can improve the building envelope. The integration of PV systems into a double envelope becomes part of the general building design (Hestnes 1999). The PV systems must replace the conventional building elements in addition to their ability to produce energy.

2. Solar renovation concepts

Most solar renovation concepts claim to have an impact on the thermal energy requirements of the building. The specific effects of the solar features are often hidden in the total effects since most solar renovation projects also include traditional renovation activities (e.g. additional insulation and replacement of windows). Solar concepts could also be regarded as building energy conservation measures and there is a need to define more clearly the solar aspects in some applied concepts. Major solar renovation concepts with the possible influence are described and discussed as following:

- Double skin/glazed façade;
- Façade Integrated photovoltaics

2.1 Double skin/glazed façade: 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.

2.2 Facades with integrated photovoltaic system: The photovoltaic system can be integrated in the building either by means of its deposit (where in 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. To achieve a multi-purpose benefit, systems that are unable to light and shade can be integrated.

2.3 Plus, energy buildings: According to (Leeb 2014) 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".

3. Analysis of selected buildings

Although Republic of the North Macedonia has a small area (25,713 km2), 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 North Macedonia (Magyar, 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 the Republic of 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 Macedonia is promising. The optimal tilt of the module is 42 ° - 57 °. 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 (Aronova, 2015).

While selecting a category of buildings in the Republic of North Macedonia, buildings of educational institutions will be considered. The research covers three educational institutions in different municipalities in northwestern Macedonia.

The building being investigated is "Hasan Prishtina" Primary School in Čair Municipality in Skopje.

3.1 Analysis of the existing building of elementary school "Hasan Prishtina", Cair – Skopje: The building is located in the area of Čair Municipality in Skopje, at Koste Abrashević Street no. 7. It was built in 1980. Primary School "Hasan Prishtina" is a building with a basement, ground floor, and two floors. In 2012 was carried out reconstruction.

Figure 1 The building of the "Hasan Prishtina" Elementary School, Čair-Skopje: a) part of the east and north façade, b) west facade (photographed in: August 8, 2017)

Figure 2. Inner appearance: a) entrance door, b) exterior openings, c) economic room (photographed in: August 8,2017)

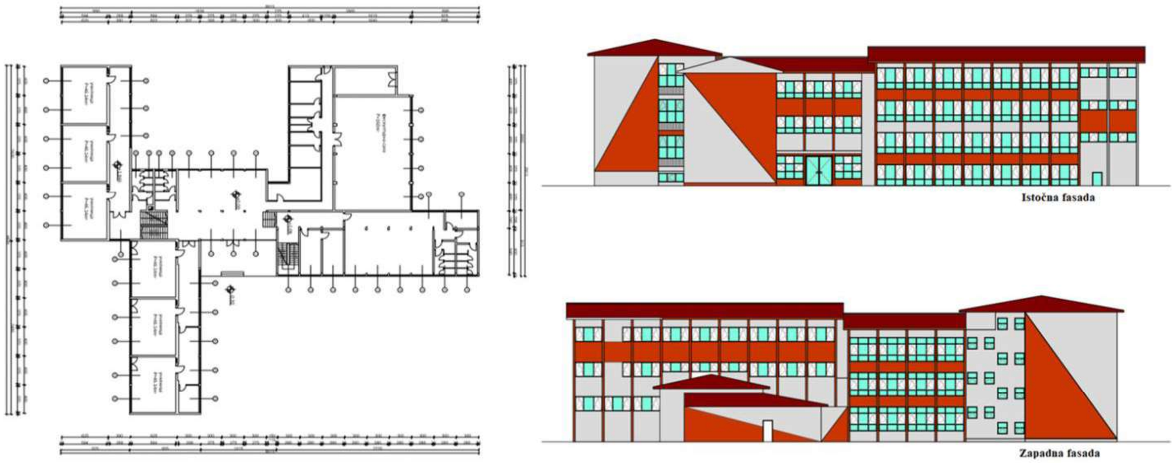

Figure 3. Draft: Ground floor and the elevations of the building "Hasan Prishtina" in Čair-Skopje Municipality, digitized existing project documentation

Table 1. Input data for Primary School "Hasan Prishtina", Čair, Skopje

Category - Educational Institutions		**Subcategory - Schools**	
North latitude	42º0`38``	Floors	Su+P+2
East latitude	21º26`36``	Average number of users	959
Above sea level	259 m	Useful area of the building A_k (m^2)	3719
Architect	L. B. Dineva; D. Paskalov	Volume of heated part of building V_e (m^3)	12.754
Buildings Geometry			
Northern walls (m^2)	614	Eastern windows (m^2)	276,29
Eastern walls (m^2)	713	Southern windows (m^2)	309,18
Southern walls (m^2)	608	Western windows (m^2)	169,36
Western walls (m^2)	721	Roof (m^2)	1390
Northern windows (m^2)	240,1	Floor (m^2)	1239,78

