ENERGY EFFICIENCY IN THE PUBLIC BUILDINGS SECTOR IN THE TERRITORY OF THE CITY OF KRAGUJEVAC – CASE STUDY OF "MILUTIN AND DRAGINJA TODOROVIĆ" ELEMENTARY SCHOOL

Ana RADOJEVIĆ, Aleksandar NEŠOVIĆ, Jasmina SKERLIĆ, Dušan GORDIĆ, Danijela NIKOLIĆ
aradojevic@kg.org.rs, aca.nesovic@gmail.com, j.skerlic@pr.ac.rs, gordic@kg.ac.rs

1. Introduction

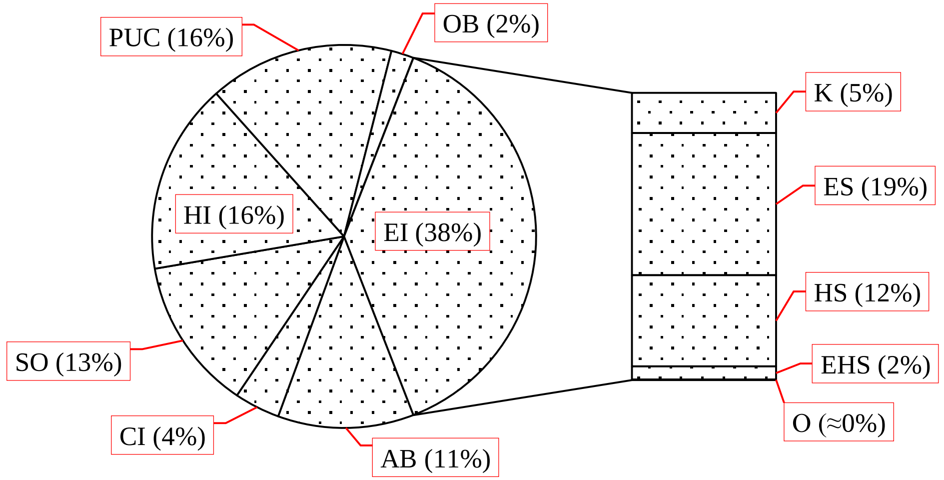

Fig. 1. The electric power consumption in PBS in the City of Kragujevac according to the facility structure [1]
EI – Educational Institutions; AB – Administrative Buildings; CI – Cultural Institutions; SF – Sports Objects; HI – Health Institutions; PUC – Public Utility Companies; OB – Other Buildings; K – Kindergarten; ES – Elementary School; HS – High School; EHS – Elementary and High School; O – Other

2. Materials and methods

The subject of the research is the "Milutin and Draginja Todorović" Elementary School building (Fig. 2). The building has four floors with a total area of 4424.74 m^2, as follows: basement (683.3 m^2), ground floor (1986.94 m^2), first floor (823.55 m^2) and second floor (930.95 m^2). The main entrance is oriented to the southwest (SW).

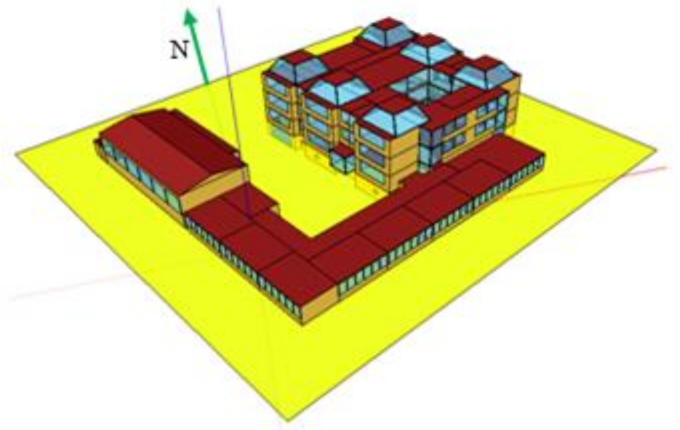

Fig. 2. Isometric view of the ES "Milutin and Draginja Todorović"

