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Contents

Energy Efficient Refurbishment of Educational Buildings: Case Study Niš

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Abstract: Extremely affected by the need for energy efficiency improvements, this research directs to help reduce energy consumption by applying successful energy actions. Improvements in a building's energy efficiency has the largest potential in terms of saving energy. In this work, we analyzed 23 elementary schools and 21 kindergartens, which are located in the city of Niš. Through the case study we will indicate the deficiencies that were identified in the school facilities and also give a proposal for the improvement of energy efficiency. The aim of this engineering analysis is to affect some relevant future conclusions concerning the organized refurbishment and improvement of the existing educational buildings in order to continuously reduce energy consumption. Instead of dispossessing the users anywise, energy saving benefits the competitiveness of the facility, comfort and quality of the environment.

Keywords: educational buildings, energy efficiency, kindergartens, improvement, Niš, schools

1. Introduction

The increasing need for protection, promotion and preservation of natural resources, based on the fact that overpopulation, and urban concentration negatively affected the changes that have occurred in nature. Efficient use of electric energy became a priority in terms of natural environment protection. The building sector is one of the most important consumers of energy, there is about 50% of the total energy produced is spent in facilities, on what conditions need to propose measures for improving energy efficiency [1].

The task of modern society is to manage natural resources today rational, and to predict and avoid negative consequences of human impact in the future. For that reason, the subject of analyses in this paper are primary schools and kindergartens which located in city of Niš (Republic of Serbia). Beside significant savings in energy consumption, by implementing the principles of efficient energy consumption in school facilities, we are investing in future generations which are going to benefit all advantages which will come as a result of these actions. Kindergartens and primary schools account for 11% of the total energy used by institutional/commercial sector and are the second largest energy consumers in this sector. More than half of preschool buildings in Serbia are in urgent need of energy efficiency improvements, as they are wasting expensive energy (approximately 2500 nurseries and kindergartens) [2]. Beside of future school facilities which are going to be built according to principles of efficient energy consumption, there is a need to revitalize already built objects in way to become more comfortable, healthy and ecological place for children stay. The opportunities for energy efficiency in existing building are vary widely, depending on [3]:

- the climate-zone where the building is located,
- the age of the building and the type of construction and
- the requirements and incentives involved

As all analysed objects are placed on territory of the city of Nis, we are going to analyse its current states and to find solution how to influence the energy savings in these facilities. We will try to determine whether the year of construction of the facilities had an impact on the state of the facilities for the youngest, but also how much it is possible to improve their energy efficiency in the use of solar panels.

The aim is to point out the defects in terms of energy consumption and to give guidelines for their improvement and increase the comfort of the facilities. Also, in the state of kindergartens and primary schools in Nis on mistakes that could be prevented and avoided in the construction of future buildings intended for children.

2. Review of the current state of educational objects

Modern principles of projecting objects have a big emphasize at importance of the sustainable architecture, use of natural resources and modern technologic innovations. Using these principles whether in building of the new objects or through reconstructing of already built ones, it ensures significantly healthier living, and also the significant savings.

