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Reducing Energy Consumption by Optimizing Thermal Losses and Measures of Energy Recovery in Preschools

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Abstract

The article deals with the problem of energy saving by optimizing heat loss and measures for energy recovery in the existing preschools. The paper presents a theoretical basis, simulation and computations - calculations of heating energy needs for established models, by using appropriate software packages. The program and development of models for improving energy qualities of the envelope, with the tendency of switching to renewable energy sources, are defined. The methods used in this paper include the method of modelling based on the digital simulation of the representative facility, as well as local visits and interviews with relevant researchers, policy makers and preschool educators. The survey is conducted through a case study on the territory of the City of Nis.

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Keywords: Energy efficiency, existing preschools, heat loss, energy recovery, heating.

1. Introduction

Energy consumption is increased on daily basis due to constant global population growth and increase of many activities: construction of residential and non-residential buildings equipped with growing number of devices that consume more energy (heating, cooling and household appliances), manufacturing and commissioning of the

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growing number of road vehicles, development of production in industry and the like. Production of energy is a key sector of a county's economy, and growing demand for energy is an important factor in economic development [1]. Therefore, energy efficiency is one of the persistent problems that humanity is and will be facing in the future. The fact is that energy savings have not been much thought about before the first energy crisis in 1973 and 1979. Since then, issues of saving energy and providing energy from alternative sources (solar energy, kinetic energy of wind, biomass, etc.) [2] have been taken into consideration. The aim of a large number of scientific studies done after the aforementioned crisis has been to find the best system for energy efficiency.

As numerous human activities take place indoors, buildings are considered to consume a lot of energy. Therefore, the question of energy savings in buildings is one of the most important topics and challenges of construction industry today [3]. The building sector is particularly interesting because it is a major consumer of energy. However, there are numerous possibilities and potentials for savings. In EU countries, residential and tertiary sectors use approximately 41% of total energy consumption and on average about 55% of it goes to heating. Similarly, in Serbia, about 50% of the total energy consumption is used by buildings and 60% of it goes to heating.

Quality heated buildings provide a pleasant and healthy space to the beneficiaries. In this regard, the most important spaces are those designed for childcare. Preschools, which primarily accomodate children, aim to achieve an ideal environment for childre's growth and development. The needs of children in preschool institutions are expressed through demands in function, design and construction. However, an important factor that must be fulfilled in order to achieve a pleasant stay is thermal comfort [4]. Thermal comfort for preschools means the establishment of thermally neutral environment in which thermal equilibrium of the child's body is reached, without inconvenience and unpleasant feeling that the child is too hot or cold. In order to secure adequate thermal comfort and thermal protection from changing weather conditions, preschool facilities are to have adequate thermal insulation and heating in winter, and sunscreen, possibly cooling and adequate ventilation in summer [4].

Planning, designing and constructing adequate space for child care is one of the most comprehensive problems in the construction industry which begins with different approaches and ends with its realization. It is easier to take into account energy savings and to ensure energy efficiency in the sole process of designing new preschool facilities. Legislation today (Serbian Rulebook on Conditions, Content and Manner of Issuing Certificate of Energy Performance of Buildings, 2011; Regulation on Energy Efficiency of Buildings, 2011, Act on the Effective Use of Energy, 2013) is applied to newly built facilities which must meet the required energy performance. The problem of energy efficiency occurs with the existing old buildings which are large consumers of energy. One of many ways in which energy consumption can be reduced is remodeling, recycling and re-using the existing buildings as much as possible [5]. Therefore, one of the solutions to the problem of energy saving may be adaptation and application of active and passive principles of utilization of alternative energy sources. Another way to revitalize facilities is to improve the building envelope insulation and replace old worn out windows, thus reducing heat loss. The method of intervention can be distinguished by analyzing the elements of the building envelope, walls, floors, windows and cladding. Thermal insulation of the building envelope and joinery replacement are among the most implemented measures. They represent major contributions in this process because they have the greatest effect. An adequate insulation of the building reduces unwanted heat loss or gain, decreases energy demands for heating and cooling, and also brings additional benefits in energy savings, resulting in lower energy bills and protecting the environment by cutting $CO2$ emissions [8].