ENERGY EFFICIENCY IN THE PUBLIC BUILDINGS SECTOR IN THE TERRITORY OF THE CITY OF KRAGUJEVAC – CASE STUDY OF "MILUTIN AND DRAGINJA TODOROVIĆ" ELEMENTARY SCHOOL

Kragujevac (located in GMT+1 h time zone) is characterized by a moderate continental climate with distinct seasons. Summers are hot and humid, with temperatures reaching +37°C. On the other hand, winters are cold (temperatures drop to -12°C) with snow. The city is located at 44°02′ N and 20°92′ E, at the altitude of 209 m [15].

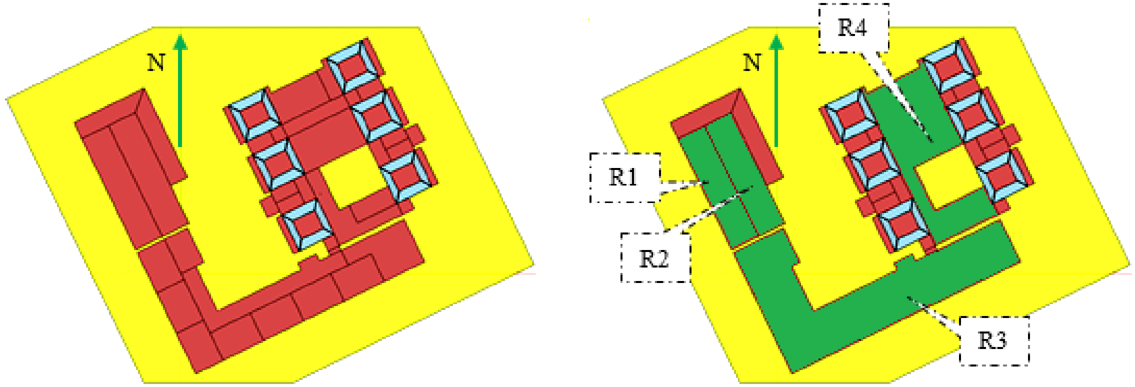

Fig. 3. View of the roof flats of the ES "Milutin and Draginja Todorović"

Taking into account the specific factor of the building shape and orientation, the Fig. 3. shows potential roof surfaces for the installation of PV panels. The characteristics of the listed roof surfaces are given in Tab. 2.

Tab. 2. Characteristics of potential roof surfaces for installing PV panels

Name	Designation	P [m^2]	Characteristic	I_{TOT} [$kWh/m^2/a$]	Conclusion
Roof 1	R1	145.24	Hip roof (≈9.6° to SW)	1367.52	Suitable for installing PV panels
Roof 2	R2	145.24	Hip roof (≈9.6° to NE)	1247.63	Not suitable for installing PV panels
Roof 3	R3	647.95	Flat roof	1278.14	Suitable for installing PV panels
Roof 4	R4	366.35	Flat roof	1242.86	Not suitable for installing PV panels

P – Roof area; I_{TOT} – Total solar radiation incident on roof area

It is possible to install 72 monocrystalline PV panels, measuring 1940×990×40 mm in size, with the total installed (maximum) power of 24480 W [16] on the Roof 1. Taking into account the optimal angle of inclination of the PV panels, which is 37.5° for the city of Kragujevac [17], the recommendations from [18] related to the method of assembly and installation of PV panels, the impact of shadow due to the factor of orientation and shape of the building (Fig. 4), as well as the formula (Eq.1 [19]) for determining the optimal distance between the rows of PV panels (Fig. 5), it is possible to place a total of 88 monocrystalline PV panels (of same dimensions) with the total installed (maximum) power of 29920 W on the Roof 3.