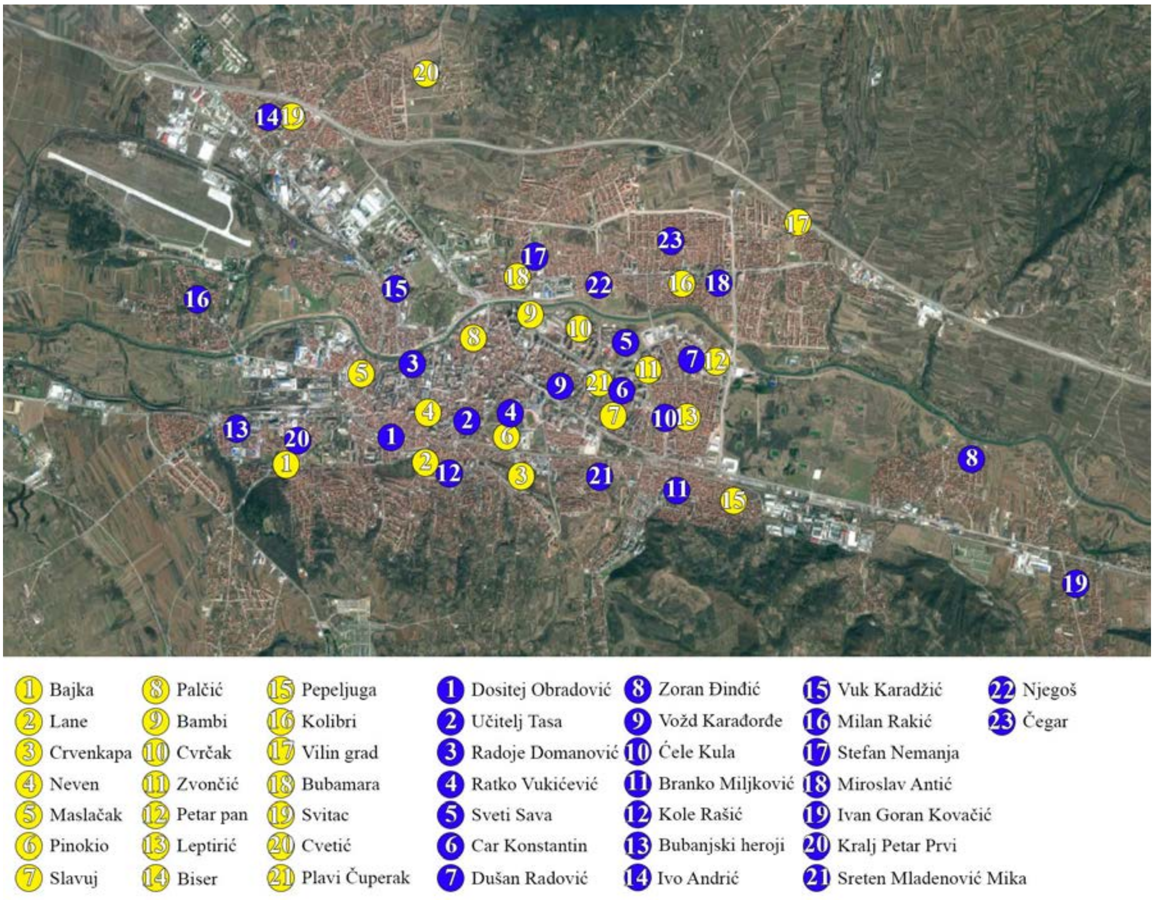

Figure 1: The location of the analyzed objects in the city of Nis

In which way is it possible to implement new principles of energy efficiency in existing school objects on territory of the city of Nis, and what result would such intervention bring, we are going to answer in the following chapters.

Through an analysis of the current state, we will observe the condition of the facilities today, and what steps should be taken in order to raise the energy balance in these buildings. A total of 44 buildings have been analyzed, of which 21 were kindergartens (yellow) and 23 were primary schools (blue) (Figure 1). A large number of facilities are located in urban city areas, while a small number of only 14% are located in peripheral town settlements (Branko Bjegović, Medoševac, Brzi Brod..).