The first part of this chapter precisely analyzes heat loss in preschool facilities in the City of Nis. This problem is approached on the basis of data gathered in the previous research which has been conducted through the project "Revitalization of preschool facilities in Serbia: The program and methods of environmental, functional and energy efficiency improvement", which, among other things, analyzes the features of the preschool construction fund in Serbia. The chapter starts from the premise that energy savings can be achieved by reducing heat loss undertaking the interventions in the façade building layer. The main objective of the abovementioned research is to determine the practical model of saving energy by reducing heat loss in preschool facilities. Such possibilities are observed through the calculation of profitability of old window replacement and additional wall insulation cladding of the building. In the second part of the chapter the main objective is requirement analysis, development and determination of the optimal model for energy recovery within the process of a comprehensive revitalization of the existing preschool facilities, as well as its implementation in local conditions.

The chapter is composed of a theoretical basis, simulation and computations- calculations of heating energy needs for established models, by using appropriate software packages. The program and development of models for improving energy qualities of the envelope, with the tendency of switching to renewable energy sources, are defined. In order to comprehensively review the subject of research and realize the set goal, the following methods are used: literature review, analysis and synthesis, generalization and specialization, induction and deduction. The methods used in this survey include the method of modelling based on the digital simulation of the representative facility, as well as local visits and interviews with relevant researchers, policy makers and preschool educators. The survey is conducted through a case study on the territory of the City of Nis.

2. Energy savings by optimizing heat

2.1. Heat losses of buildings: a review

In winter, when the outside air temperature is lower than the desired temperature in the building, indoor heat is emitted outside through the building envelope. The quantity of heat emitted into the environment is compensated by the heating system. In order to maintain the desired temperature of indoor air, it is necessary to supply the room with adequate quantity of heating energy. The required quantity of heating is equal to the emitted heat into the environment. In engineering practice, this quantity of heat is called heat losses. Thermal insulation in construction means, above all, the ability of architectural structures to prevent heat loss in the most appropriate way. Heat losses in buildings occur as a result of heat exchange between internal and external air in winter. At the same time, the size of these losses, among other parameters, depends on heat-protective properties of the building envelope. Given the origins of heat losses, one can differentiate transmission heat losses through the building envelope, and ventilation and infiltration heat losses, as a result of air infiltration through the joints of building envelope.

2.1.1. Heat loss through the envelope of a building

Heat transfer by transmission (or only transmission) is the exchange of thermal energy through the building envelope by heat transfer mechanism, which is defined by heat transfer coefficient (W/m2K). Heat transfer involves the mechanisms of heat conduction and heat transmission. Heat conduction (or just conduction) is a mechanism of heat transfer through solids, in which the heat flux is directed from the warmer to the colder side. It is defined by thermal conductivity λ (W/mK), which is a thermo-physical property of materials. Heat transmission is the mechanism of heat transfer which occurs when a fluid flows (convection) over a solid surface [7].

2.1.2. Heat loss due to ventilation and infiltration

Heat losses in buildings occur as a result of heat exchange between internal and external air in winter. At the same time, the size of these losses, among other parameters, depends on heat-protective properties of the building envelope. Given the origins of heat losses, one can differentiate transmission heat losses through the building envelope, and ventilation heat losses, as a result of air infiltration through the joints of building envelope. The places of ventilation heat losses origin are surfaces of fixed external barriers, coupling of prefabricated external partitions, vents and windows as well as external doors. Heat losses due to ventilation and infiltration can amount to 20% - 50% of the total heat loss from a building. Windows bring air and light into a room and connect the room with the world outside. They introduce different ventilation and lighting requirements for educational buildings, and the choice of window system has an impact on both the owner and the user [9]. Ventilation systems expend energy and there is a trend to save energy by reducing ventilation rates. Ventilation design should first try to use the natural movement of the outside air into the preschool building by using the rising warm air leaving the classroom, or the prevailing winds, to draw the fresh air into the rooms.

2.2. Methodology

Methodologically, the analysis of the energy performance of preschool building has been partly done empirically, deriving formula by performing mathematical-physical calculations, and partly using specialized computer software. We have used software package "Autodesk" (AutoDesk), and a commercial software of "URSA" and "Knaufinsulation" companies. For the purposes of calculating thermal characteristics of building envelope, both surface and linear, we have used the software of "URSA" company, URSA Building Physics 2, version V1.0-0.26, a parallel result is controlled through the software of "Knaufinsulation" company, KnaufTerm 2 versions 2.3. Calculation is in accordance with EN 12831 code.