$$Z = H \cdot \frac{\sin\left(180^\circ - (\alpha + \beta)\right)}{\sin\beta} = 1.94m \cdot \frac{\sin\left(180^\circ - \left(37.5^\circ + 22.5^\circ\right)\right)}{\sin 22.5^\circ} = 2.24m \qquad \text{(Eq. 1)}$$

ENERGY EFFICIENCY IN THE PUBLIC BUILDINGS SECTOR IN THE TERRITORY OF THE CITY OF KRAGUJEVAC – CASE STUDY OF "MILUTIN AND DRAGINJA TODOROVIĆ" ELEMENTARY SCHOOL

The impact of the shadow (the so-called shadow line) is determined for the spring (March 21) and autumn (September 23) equinox, when the length of the day and night is 12 hours each.

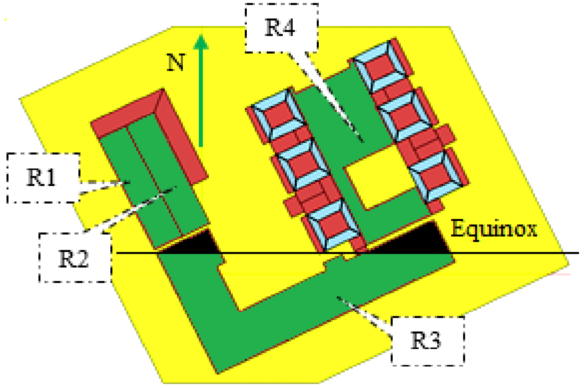

Fig. 4. Net roof surface for PV panel installation on the Roof 3

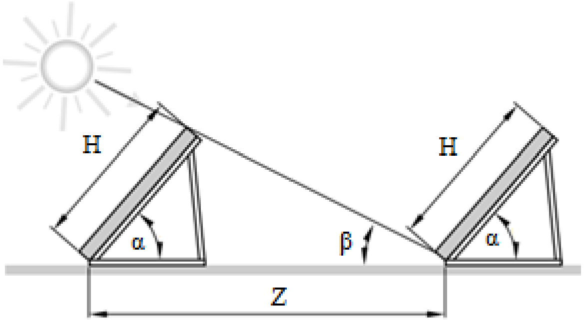

Fig. 5. Optimal distance between the rows of PV panels

Isometric view of the conceptual design of the solar power plant on the roof of the "Milutin and Draginja Todorović" Elementary School building with a total installed (maximum) power of 54400 W is shown in Fig. 6.

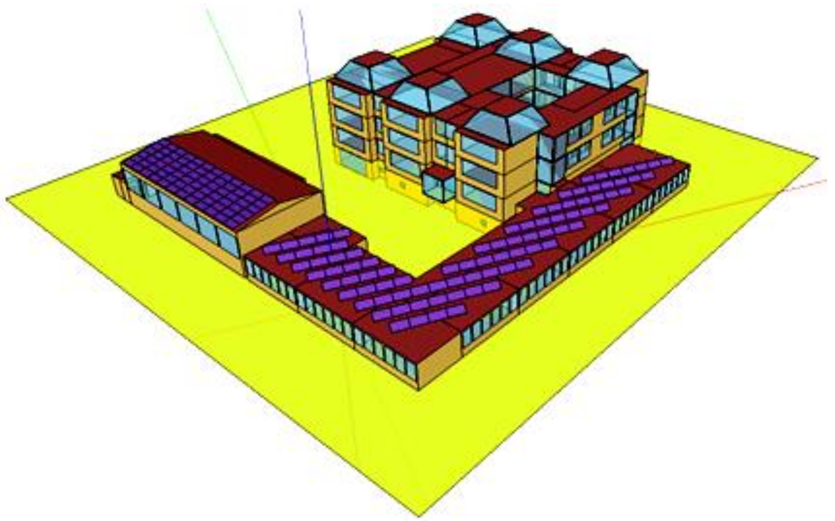

Fig. 6. Isometric view of the conceptual design of the solar power plant on the roof of the "Milutin and Draginja Todorović" ES building

3. Research results

Electric power consumption in the "Milutin and Draginja Todorović" Elementary School building, by months, for the period 2015-2019, is shown in Fig. 7.

