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Implementation of solar energy systems and power efficiency increase for preschool facilities in city of Niš (Republic of Serbia)

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ABSTRACT

The principles of sustainable development emphasize the significance of the use of renewable energy resources in architecture. This paper is analyzing certain architectural characteristics of preschool facilities that are of the importance for the application and use of solar energy systems. It reviews all aspects of possible applications and use of these systems in this kind of facilities. The goal of the planned research is establishing practical, applicable model of the implementation and use of solar energy systems in existing preschools and kindergartens. The possibilities of solar energy systems application and use are reviewed based on suggested remodeled form of the preschool facilities in city of Nis, Serbia. In this article classification of active building-integrated solar systems and building-integrated photovoltaic (BIPV) technologies is presented. Application variants of solar energy systems for preschool facilities energy supply are considered. Optimization factors for application of solar energy systems in preschools facilities are given. Application and use of solar energy systems based on suggested remodeled form of the preschool facilities in city of Nis, Serbia are reviewed.

Contents

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1. Introduction

Contemporary design principles emphasize the importance of sustainable architecture planning, or engineering, which are defined as designing and also as responsible managing of the healthy building environment, based on energy-efficient use of natural resources, ecological principles and application of modern technological innovations.

Intensive use of solar energy in the design of facilities, integrated into the overall energy concept, with enhanced thermal insulation and controlled ventilation, with system for heat recovery could provide significant energy savings. Application of these principles, in the design of new or reconstruction of existing pre-school facilities, could significantly contributes to the total energy balance of the buildings [1 - 3]. There are about 20 preschools facilities in the city of Nis that has a population of 300000 people [2]. Most of these preschools facilities were built during the 1970's and 1980's or after 2000, and little has been invested in them since then [3 - 6]. These preschools facilities do not fulfill the current standards in many aspects and thus need to be reconstructed. The reconstruction done so far has been limited to repainting the walls and repairing the roofs, while nothing has been done in order to improve the energy efficiency. This paper argues that reconstruction of existing preschool facilities, trough architectural redesign and incorporation of solar energy systems, will increase its energy efficiency. The main subject of this paper is exploring all different possible principles of solar energy systems implementation in preschool facilities. The application of adopted principles in reconstruction of existing preschool facilities is in accordance with contemporary trends and sustainability principles. Main goal of the conducted research is establishing practical, applicable model of the implementation and use of solar energy systems in existing preschools and kindergartens in Nis (Serbia), as typical urban environment. The possibilities of implementation of solar energy systems are reviewed based on suggested remodeling of facilities „Petar Pan“, „Bajka“.

2. Architectural form and materialization

The architectural form is a key parameter in the design of pre-school facilities. The form and exterior of these buildings should be carefully designed because the time that child spends in the preschool has great significance for its psycho-physical development [7 - 9].

Preschool facilities with its forms and materialization should ensure, in addition with concern about the creative development of children, the application of basic principles of sustainable architecture. The envelope of the building in such context is increasingly seen as a solution that reconciles the function and the form of these buildings. "It answers on more and more complex, social and environmental requirements" [10].

3. Space development of the architectural plan

Preschool facilities characterize spatial developed architectural plan, which is caused by a number of urban, architectural parameters and program requirements, but also by the character of the environment in which the building is located. The most significant impact on the spatial development of the architectural plan has its high. In terms of number of floors in pre-school buildings, according to the adopted hygiene standards, in our region and also in the world, it should be limited on ground level and first floor (G +1), or the ground level and two upper floors (G +2) if the case is adaptation and reuse of other buildings into the pre-school facilities. However, the valid general recommendation is the construction of single-store objects for preschool facilities, because of security reasons for children and close connection within the building itself and surrounding open areas [11]. The number of flooring most affects the available land area. Application of single-store building contributes to a larger spatial development of the architectural plan of preschool facility, and therefore required more building area on the location. Although it should strive to build a compact object with reduced forms, because the proportional relationship of elements efficiently reduces heat loss, the construction of single-storey building creates a dominant horizontal volume of the building and provides significant capacity at the roof level which can be used to accommodate the installation and application devices for collecting solar radiation. The result of the significant spatial development in the architectural plan is a large roof area; witch could provide great capacity in terms of space that could be used for installation of solar systems. Therefore it is desirable the multifunctional roof treatment. "The roof becomes multi-functional structure which, in addition to protect against weather, supplies object with heat and electricity, contributes to natural ventilation and cools the building, allows natural lighting into interior space but also protects from the sun, supplies with technical water and etc." [12]