In order to test the number of air changes in preschool classrooms, we have used sucking air ventilator, a device for measuring the quantity of sucking air with a calibrated measuring tube, a differential electronic micro manometer, mounting panel for mounting on the entrance door of the room and a digital thermometer.

In this chapter, analysis of ventilation heat losses has been conducted on preschool models. All the characteristic impact factors have been taken into account during analysis [6]. Given the overall quality of installed windows, the real parameters of air exchange in current preschool classrooms have been considered. The research has demonstrated large deviations of actual values from the minimal ventilation heat losses. Replacement of old windows and doors in preschools leads to a reduction in energy consumption for heating. Based on the minimal ventilation heat losses the values of energy consumption and saving have been defined. Compared to the obtained results, the analysis of costs of proposed investments and repayment time has been carried out.

2.3. Characteristics of preschool building fund in the City of Nis

Nis is a city with a population of over 300 000 and there are 20 preschool buildings in the urban area of the city. Most of these preschool facilities were built during the 1970s and 1980s, and little has been invested in them since then. Almost all preschools have been built before the adoption of thermal protection regulations in the construction industry, so it is likely that they are now energy-inefficient and need to be revitalized, primarily in order to save energy. Revitalization which has been done so far is limited to repainting the walls and repairing the roofs, while nothing has been done in order to improve energy efficiency. In addition to energy savings, increasing energy efficiency would significantly contribute to the quality and standard of stay and education of children in preschools.

The question of preschool facility age is not directly generative to structuring energy, but it can serve as base for the evaluation of a number of other features such as equipment, installation, structure of the building as well as its energy performance [13]. By analyzing preschool facilities through the project "Revitalization of preschool facilities in Serbia: The program and methods for environmental, functional and energy efficiency improvement" from 2011 to 2014, we have received a lot of important information regarding the general condition of the buildings, including structural details, floor area of buildings, the year of construction, type of building envelope, thermal and energy performance, and the like (Table 1). These data have been mainly collected through surveys and local contacts in situ and also through architectural drawings.

Table 1. Basic construction characteristics of preschools in the urban area of the City of Nis

Preschool	Const. Year	Obj. type	Fl.	Façade type	Roof/ attic	Joinery
Bajka	1977	Freestanding object	2	Brick	Sl./attic	Wood
Bambi	1978		2	Brick	Flat	Al
Bubamara	1963		1	Plaster	Sl./attic	W/PVC
Crvenkapa	1976		2	Brick	Sl./attic	Al
Cvetic	2012		3	Plaster	Sl./attic	PVC
Cvrcak	1983		2	Brick	Sl./attic	Wood
Kolibri	1977		2	Brick/plaster	Sl./attic	Al/PVC

Lane	2012*	1	Brick/plaster	Sl./attic	PVC
Leptiric	1978	2	Brick	Flat	Al
Maslacak	1976	2	Brick	Flat	PVC
Neven	1976	2	Brick/plaster	Sl./flat	Wood
Palcic	1963	2	Plaster	Sl./attic	PVC
Pepeljuga	1980	2	Plaster	Sl./attic	Wood
Petar Pan	2005	2	Brick	Sl./attic	Al
Pinokio	1979	2	Brick	Sl./attic	PVC
Plavi Cuperak	1983	2	Brick/plaster	Sl./attic	PVC
Slavuj	1970	2	Plaster	Sl./attic	PVC
Svitac	2002	2	Brick	Sl./attic	PVC
Vilin Grad	2000	2	Brick	Sl./attic	PVC
Zvoncic	1992	2	Brick	Sl./attic	Al

* renewed

Most of the buildings have the same type of façade walls (brick block 25cm, 5cm insulation of mineral wool, and façade brick 12cm, Table 2), uninsulated floor on the ground, roof type (flat roof or sloped roof with unheated attic, and isolated ceiling, with mineral wool 5 -10 cm thick, Table 3) and external joinery type (wood, aluminum or PVC profiles and double glazing). All of them are free-standing type facilities, located on flat ground, and in most cases they are two-storey buildings (ground floor and first floor). Central heating system prevails in preschool facilities in Nis: four buildings use individual coal and wood boilers, six of them use oil boilers while ten preschool buildings are connected to the district heating system.