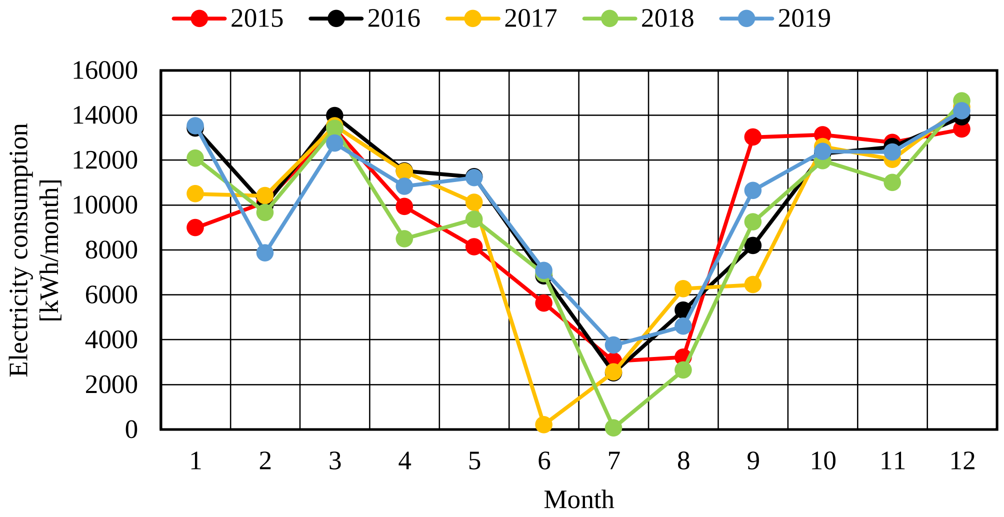

Fig. 7. Monthly consumption of electricity in "Milutin and Draginja Todorović" ES building (2015-2019)

The impact of the shadow (the so-called shadow line) is determined for the spring (March 21) and autumn (September 23) equinox, when the length of the day and night is 12 hours each.

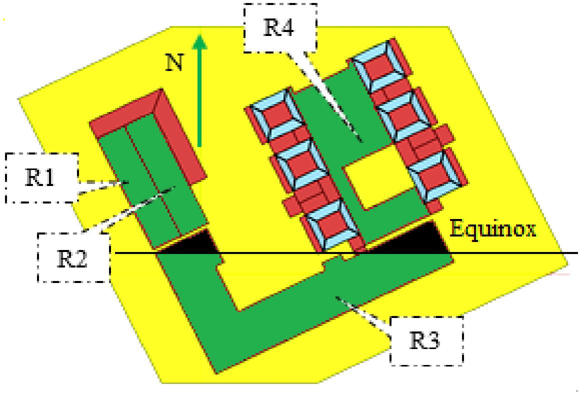

Fig. 4. Net roof surface for PV panel installation on the Roof 3

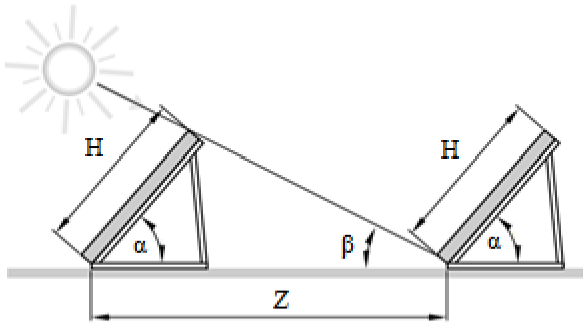

Fig. 5. Optimal distance between the rows of PV panels

ENERGY EFFICIENCY IN THE PUBLIC BUILDINGS SECTOR IN THE TERRITORY OF THE CITY OF KRAGUJEVAC – CASE STUDY OF "MILUTIN AND DRAGINJA TODOROVIĆ" ELEMENTARY SCHOOL

Fig. 8. shows the relationship between the monthly production of electricity from the solar power plant and its average consumption in the period from 2015 to 2019 in the analyzed building.