4. Possibility of application of solar energy systems in preschools facilities

The solar energy systems are generally divided to passive and active solar energy systems. Passive use of solar energy can be achieved in many different ways, some of which are: adequate orientation of the building towards the Sun, the use of canopies, shades, adequate position of window and door openings, the use of Trombe's Wall and water wall, the use of greenhouses, air collectors, under-floor heat collectors, etc. Active use of solar energy in buildings, nowadays, is primarily meeting the needs and demands for hot water, trough solar thermal collectors and for electricity through photovoltaic cells [5, 13, 14]. The use of passive solar systems in newly-designed buildings is certainly possible and is often used in favor of optimal use of solar energy. However, the possibilities of afterward implementation and improvement of solar systems in existing buildings are minimal. This comes as a consequence of tight connection between passive solar systems and original architectural design, which, if changed, would mean larger reconstruction and higher costs. The possibilities of smaller interventions within preschool facilities, that would enhance the use of passive solar energy, lie in the newly formed canopies and shades that would allow the intrusion of Sunlight and improve indoor heating, when needed, or block it during the summer months, with higher temperature. On the other hand, there are many possibilities of the use of active solar energy systems, in newly designed buildings as well as in reconstructed, already existing buildings. Their flexibility and the very wide range of their possible use, make these systems very convenient for use within preschool facilities. Because of relatively high demands for sanitary hot water and low cost of solar collectors, which makes the return on investment in these systems very quick, the use of solar collectors is fully justified and valid.

One of the most prospective active solar energy systems are building-integrated solar systems. Usage of active building-integrated solar systems for independent energy supply of preschool facilities creates the required pre-requisites for zero energy buildings construction [15, 16]. Active building-integrated solar systems can be divided into three groups, by the type of energy produced:

- photovoltaic (PV) systems (BIPV);
- thermal systems (BIST);
- PV and thermal systems (BIPVT).

Solar photovoltaic (PV) systems are one of the most promising renewable energy technologies for building application, producing electricity directly from solar radiation without harming the environment. Building integrated photovoltaic (BIPV) systems, where solar cells are integrated within the climate envelopes of buildings and use solar radiation to generate electricity. Also it is possible to integrate solar thermal (BIST) systems into the building envelope in order to alter solar energy into thermal [17 - 19]. One of the last technologies in this sphere is building-integrated photovoltaic and thermal (BIPVT) systems, which supplies generation of thermal and electrical energy at the same time. The photovoltaic thermal system usually includes high efficiency photovoltaic (PV) module and spiral flow absorber (Fig. 2). These competitive new technologies may represent a powerful and versatile tool for reaching main goals with respect to aesthetical, economical and technical solutions. Figure 1 and 2 shows the photovoltaic (PV) systems and thermal systems.

Figure 1. Examples of BIST

Figure 2. Examples of BIPV

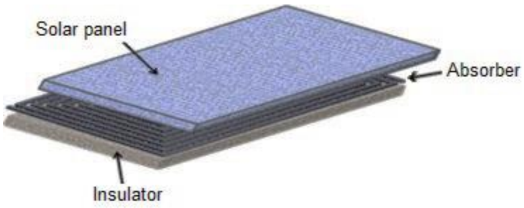

Figure 3. Photovoltaic thermal system

5. BIPV products categorization

The wide range of BIPV products can be divided in to several groups. This categorization mainly based on the description of the product. BIPV products can be divided into following groups:

- BIPV tile products;
- BIPV foil products;
- BIPV glazing products.

BIPV tile products may cover the entire roof or just selected parts of the roof. This type of BIPV products looks like traditional roof tiles with the identical characteristics, but with the functions of PV modules. BIPV roof tiles are suitable for easy roofs refitting. Example of BIPV tiles is shown on figure 4.

BIPV foil products are lightweight and flexible, which leads to easy installation prevailing weight constraints. BIPV foil products are made from thin-film cells to maintain the flexibility in the foil. Because of these properties, such as flexibility and lightweight, this kind of BIPV products can be maintained into practically every part of the building: roof, façade, etc.

Figure 4. Example of BIPV tiles

BIPV glazing products provide a great variety of options for windows, façades, roofs etc. (fig. 5). The solar cells glazing modules transmit daylight and serve water and sun protections. The distance between the solar cells depends on needed transparency level and the criteria of electricity production.