Table 2. Review of characteristic types of façade walls in preschools in the City of Nis

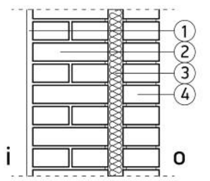
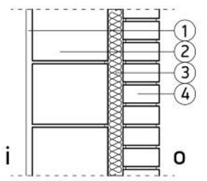
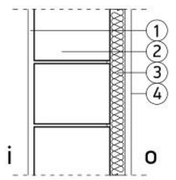
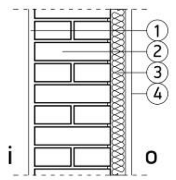
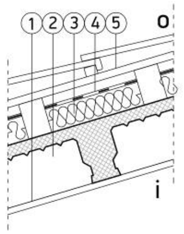
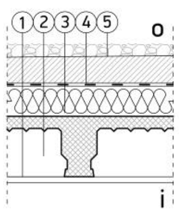
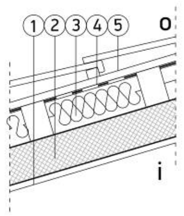
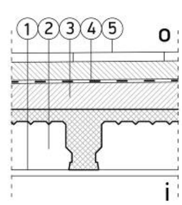
1	2	3	4
			
1. lime mortar d=1.5cm; 2. brick d=25cm; 3. mineral wool insulation d=5cm; 4. façade brick d=12cm	1. lime mortar d=1.5cm; 2. brick block d=25cm; 3. mineral wool insulation d=5cm; 4. façade brick d=12cm	1. lime mortar d=1.5cm; 2. brick block d=25cm; 3. mineral wool insulation d=5cm; 4. cement mortar d=2cm	1. lime mortar d=1.5cm; 2. brick d=25cm; 3. mineral wool insulation d=5cm; 4. cement mortar d=2cm
U1=0.437 W/m2K	U1=0.474 W/m2K	U1=0.464 W/m2K	U1=0.486 W/m2K

Table 3. Review of characteristic types of roofs in preschools in the City of Nis

1	2	3	4
			

1. lime mortar d=1.5cm; 2. Ceiling construction d=20cm; 3. mineral wool insulation d=8cm; 4. hydro insulation; 5. boards with roof tiles d=2.4+5cm	1. lime mortar d=1.5cm; 2. ceiling construction d=20cm; 3 mineral wool insulation d=10cm; 4. Hydro insulation; 5. concrete and gravel d=6+3cm	1. lime mortar d=1.5cm; 2. Ceiling construction d=12cm; 3 mineral wool insulation d=10cm; 4. hydro insulation; 5. boards with roof tiles d=2.4+5cm	1. lime mortar d=1.5cm; 2. ceiling construction d=20cm; 3. concrete d=10cm; 4. Hydro insulation; 5. concrete and tiles d=6+2cm
U1=0.430 W/m2K	U1=0.280 W/m2K	U1=0.313 W/m2K	U1=2.252 W/m2K

Preschool facilities meet the standards of the time in which they have been built, but none of the twenty preschool buildings in Nis meets the new standard requirements (Rulebook on the Conditions, Content and Manner of Issuing Certificate of Energy Performance of Buildings, 2011, Regulations on Energy Efficiency of Buildings, 2011, Act on Effective Use of Energy, 2013) in terms of energy efficiency. "Our practice has generally followed foreign standards while slightly adapting them to local characteristics.

The following standards were adopted: in 1967 (definition of maximum heat transfer coefficient), in 1970 (the parameter coefficient k), 1980 (summer treatment regime was introduced in the budget), 1987 (specific heat losses of buildings), 1998 (specifying the methods and manners of calculation). These points in time can generally be regarded as characteristic points of architectural practice changes, in other words, they are important aspects of energy performance of buildings" [13]. Since more than 60% of preschool buildings in Nis were built in 1970s and 1980s with no or minimal insulation, it was clear that there were possibilities of potential energy saving at these facilities.

Revitalization of old buildings for childcare is a logical choice in the absence of available space in urban areas. It is also significant in terms of reducing energy consumption. Along with environmental and economic benefits, justification for revitalization can also be seen in other facts.

It is important to notice that the improvement of energy performance of the building envelope has a large positive effect on the improvement of indoor physical and thermal comfort. This is of great importance, especially for preschool and other childcare buildings, because it significantly affects the performance of building occupants (staff and children). The learning effect, motivation and performance are closely related to the environment quality and are greatly affected by air temperature.