Table 1: Data on analyzed schools and kindergartens in Nis

Kinder gartens	Year of const	Number of floors	Type of the roof	Elementary school	Year of const	Number of floors	Type of the roof
Bajka	1977	P+1	pitched	Dositej Obradović	1962	P+1	flat+pitched
Lane	2012	P+0	pitched	Učitelj Tasa	1935	P+3	pitched
Crvenkapa	1976	P+1	pitched	Radoje	1932	P+1	pitched
Neven	1976	P+1	flat	Ratko Vukićević	1958	P+3	pitched
Maslačak	1976	Po+P+1+Pk	flat	Sveti Sava	1980	P+1	pitched
Pinokio	1979	P+1	pitched	Car Konstantin	1962	P+1	pitched
Slavuj	1970	Po+P+1	pitched	Dušan Radović	1987	P+1	pitched
Palčić	1963	Po+P+1	pitched	Zoran Đinđić	1963	P+1	pitched
Bambi	1978	P+1	flat	Vožd Karađorđe	1889	P+1	pitched
Cvrčak	1983	P+1	pitched	Ćele Kula	1966	P+1	pitched
Zvončić	1992	P+1	pitched	Branko Miljković	1965	P+1	pitched
Petar Pan	2005	P+1	pitched	Kole Rašić	1977	P+1	pitched
Leptirić	1978	P+1	flat	Bubanjski heroji	1972	P+1	pitched
Biser	2010	Po+P+1	pitched	Ivo Andrić	1974	P+1	pitched
Pepeljuga	1980	P+1	pitched	Vuk Karadžić	1960	P+1	pitched
Kolibri	1977	Po+P+1	pitched	Milan Rakić	1964	P+1	pitched
Vilin grad	2000	P+1	pitched	Stefan Nemanja	1973	P+2	pitched
Bubamara	1963	P+0	pitched	Miroslav Antić	1983	P+1	flat+pitched
Svitac	2002	P+1	pitched	Ivan Goran	1963	P+1	pitched
Cvetić	2012	P+1+Pk	pitched	Kralj Petar Prvi	1933	P+2	pitched
Plavi	1983	P+1	pitched	Sreten	1982	P+1	pitched
				Njegoš	1955	P+1	pitched
				Čegar	1959	P+1	pitched

The period of greatest development of the city of Niš has undergone during the 70s (Table 1) of the last century, when it came to rapid urbanization, construction and settlement. During this period, the largest number of facilities for education were built, and the existing ones were renovated during that period. Since that period, little has been invested in them. Most of the works included painting the walls and repairs of the roof, while nothing was done in terms of energy efficiency.[4] The Law on Energy Efficiency was adopted in 2012 and clearly sets out the goals that buildings need to realize, so they are the main reasons for reconstruction [2]:

- The building's conditions are technical reasons for reconstruction. There are overheat energy losses trough the walls, the windows, doors and roof of the school or kindergarten building;
- Socio-economics reasons for reconstruction refer to the increased energy consumption in the building and unsatisfactory conditions in kindergartens.

Some of the measures that are undertaken in order to reduce energy loss and increase energy efficiency are the isolation of buildings, the replacement of worn-out joinery, and the implementation of solar systems.

2.1. Analysis of schools and kindergartens in nis from the aspect of energy efficiency

The use of solar energy is one of the basic strategies in modern sustainable architectural design. Solar energy can be used through two systems: passive and active solar systems. There are two approaches of using solar energy in architecture [5]:

• Active systems - which places emphasis on installation equipment;

• Passive systems - which translate energy phenomena in the architectural concept where the house becomes a receiver that covers and protects most of the sun's energy.

The active systems include primarily the use of solar collectors that cover the requirements of the hot water facility, and photovoltaic panels that influence the rationalization of the use of electricity. Photovoltaic panels produce electricity directly due to the effects of sunlight, panels are easily implemented in existing buildings and are environmentally acceptable. In order for collectors to be cost effective, they need to be placed in places that have enough sunlight. According to the Ministry of Energetic of Serbia, the number of sunny hours in Serbia for one year is greater than 2000h. This is more than in the most European countries, but solar potential is completely unused. The average annual value of global radiation for the horizontal surface in the north of the country is 1294 kWh / m2, and in the south 1578 kWh / m2, specifically for Niš 1531,40 kWh / m2. [9] For this reason, we consider analysis of the possibility of installing photovoltaic panels in educational facilities on the territory of the city of Niš as justified.

The panels are usually installed on rooftops because they are large free surfaces that are not used for other purposes, but also represent the highest point of buildings and thus receive the most sunlight. "Photovoltaic systems can be installed on all types of roofs, but the difference between flat, glass and sloping roofs must be made" [6].