Figure 5. Example of BIPV glazing products for roofs

BIPV systems are considered as a functional part of the building structure or they are architecturally integrated into the building design, thus serving simultaneously as both a building envelope material and a power source generating electricity. I.e., the BIPV system must fulfil the requirements of both the building envelope material and construction, and the PV solar cells. Such characteristics of BIPV system as mechanical properties, durability versus climatic exposure conditions, rain and wind tightness, etc. have to be considered and accounted for [20, 21].

6. Optimization factors for application of solar energy systems in preschools facilities

Possibility for installation of solar energy systems depends primarily on the characteristics of the architectural structure. Considering the specifics that characterize the preschool facilities, installation of these systems will primarily depend on the whole building composition, the position and the form of its individual parts, construction characteristics and final materialization of the object envelope. “As the pre-school facilities characterize specific functional organization, important factors for achievement of optimum solar energy gain are:

- the position of the architectural composition;
- architectural form and materialization;
- spatial development of the architectural building plan” [1, 6].

Position of the building and its individual parts toward the appropriate orientation represents the basis for the proper usage of solar energy. The functional solution for the buildings should be adjusted in comparison with daily activities, and with predicted direction of the sun during the day. Rooms planned for the children should be oriented towards the south, in order to have a high level of insulation during the day. In addition to the south, as an alternative it is possible to use the southeast or east orientation, with a deviation of 20° to the east. For this deviation the building will receive up to 15% (depends on the area) less energy than the energy it would have received if it were strictly oriented towards the south. The other rooms and spaces that do not require a particular exposure to sunlight can be oriented to the north [22, 23]. More detailed results can be get by the developed program, which gives a possibility to calculate daily, monthly and annual income of global solar irradiance on differently orientated inclined surfaces in point with inputted geographical coordinates (longitude, latitude) considering atmosphere losses in real cloudiness conditions.

Changing monthly sums of solar radiation received on a horizontal surface (Nis) with coordinates 43 ° 19'09'' N and 21 ° 53'46'' E, shown in figure 6 and table 1.

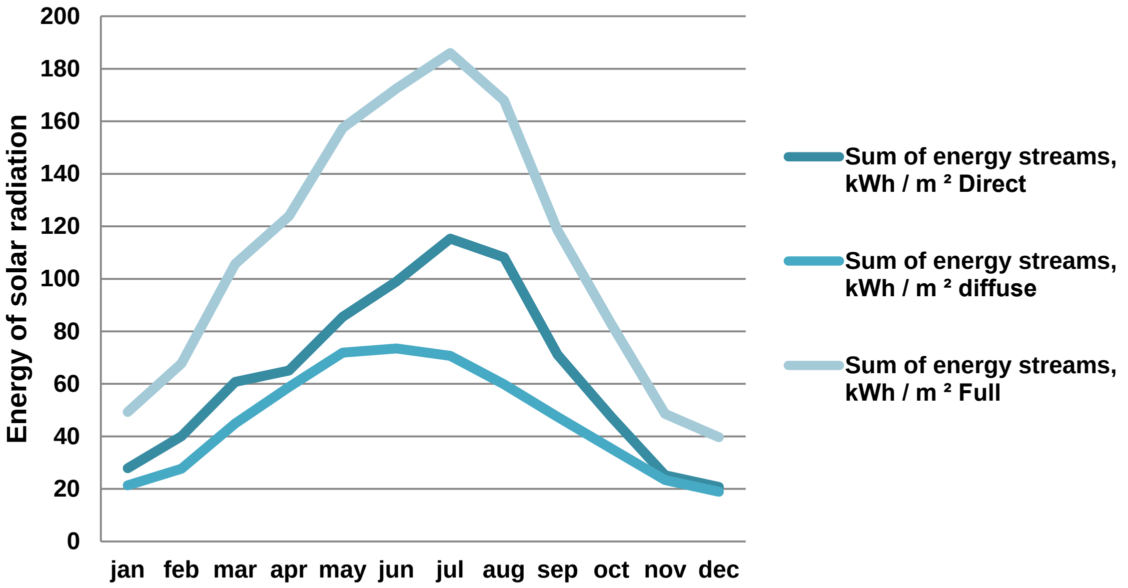

Figure. 6. Changing monthly sums energy, direct and diffuse solar radiation on a horizontal surface supplied during the year