There are many other benefits, such as: prevention of condensation, noise reduction, better fire protection, preventing damage to the building structure by minimizing temperature fluctuations and undesirable thermal movements, etc.

From visual aspect, it can be said that the façade reconstruction contributes to the architectural identity and integrity improvement as achieving contemporary architectural expression. The façade reconstructions also develop positive feelings which help children accept the environment in which they spend a large part of the day easily.

2.4. Heat losses in preschools

Analysis of preschool facilities energy performance and thermal losses has been done taking into consideration the condition of preschool buildings, façade envelope layers, condition of windows and other elements. As noted above, all the calculations have been done using software package URSA Building Physics 2 with controlling results by software package KnaufTerm2. The results of transmission and ventilation heat loss, as well as the specific annual energy required for heating are shown in Table 4. Calculation has covered twenty preschool facilities in the urban area of City of Nis.

Calculations have been performed on the basis of Regulations on Energy Efficiency in buildings and the values of all relevant parameters (U-coefficients, vapor diffusion, specific transmission heat loss, specific annual heating energy demands, etc.) have been obtained in compliance with the specified standards. Thermo-physical material properties provided in the Regulations have been used, so as characteristics of URSA thermal insulating materials. For input parameters in the calculation the following values have been taken: External design temperature QH, e 14.5ºC; Number of heating days 179; Average temperature of heating period QH, mn 5.4ºC; Indoor design temperature for winter Ti 20ºC; Indoor design temperature for summer Ti 26ºC; Outdoor relative humidity φe 90%;

Indoor relative humidity for winter φi 55%; Indoor relative humidity for summer φi65%; Condensation in winter/drying in summer 60/90 days.

Table 4. Review of heat losses in preschools in the City of Nis

Preschool	Qtr (kWh)	Qi,v (kWh)	Qh,an (kWh/m2a)	EC
Bajka	109847.91	76509	105.5	D
Bambi	182119.32	69250	142.7	E
Bubamara	167391.09	38861	399.3	G
Crvenkapa	129736.87	48854	112.5	D
Cvetic	159702.37	61059	218.8	G
Cvrcak	111539.01	48361	76.4	D
Kolibri	105827.62	43524	110.9	D
Lane	46985.63	16691	136.3	G
Leptiric	187436.84	54381	119.3	E
Maslacak	112563.76	37307	116.5	E
Neven	136062.47	53295	115.4	E
Palcic	145661.38	34882	164.0	F
Pepeljuga	101163.36	40504	151.3	F
Petar Pan	135978.17	68337	93.1	E
Pinokio	111995.81	55072	166.9	F
Plavi Cuperak	121862.42	53460	125.1	E
Slavuj	109574.64	64251	124.0	E
Svitac	99491.64	11369	133.0	E
Vilin Grad	144781.65	46979	119.2	E
Zvoncic	159460.39	43862	137.7	E

Symbols in the Table 4 are as follows: Qtr, transmission heat loss for heated space, Qi,v, ventilation heat loss for heated space; Qh,an, specific annual energy required for heating; EC, energy class of the structure.

The values of specific annual energy required for heating (Qh,an) have been obtained as the final results of the calculations, upon which the determination of the energy class has been made for the current condition of the building. New regulations (Serbian Rulebook on Conditions, Content and Manner of Issuing Certificate of Energy Performance of Buildings, 2011; Regulation on Energy Efficiency of Buildings, 2011, Act on the Effective Use of Energy, 2013) made compulsory for all buildings to be classified into energy classes (from best A+ to worst G) according to the annual heating energy consumption.

The nature of activities in preschool buildings, particularly in educational facilities, points out the great importance of daylight, makes windows basic details of building volume and preschool building architecture recognizable. In educational buildings, the supply of adequate fresh air, and hence perceived acceptable air quality, should be high on the list of priorities to help ensure healthy working conditions for learning. Large ventilation rates, required in crowded spaces for providing adequate indoor air quality, may cause significant energy losses in preschool buildings. Analysis of ventilation heat losses in the process of planning and revitalization of preschool buildings is significant because of the specific requirements in terms of natural lighting of educational facilities, which cause a certain size, shape and rhythm of windows. It has been shown that in certain situations, ventilation losses may exceed transmission heat losses. The aim of evaluation and analysis of ventilation heat losses of educational facilities in preschool buildings is to reach the most appropriate solution for energy savings in the process of revitalization.