Analyzed schools and kindergartens are in very high level P + 1 and there are no glass roofs. The most common is the sloping roof in as much as 88% of the buildings, while in only 4 buildings there are only flat roofs. Miroslav Antić and Dositej Obradović schools have a combination of both roof levels. The following table shows the ratio of flat, hip and gable roofs to schools and kindergartens (Figure2).

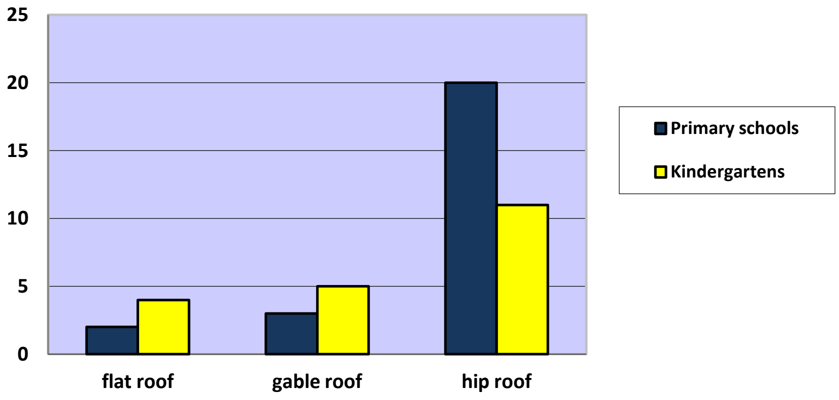

Figure 2: Ratio of different roof structures in analyzed objects

The advantage of flat roofs is the possibility of placing panels at different angles, depending on the orientation of the building. With sloping roofs, there is a possibility of implementation in an already existing roof structure, which is aesthetically most acceptable.

For solar panels, the southern orientation is ideal, because in this case it is the most exposed to sunlight. If they are installed to the east or west, the utilization is almost twice as low, so we will analyze the possibility of placing the panels exclusively on the south side.

Facilities with flat roof are the kindergartens Leptirić, Bambi, Maslačak and Neven.

Figure 3: Analysis of possibilities for setting up photovoltaic panels on the roofs of kindergartens

At the kindergartens Bambi, Leptirić and Neven it is possible to install photovoltaic panels almost in the entire roof area. As it is a flat roof, the panels that are placed need to be turned to the south side in order to receive as much energy as possible and thus justify this intervention. Unlike these objects, where there are no objects that would put shadow on the object with their proximity, this is not the case in the Maslačak kindergarten. The building is located in the city center, where there is a high density of construction, so around the building there are residential buildings of higher floors that throw shadow on the analyzed object. Due to its position, the kindergarten Maslačak is mostly in the shade, and for this reason it is not profitable to use the panels at this facility.

Among the analyzed objects, there is a case where flat and pitched roofs occur, in the case of school buildings Dositej Obradović and Miroslav Antić. In these schools it is possible to install roof panels on the part of a flat roof. The roof tile is not suitable for panel installation due to poor orientation. In the Dositej Obradović school, panels can be placed on the tract with classrooms, while at Miroslav Antić school it can be done on a part of the roof placed above the sports hall.

Figure 4: Analysis of possibilities for setting up photovoltaic panels on the roofs of primary schools

When we observe objects that have a gable roof, it is clear that we will plan panels towards the southern orientation. It is possible to plan panels at Maslačak and Plavi čuperak kindergartens, while at the Kolibri kindergarten this is not the case because of inadequate orientation of the building. School Ratko Vukićević, despite the fact that the area that is adequate for placement of panels does not have a purely southern orientation, we consider that the savings caused by such intervention would be significant. The non-typical number of floors of the building (P + 3) emphasizes this object as the highest in the surrounding envi ronment. For this reason, it is sunny for most of the day, so the planning of solar panels, despite the southeast orientation of the roof level, is justified, the same case occurs at the Učitelj Tasa School, which has a hip roof.