Table 1

Month of year	Sum of the energy flow solar radiation, kW h / m ²			The share of direct solar radiation as part of the total solar radiation
	Direct	Diffuse	Full	
January	27,9	21,39	49,29	0.57
February	40,04	27,72	67,76	0.59
March	60,76	44,95	105,71	0.57
April	65,1	58,8	123,9	0.53
May	85,56	71,92	157,48	0.54
June	99	73,5	172,5	0.57
July	115,32	70,68	186	0.62
August	108,19	59,83	168,02	0.64
September	71,1	47,4	118,5	0.60
October	47,43	35,34	82,77	0.57
November	25,2	23,4	48,6	0.52
December	20,77	18,91	39,68	0.52
year	766.37	553.84	1320.21	

The architectural form is a key parameter in the design of pre-school facilities. Preschool facilities with its forms and materialization should ensure, in addition with concern about the creative development of children, the application of basic principles of sustainable architecture. Since the preschool facilities are low-storey buildings, mainly oriented toward the south, it is possible to use the south area of the facade layer and create a unique integrated system which would at the same time served as a cover and as a system for receiving the solar energy. The biggest problem in the buildings, that are oriented in a way to obtain a great amount of solar energy, is overheating in the summer periods. The most effective way for excessive over-heating of the rooms during the summer is to protect openings from direct sunlight using shading devices [24, 25].

A possible form of protection against excessive overheating in the summer is the usage of canopies. Planning deep canopies on the south side allows the usage of solar heat gains in winter (allows the horizontal break-sunrays), and reduces the need for cooling energy in the summer (protects against intrusion of slanting sunrays). Canopies should be of such dimensions that in the summer it prevents, and during winter facilitates the penetration of sunlight in the areas intended for child staying.

Preschool facilities characterize spatial developed architectural plan, which is caused by a number of urban, architectural parameters and program requirements, but also by the character of the environment in which the building is located. The most significant impact on the spatial development of the architectural plan has its high. In terms of number of floors in pre-school buildings, according to the adopted hygiene standards in the world, it should be limited on ground level and first floor, or the ground level and two upper floors if the case is adaptation and reuse of other buildings into the pre-school facilities. However, the valid general recommendation is the construction of single-storey objects for preschool facilities, because of security reasons for children and close connection within the building itself and surrounding open areas.

The result of the significant spatial development in the architectural plan is a large roof area; witch could provide great capacity in terms of space that could be used for installation of solar systems. Therefore it is desirable the multifunctional roof treatment.

7. Example of remodeling preschool facilities in context of solar energy systems application

As an example of solar energy systems application for remodeling preschool facilities will be described two projects of kindergartens remodeling: the “Petar Pan” and the “Bajka“, situated in Nis, Serbia. The study of the preschool facilities remodeling has been done using methods of analysis and classification, but also by experimenting on models. These were selected as the most representative, so that the results can by inductively applied to other kindergartens with similar properties. This sample is sufficiently big to draw valid conclusions about other kindergartens in the same area.

The “Petar Pan” kindergarten was built in 2005 (figure 6). Two more kindergartens were built based on the same architectural design, “Zvončici” in 1992, and “Vilin Grad” in 2001. They have an area of about 1300 m^2, and host about 200 children. Through this model is being suggested a few different concepts of implementation of solar energy systems that would improve energy efficiency in this building. Some parts of the roof construction have been removed, so a flat roof is formed. This allows for the installation of solar or photovoltaic panels that would make the building more independent from the exterior power network. The south façade has also modified to a double façade in order to reduce energy consumption. The current outlook of the kindergarten and the proposed remodeling are shown in figure 7.