Although certain studies have shown that as much as 50 to 80% of heating energy can be saved by high quality building insulation, in this chapter, however, we will deal with the calculations of energy savings by improving the thermal insulation layers of preschools in Nis and calculations of profitability of such investment. Furthermore, the study will pay attention to investment profitability of replacing old windows. It is assumed that new windows have better heat insulation properties. The calculation of energy savings by reducing ventilation and conductive losses is analysis of the percentage of annual cost savings and return on investment of time

2.5. Energy savings in terms of reduced heat losses from conducting

In order to achieve optimal solutions for energy savings, an additional thermal insulation façade layer of preschool buildings has been taken into account. By analyzing the whole capacity of preschool buildings in Nis, it has been found out that insulation façade layers do not satisfy the maximal aloud heat transfer coefficient. This is the reason why minimal thickness of an additional thermal insulation layer is planned in this model. In this way, new heat transfer coefficient is lower than the maximal aloud heat transfer coefficient (U2<Umax).

The aim of this approach is certainly the price of insulation materials, as well as the works price in order to achieve the return on investment and meet the minimum requirements of the new energy efficiency legislation (Regulation on Energy Efficiency of Buildings, 2011). Therefore, additional thermal insulation layer is installed on the façade and it is installed directly over the old façade layer. In this calculation, mineral wool panels of 5 cm thickness and density of 120kg/m3 with acrylic plastic finishes are used. Depending on the type of roof, several different variants of cladding are planned. For pitched roofs, the new insulation is added between rafters. Mineral wool is planned as thermal insulation material. On the other hand, for flat roofs, XPS styrodur should be used, in adequate thickness and under the finishing cladding layer. Finally, additional insulation will be installed on the ceiling above the rooms which are heated in buildings with attics. Characteristic types of interventions are presented in Tables 5 and 6.

Table 5. Review of characteristic types of façade walls with added appropriate insulation

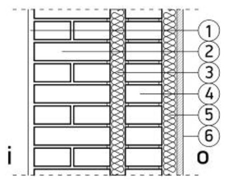
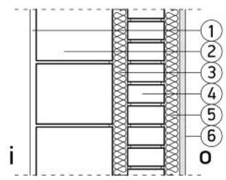
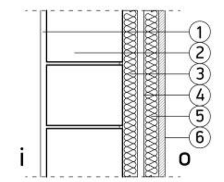
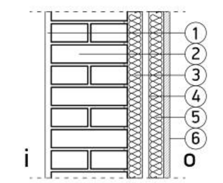
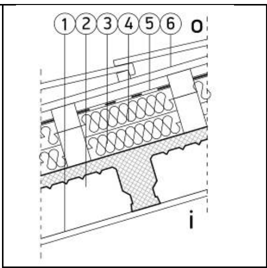
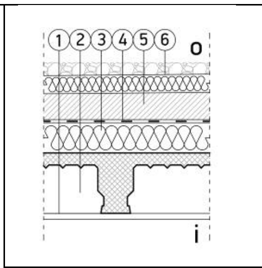
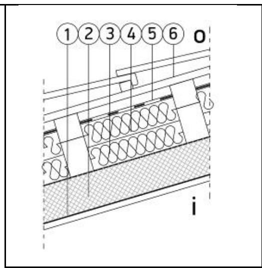
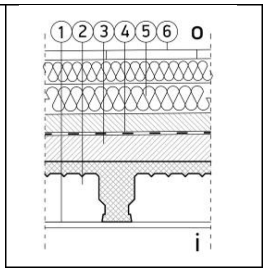
1		2		3		4	
	1. lime mortar d=1.5cm; 2. brick d=25cm; 3. mineral wool insulation d=5cm; 4. façade brick d=12cm; 5. New insulation of mineral wool d=5cm; 6. cement mortar d=2cm		1. lime mortar d=1.5cm; 2. brick block d=25cm; 3. mineral wool insulation d=5cm; 4. façade brick d=12cm; 5. New insulation of mineral wool d=5cm; 6. cement mortar d=2cm		1. lime mortar d=1.5cm; 2. brick block d=25cm; 3. mineral wool insulation d=5cm; 4. cement mortar d=2cm; 5. New insulation of mineral wool d=5cm; 6. cement mortar d=2cm		1. lime mortar d=1.5cm; 2. brick d=25cm; 3. mineral wool insulation d=5cm; 4. cement mortar d=2cm; 5. New insulation of mineral wool d=5cm; 6. cement mortar d=2cm
	U2=0.279 W/m2K		U2=0.294 W/m2K		U2=0.234 W/m2K		U2=0.298 W/m2K