In school buildings with hip roof panels we can plan on as many as 9 buildings. In schools Sveti Sava and Miroslav Antić, panels can be installed only on the roofs of sport hall, due to the orientation of school buildings. In school buildings with hip roof panels can be placed along entire areas in which classrooms are located. The good example would be situation of the Njegoš and Čegar school, which are designed with two classroom areas, and these areas are ideal for locating panels on such roofs. The savings in the installation of the panels would be large because of the large roof surfaces.

The most common reasons why it is not possible to plan panels instalation on other objects is inadequate orientation (Zoran Đinđić, Ćele Kula, Miroslav Antić, Ivan Goran Kovačić and Kralj Petar Prvi) and surrounding of the buildings, which is made from high greenery and buildings (Bubanjski heroji and Car Konstantin). For kindergartens with hip roof, it is possible to place panels in four buildings: Zvončić, Petar Pan, Pepeljuga and Vilin grad on a small part of the roof surface. For other facilities for the youngest, the most common reason is the inadequate orientation of the buildings.

2.2.Discussion

There are numerous reasons why there is a need to reconstruct the analyzed objects. One of the most important is that school and preschool facilities, as public institutions, are a good presenter of new technologies, thus they can serve as a good example for visitors and who can use it in their households as well. In addition, users of the analyzed objects are children, so if we could get used to using renewable sources at an early age, we could be sure that the future of our environment will be in good hands [4].

From the paper we can see that for the largest number of analyzed objects the reason why there is a need to reconstruct the analyzed objects is that the greatest number of objects is over 30 years old, and in that time the heat transfer coefficient according to the law was k=0,9 W/m²K, while today it is limited to the values of k=0.25-0.35 W/m²K. Consequently, the construction years play a major role in the construction of buildings in accordance with energy standards.

According to the analysis of the current situation, we can see that the implementation of solar panels is possible in as many as 9 kindergartens and 16 elementary schools. In the given view we can see that the percentage of possible implantation is higher in schools than in kindergartens (Figure5).

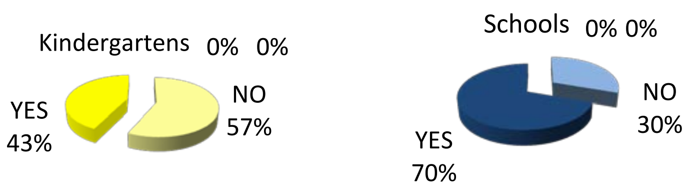

Figure 5: Percentage of objects in which intervention can be made

This is due to the fact that in schools, in most cases, it is planned that the tract with the classrooms be on the south side, as well as the possibility of placing panels on the roofs of the sports hall. The most common problems we have observed when planning photovoltaic panels are:

• poor orientation of the object, or objects that do not have a roof surface that can be used for the south-facing installation. In the kindergarten, this is the case with the Pinokio, Cvrčak, Bubamara and Svitac objects, and for schools: the school building Sveti Sava (for sports hall there is a possibility), Zoran Đinđić, Ćele Kula, Miroslav Antić and Ivan Goran Kovačić.

• The shelter of the building by higher buildings which are in the neighborhood or high greenery that casts shadows on the analyzed object: Lane kindergarten and schools Car Konstantin and Bubanjski heroji

• Great dismounting of the roof surface or curved roof case (sports hall at the school Zoran Đinđić) and therefore a small roof surface where it is possible to plan panels installation. This relates to a hexagonal roof where there is no possibility of implementation because of the small surface on which panels can be installed. This case occurred in three kindergartens: Crvenkapa, Leptirić and Cvetić.

According to the data collected for 45% of facilities, the energy consumption in the analyzed facilities is about 583.000 kWh / year [9], which means that the average consumption for 1m2 is 390.75 kWh. Such data indicate emergency intervention, as according to the analyzed data, the average consumption of electricity in public facilities for the EU is 286 kWh / m2 [7].