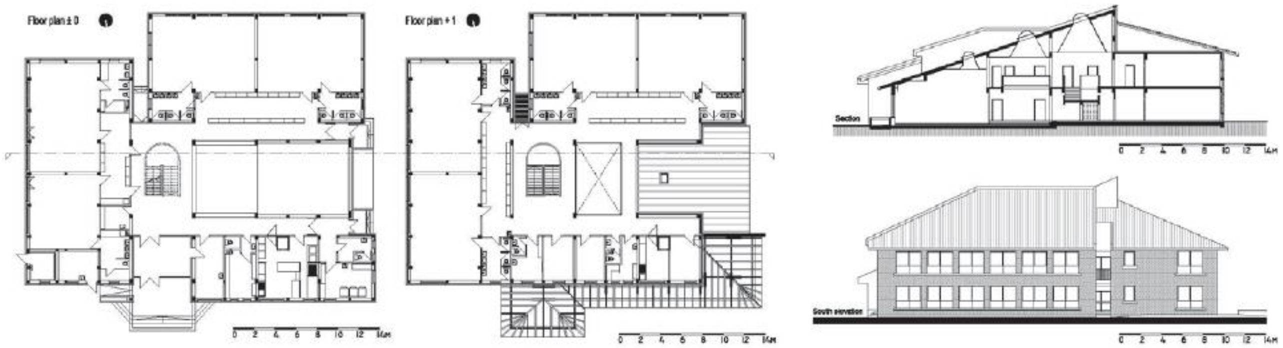

Figure 7. Floor plan, section and elevation of the Petar Pan kindergarten

Figure 8. The Petar Pan kindergarten and proposed remodeling

The “Bajka“ kindergarten was built in 1975 (figure 8) and is the typical representative of the kindergarten architecture of that time. There are two more buildings of similar form and structure and related function that have been built in the same period on the wider area of the city of Nis. Their attributes are materialization done in combined facade bricks and masonry walls, while their forms consist of sharp angles and double pitched roofs. Kindergarten has an area of 725 m2, and is currently hosting 150 children. Pictures of the current state and the proposed remodeling are given in Figure 9. Several changes to the façade of the building have been done. The vertical elements in different colors have been added on the terrace fences. Their role is to contribute to the esthetics of the building, but also to block the Sunrays from the West. The elements are with the motif of color markers in children's pencil cases. Replacement of all windows and portals is planned to reduce ventilation losses, which are high because of their obsolescence. Slope of roof plane to the south is used for installation of solar panels. This would achieve greater kindergarten energy independence.

Figure 9. Floor plan, section and elevation of the Bajka kindergarten

Figure 10. The Bajka kindergarten and proposed remodeling

8. Conclusion

Preschool facilities are relatively small buildings and are relatively rare compared to other types of buildings. As such they consume little part of all the energy spent in buildings. However, there are several good reasons for the improvement of energy efficiency in preschool facilities.

When choosing an energy concept for preschool facilities, architectural predisposition of these objects may represent the basis for designing a system that would be based on the use of solar energy. Architectural predispositions of preschool facilities represent the starting and main influential factor in the whole concept of the implementation and application of solar energy systems. Featured specifics of the particular systems listed above, in relation to basic characteristics of functional space organization of the preschool facilities, are defining the position of the overall architectural composition, the development of the architectural plan and architectural form as well as the materialization, as main factors that can directly affect the optimal gain of solar energy.

The preferred design concept with dynamic architectural forms and materials in the process of designing and planning of preschool facilities provides significant opportunities for a more complete application of systems for using solar energy. Inclination along some parts of the facade creates conditions for the efficient usage of photovoltaic panels. Based on the defined architectural predisposition of the pre-school facilities, it is possible to pursue the concept of application systems for using solar energy with a tendency to provide a complete energetic autonomy of the building. Promotion of use of energy efficiency systems on the public facilities is one of the best ways to get them accepted in private households and multifamily buildings. Beside benefits which are directly related to increasing energy efficiency and utilization of renewable natural resources, it is important to note that the application of solar system objects in the preschool facilities is extremely important for children education. In this way the children in the earliest period of their life are familiar with contemporary environmental problems and gain the responsibility to protect their environment. If we would be able to get them accustomed to the use of renewable energy sources in the youngest age, we could be sure that the future of our environment is in good hands.

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Солнечное энергоснабжение зданий и повышение энергоэффективности дошкольных учреждений в городе Ниш (Республика Сербия)

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Информация о статье	История	Ключевые слова
Статья о новом оборудовании, материалах, технике и технологиях УДК: 696	Подана в редакцию 14 апреля 2014 Оформлена 20 апреля 2014 Согласована 29 апреля 2014	солнечная энергия; энергоэффективные здания; фотоэлектрические системы; дошкольные учреждения;

АННОТАЦИЯ

Принципы устойчивого развития подчеркивают значимость использования возобновляемых источников энергии в архитектуре. В статье анализируются архитектурные характеристики дошкольных учреждений, которые имеют значение для применения систем солнечного энергоснабжения. В статье представлена классификация фотоэлектрических систем. Выполнены расчеты прихода солнечной энергии для г. Ниш. (Сербия). Систематизированы факторы оптимизирующие применение солнечных энергетических систем в дошкольном учреждении. Представлены проекты реконструкции зданий детских садов с использованием солнечной энергии для энергоснабжения.

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Николич В., Танич М., Станкович Д., Кондич С., Милошевич В., Костич И., Петров В. И., Пилипец П. А. Солнечное энергоснабжение зданий и повышение энергоэффективности дошкольных учреждений в городе Ниш (Республика Сербия). /
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