Table 6. Review of characteristic types of roofs with added appropriate insulation

1		2		3		4	
	1. lime mortar d=1.5cm; 2. Ceiling construction d=20cm; 3. mineral wool insulation d=8cm; 4. New insulation of mineral wool d=10cm; 5. hydro insulation; 6. boards with roof tiles d=2.4+5cm		1. lime mortar d=1.5cm; 2. ceiling construction d=20cm; 3. mineral wool insulation d=10cm; 4. Hydro insulation; 5. concrete d=6cm; 6. New insulation XPS styrodur d=6cm		1. lime mortar d=1.5cm; 2. Ceiling construction d=12cm; 3 mineral wool insulation d=10cm; 4. New insulation of mineral wool d=8cm; 5. hydro insulation; 6. boards with roof tiles d=2.4+5cm		1. lime mortar d=1.5cm; 2. ceiling construction d=20cm; 3. concrete d=10cm; 4. Hydro insulation; 5. concrete and tiles d=6cm; 6. New insulation XPS styrodur d=18cm + tiles d=2cm
	U2=0.193 W/m2K		U2=0.189 W/m2K		U2=0.183 W/m2K		U2=0.192 W/m2K

Up to 50% of energy required to heat the building is lost through windows. Heat transfer coefficients for older window types are larger than 3 W/m2K. European legislation defines heat transfer coefficient for windows in the range of U=1,40–1,80 W/m2K. Ventilation heat losses can be most effectively reduced by replacing old windows. Accordingly, saving heating energy that is used for heating of preschool facilities, where the replacement of windows has been performed, is achieved by reducing ventilation and conduction losses. The amount of energy savings based on reduced conduction energy losses is calculated by the formula:

$$Q_c = (U_1 - U_2) \cdot A \cdot (\theta_{\text{int},i} - \theta_e) \cdot d_n \cdot g_s \tag{1}$$

Where: U is heat transfer coefficient for windows; A is total surface area of windows in the preschool classrooms; $\theta_{\text{int},i}$ is internal design temperature of heated space (i) in degrees Celsius (°C).

The value of the average heat transfer coefficient for old windows in the preschools is about $U_1 = 4[W/m^2K]$, and heat transfer coefficient for new windows $U_2 = 1{,}8[W/m^2K]$, for PVC windows made of three chamber profiles with thermal insulated glass filled with dry air.

2.6. Energy savings based on reduced ventilation heat losses

According to the European standard EN 12831, the design ventilation heat loss, $\Phi_{V,i}$, for a heated space (i) is calculated as follows

$$\Phi_{V,i} = H_{V,i} \cdot (\theta_{\text{int},i} - \theta_e) \text{ [W]} \tag{2}$$

Where: $H_{V,i}$ is design ventilation heat loss coefficient in Watts per Kelvin (W/K); $\theta_{\text{int},i}$ is internal design temperature of heated space (i) in degrees Celsius (°C); θ_e is external design temperature in degrees Celsius (°C). Standardized average internal air temperature for educational facilities in preschool buildings is $\theta_{\text{int},i} = 20^o C$. Average outdoor air temperature for the City of Nis in the heating period is $\theta_e = 5{,}4^o C$. The design ventilation heat loss coefficient, $H_{V,i}$, of a heated space (i) is calculated as follows:

$$H_{V,i} = \dot{V}_i \cdot \rho \cdot c_p \text{ [W/K]} \tag{3}$$

Where: $\dot{V}_i \cdot$ is air flow rate of heated space (i) in cubic meters per second (m^3/s); ρ is density of air at $\theta_{\text{int},i}$; c_p is specific heat capacity of air at $\theta_{\text{int},i}$, $\rho \cdot c_p = 0{,}34$.