4. Defining types for software 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 wall with integrated transparent and semitransparent photovoltaic modules
- System B: Accordion profiled curtain walls with integrated transparent and semitransparent photovoltaic modules

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

- System A: Vertical wall with integrated photovoltaic modules at the building of elementary school "Hasan Prishtina", located in Čair – Skopje

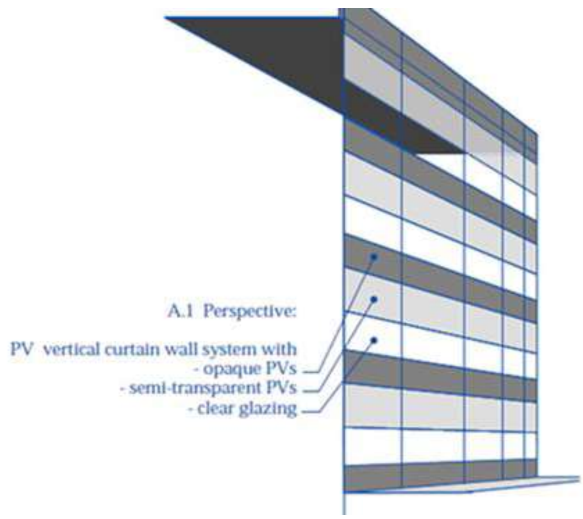

Figure 4.Vertical wall with integrated transparent and semitransparent photovoltaic modules

Figure 5. The appearance of a part of the eastern and northern façade of the Elementary School "Hasan Prishtina" in Skopje: foreseen (partially coated) double facade with integrated photovoltaic panels of system A

- Type A2: Accordion profiled curtain walls with integrated transparent and semitransparent photovoltaic modules

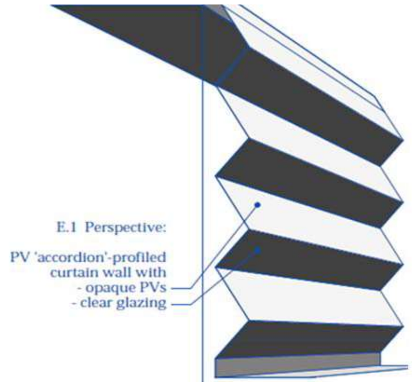

Figure 6. Accordion profiled curtain walls with integrated transparent and semitransparent photovoltaic modules

Figure 7. The appearance of a part of the east and north façade of the Elementary School "Hasan Prishtina" in Skopje: a partially coated double facade with integrated photovoltaic panels of B system

5. 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 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.

Table 2. Daily energy consumption

Device type	Number of units	Required energy (W/device)	Operating period (h / day)	Daily consumption (Wh)	Annual energy consumption (MWh / y)
LED light	200	18	3	10.800	1,944
Personal computer	50	250	8	100.000	24
Printers	10	426	1	4260	1,0224

Fax	2	65	0,5	65	0,0156
LCD projectors	10	260	0,5	1300	0,312
LCD projector	4	3200	8	102.400	24,576
Air conditioners	10	20	2	400	0,096
Other devices (DVD)	5	50	2	500	0,12
Other Devices	20	5	24	2400	0,876
Stand-by devices	4	1520	10	60.800	6,08
Total annual energy consumption (MWh / year)					50,92

5.1. Results in the application of system A: The values shown in Figure 6 clearly show the ratio of output and electricity required for different types of newly designed double facades at Elementary School "Hasan Prishtina" in Skopje. The amount of electricity produced meets the needs of the user. The energy surplus is about 36.60 - 83.60 MWh in each orientation separately.

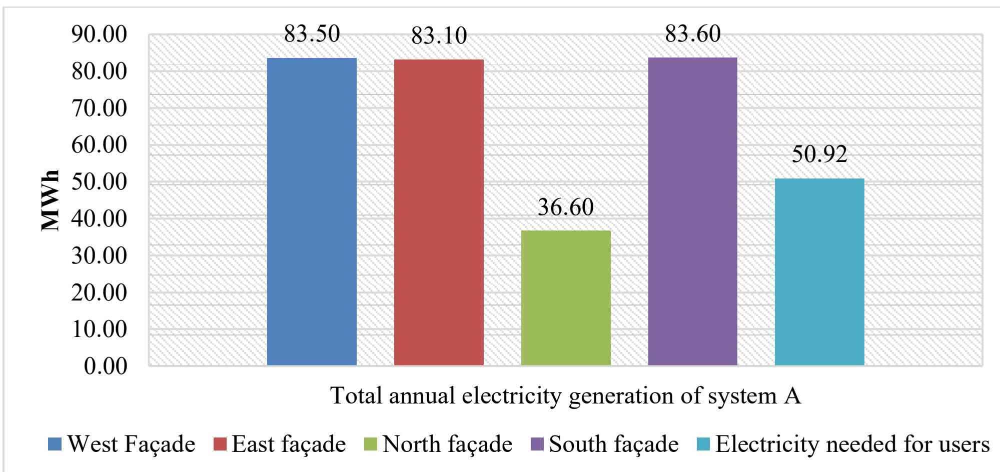

Figure 8. Comparison of the value of produced and consumed electricity on different orientations at Elementary School "Hasan Prishtina" in Skopje, by using system A

5.2. Results in the application of system B: The values shown in Figure 7 clearly show the ratio of output and electricity required for different types of newly designed double facades at Elementary School "Hasan Prishtina" in Skopje. The amount of electricity produced meets the needs of the user. The energy surplus is about 36.60 - 83.60 MWh in each orientation separately.