Most of the energy in school and preschool facilities is spent on heating and cooling the facility, which must meet the high standards, because the users of space are children. That is the reason why It is expected that the energy produced by photovoltaic panels will cover most of the total consumption.

Table 2: Review of possible energy saving for kindergarten Leptirić:

	Surface of PV panels [m^2]	Production of electric energy per month [kWh/month]	Production of electric energy per year [kWh/year]	Annual consumption of electric energy [kWh/year]	Annual consumption reduced by production of electric energy [kWh/year]	Percentage of energy savings [%]
Leptirić*	181	2402,50	28236	12883,32	-15352,68	219,17

*** Data collected for monograph: D. Stanković, M. Tanić: Revitalization of prescool facilities in Niš:** For research were used Premium S poly photovoltaic panels, with power output of 130W/m2. They were installed at 40.7° on flat roof of kindergarten Leptirić. Solar radiation energy of 3.3kWh/m2, characteristic for Serbia, was adopted.

On the example of the kindergarten Leptirić [Table 2], by implementing a simple calculation we can see that it is possible that a part of the generated energy is distributed to the city electrical network. [9] This is another advantage of this treatment, depending on the surface on which the panels are placed, we can calculate savings for other objects in a similar way. From the previous analysis, we came to the conclusion that planning the panels would be profitable to a total of 25 facilities.
In addition to the feasibility of photovoltaic panels implementation, large electricity consumption in school buildings and kindergartens in Nis is due to inadequate care of facilities, lack of investment and lack of motivation to reduce consumption. Additional measures that can be taken to achieve this goal are the following [3]:

- Insulation of building envelopes;
- heat recovery ventilation systems
- optimization of engineering equipment operation;
- installation of any types of meters and control of resource consumption.

The plan of the reconstruction includes: to change the windows, to change the outside doors, to install heat reflecting barriers and to install radiator's temperature regulators. As we know that there were no significant investments in the objects additionally after their construction, and in order to increase savings of these objects, significant investments must take their place.

3. Conclusion

Based on the analysis we have done, we can conclude that intervention on buildings is possible on a large number of schools and kindergartens. As objects built during the period when construction laws were blazed, it is necessary to adapt them to new tendencies. In this paper, we have shown in which objects it is possible to install photovoltaic panels, and which steps could be applied in order to align the characteristics of the objects with the principles of energy efficiency. Also, through the discussion, we explained the problems we have noticed that hinder the installation of solar panels in some of the analyzed kindergartens and primary schools. Consequently, we blamed which mistakes should be taken when building future facilities for the education of children.
By implementing the panels in existing and future facilities, in addition to achieving energy savings, the economic savings will be greatly influenced, as well as the healthier environment for the children who stay

in them daily. It can be expected that the project of architectural building improvement (besides improving energy efficiency - improving internal conditions of benefits, contributing to a cleaner and healthier environment) will bring positive social changes by reducing social problems. [8]. The savings that the analyzed objects would have achieved would directly affect the cost of staying in kindergartens, but also the investment in activities that would make children staying at this buildings more comfortable and more interesting.

From the analysis that is presented, it can be seen that none of the facilities currently do not meet the principles of energy efficiency. This points to the low awareness of the administration of schools and municipalities, but also of general citizens, about the impact of energy efficiency. For this reason, it is necessary to increase the interest of citizens, but also generally raise awareness of the advantages of photovoltaic panels and encourage the municipality to invest in the renovation of existing facilities. Particular emphasis should be placed on the economic aspect, as well as the impact on the preservation of the natural environment and the pleasant stay of children in schools and kindergartens.

The presented case study method performed in a individual case where the schools and kindergartens analyzed in the city of Niš, have a greater significance, precisely because it is possible, with minor modifications, to adapt to other public buildings in the city of Niš and other cities. With this illustration we pointed out the possibility of implementing photovoltaic panels in school and kindergartens, and the importance that even when constructing future facilities, it is necessary to take into account the harmonization with the principles of energy efficiency.

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