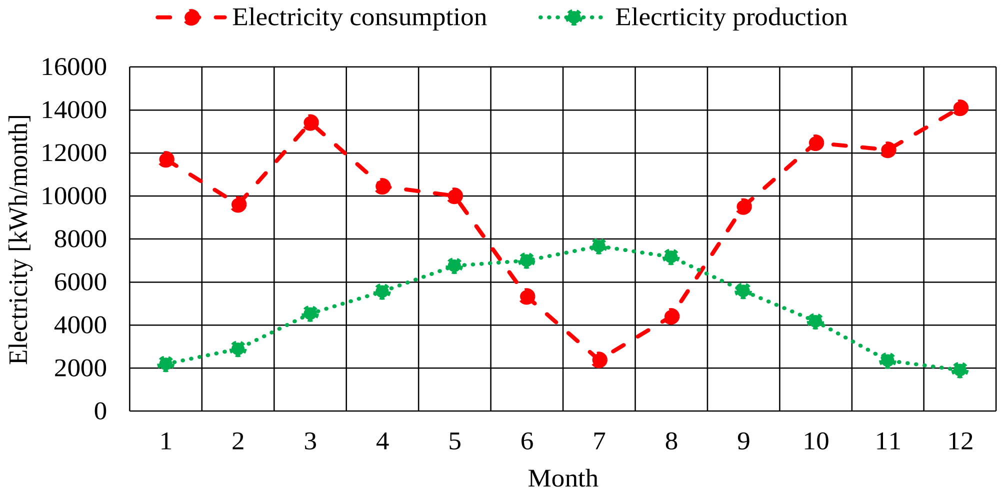

Fig. 8. Relationship between the monthly production of electricity and its average consumption in "Milutin and Draginja Todorović" ES building

The first thing to be noticed is that the solar power plant is not able to fully compensate for the school's needs for electric power from September to May, that is, school's electricity needs are much higher than the solar power plant potentials. It can also be noticed that the production of electricity is the highest in June, July and August, when the needs are the least (the production of electricity exceeds the needs of the building). As the legislation in Serbia is still not on the side of the privileged producers of electricity, the surplus electricity can be stored and then used depending on the needs of the building. This would give much more even production and consumption curves (Fig. 9).

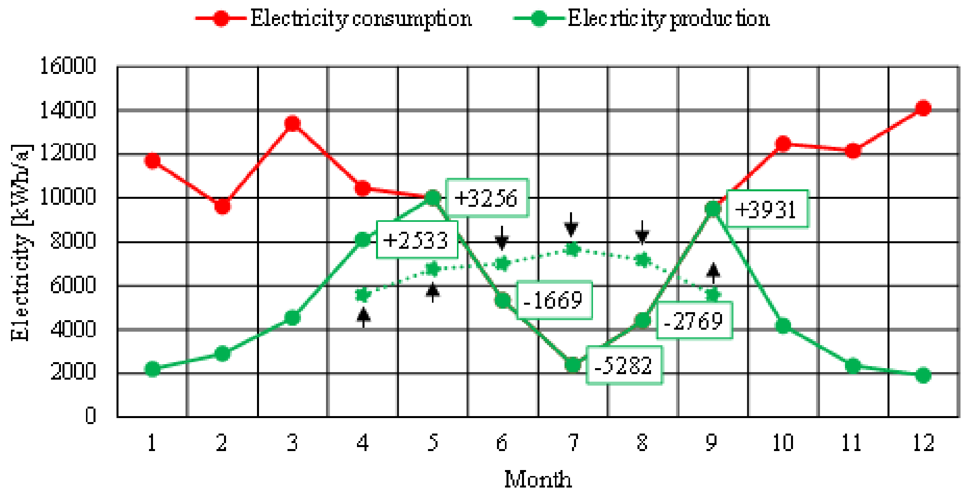

Fig. 9. Balancing of electricity consumption in "Milutin and Draginja Todorović" ES building