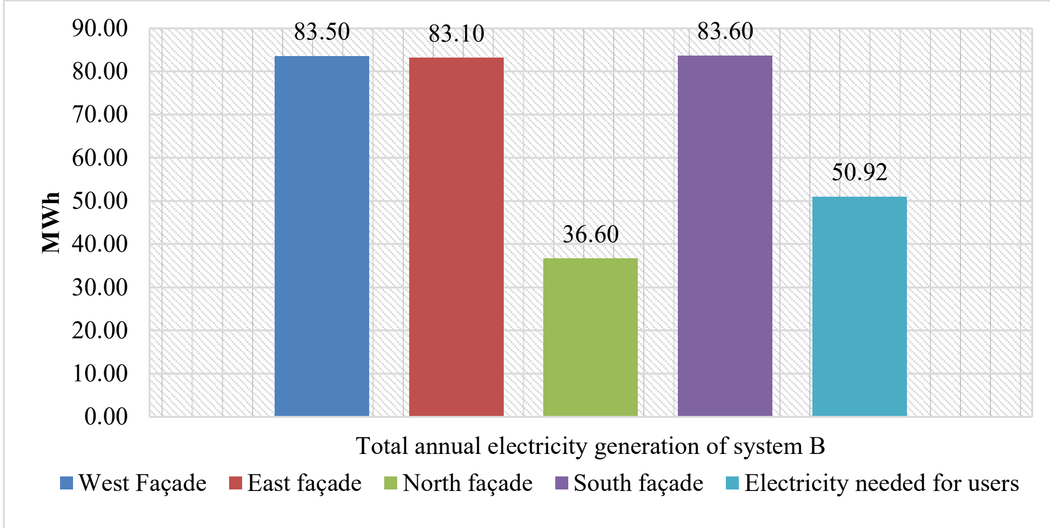

Figure 9. Comparison of the value of produced and consumed electricity on different orientations at Elementary School "Hasan Prishtina" in Skopje, by using system B

5.3. Comparison of the value produced and consumed energy in the application of systems A and B: The difference between systems A and B is obvious and its amount is about 100 MWh electricity.

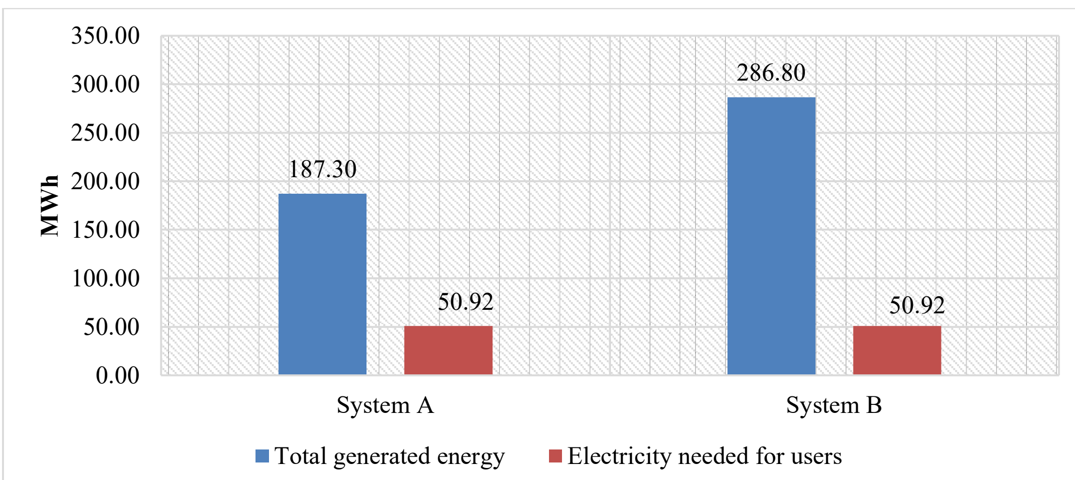

Figure 10. Comparison of the value of produced and consumed energy by using system A and B

6. Conclusion

The results obtained with graphs give a clear insight into the optimal double glassing system, accordion profiled curtain walls with integrated transparent and semitransparent 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 School buildings that have high energy requirements when renovating the building envelope. 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 accordion profiled curtain walls with integrated transparent and semitransparent photovoltaic modules represent the redesign of the envelope not only for energy saving, but also for architectural attitude. Concerning the transformation of an existing identity, the new form also represents the new architectural identity of the building.

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