As the average annual electricity consumption in the analyzed period is around 115558 kWh/a, and the average electricity production is 57795 kWh/a (with a system efficiency of 90% during the first 15 years), it can easily be concluded that, by installing a solar power plant on the roof of the "Milutin and Draginja Todorović" Elementary School building, savings in consumption of about 50% can be achieved, which means that a significant reduction in CO_2 emissions and primary energy consumptioncan be achieved as well (Fig. 10, Fig. 11).

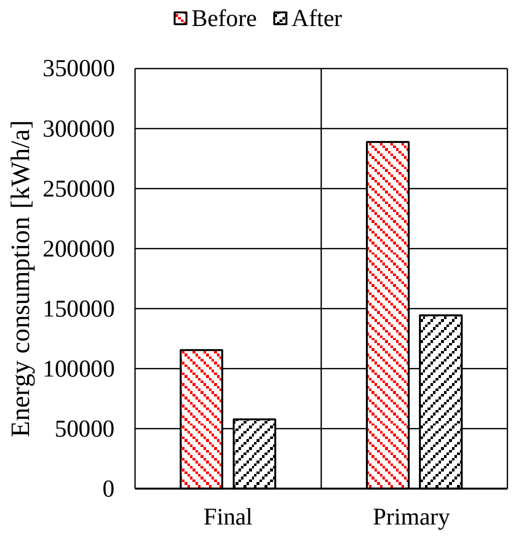

Fig. 10. Final and primary energy consumption in "Milutin and Draginja Todorović" ES building before and after energy efficiency measures [20]

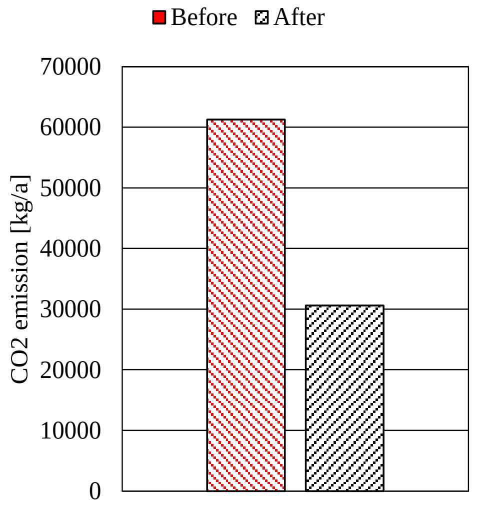

Fig. 11. CO_2 emissions in "Milutin and Draginja Todorović" ES building before and after energy efficiency measures [20]

4. Conclusion

Educational institutions (EI), with a share of approximately 38%, represent the largest category of facilities in the public buildings sector (PBS) in the City of Kragujevac when it comes to electric power consumption, which annually amounts to over 10 GWh. In order to reduce electricity consumption in EI, and even in the entire PBS, the use of PV panels can play a key role, which has been tested and shown in a number of papers around the world. It is possible to install a solar power plant with a total installed (maximum) power of 54400 W on the roof of the "Milutin and Draginja Todorović" Elementary School building in Kragujevac.

The solar power plant is not able to fully compensate for the school's needs for electric power from September to May, that is, school's electricity needs are much higher than the solar power plant potentials. The production of electricity is the highest in June, July and August, when the needs are the least (the production of electricity exceeds the needs of the building).

By installing a solar power plant on the roof of the "Milutin and Draginja Todorović" Elementary School building, savings in consumption of about 50% can be achieved, which means that a significant reduction in CO_2 emissions and primary energy consumption can be achieved as well. As the legislation in Serbia is still not on the side of the privileged producers of electricity, the surplus electricity can be stored and then used depending on the needs of the building.