The value of the air flow rate depends on air exchange rate per hour, volume of heated space in cubic meters (m3), calculated on the basis of internal dimensions, shielding coefficient and height correction factor. Numerous studies have been carried out in order to find the amount of air in the room to be changed per hour. For residential buildings, these values range from 0,3 to 1, depending on purpose of room. German standard defines minimal air change values for residential rooms per hour. Average air exchange value per hour is 0,7. Current European standard for preschool buildings and their educational facilities, EN 12831 defines minimum two air changes in the room in one hour. Energy savings by reducing ventilation losses to a minimum are calculated based on the following formula:

$$Q_v = (\Phi_{\inf,i} - \Phi_{\min}) \cdot d_n \cdot g_s \text{ [kWh]} \quad (4)$$

$$\Phi_{\inf,i} = n_1 \cdot V_i \cdot \rho \cdot c_p \cdot (\theta_{\text{int},i} - \theta_e) \text{ [kW]} \quad (5)$$

$$\Phi_{\min} = n_{\min} \cdot V_i \cdot \rho \cdot c_p \cdot (\theta_{\text{int},i} - \theta_e) \text{ [kW]} \quad (6)$$

$$Q_v = (n_1 - n_{\min}) \cdot V_i \cdot \rho \cdot c_p \cdot (\theta_{\text{int},i} - \theta_e) \cdot d_n \cdot g_s \text{ [kWh]} \quad (7)$$

The total number of heating days in preschools in City of Nis is 179 days. Winter holidays and non-working days are exempted from the number of heating days. Thus, the total number of days in the heating season in preschools is with heating hours during the day (6h to 19h).

Table 7. Energy savings based on the reduced heat losses from conducting and ventilation heat losses

Preschool	Qc(kWh/a)	Qv(kWh/a)
Bajka	48895.75	46823
Bambi	88533.31	39421
Bubamara	85742.68	16988
Crvenkapa	63312.51	24915
Cvetic	70568.08	31140
Cvrcak	53134.34	21140
Kolibri	43903.37	23254
Lane	11121.42	8720
Leptiric	295071.9	26274
Maslacak	46898.21	19026
Neven	70396.91	32617
Palcic	89785.09	17334
Pepeljuga	34373.64	18362
Petar Pan	85298.62	41822
Pinokio	43896.46	28086
Plavi Cuperak	42326.85	27264
Slavuj	46940.85	46811
Svitac	48064.57	6765
Vilin Grad	53454.61	19731
Zvoncic	67293.76	16777

Table 7 shows the results of energy savings by replacing old windows in the nursery. Results are obtained from the formulas (1) and (7) where Qv is energy savings by reducing ventilation losses to a minimum and Qc is the amount of energy savings based on reduced conduction energy losses.

2.5. Analysis of investment profitability

Optimal energy consumption of analyzed preschools would be obtained by total energy savings due to reduced ventilation and conductive heat losses. Energy saving are

$$Q = Q_v + Q_c \quad (8)$$

Table 8. Saving heat energy and payback period

Preschool	for window replacement			for added insulation			∑		
	Total annual savings (%)	Cp, invesment (€)	Ip, Return on investment (years)	Total annual savings (%)	Cp, invesment (€)	Ip, Return on investment (years)	Total annual savings (%)	Cp, invesment (€)	Ip, Return on investment (years)
Bajka	57	27720	5.1	45	33920	6.5	49	61640	5.8
Bambi	50	30008	8.7	49	35280	4.7	49	65288	5.9
Bubamara	41	22800	13.2	51	33800	4.6	50	56600	6.3
Crvenkapa	47	24600	4.1	49	30380	2.3	51	54980	2.8
Cvetic	43	91200	18.2	44	35400	4.7	54	126600	10.3
Cvrcak	41	34600	6.2	48	27580	2.5	54	62180	3.7
Kolibri	47	40600	12.1	41	33820	7.2	55	74420	9.5
Lane	48	8900	4.2	24	16840	7.1	69	25740	5.7
Leptiric	42	76000	18.6	51	54080	5.3	50	130080	9.2
Maslacak	44	46600	16.6	42	33960	6.8	56	80560	10.3
Neven	51	55800	6.3	52	28840	1.9	46	84640	3.5
Palcic	42	57800	10.2	62	26780	1.4	41	84580	3.4
Pepeljuga	41	42400	15.9	34	32300	8.8	63	74700	11.8
Petar Pan	57	26880	6.8	63	37040	5.1	38	63920	5.7
Pinokio	48	20600	6.2	39	50360	10.8	57	70960	8.9
Plavi Cuperak	48	24000	9.1	35	33820	9.4	60	57820	9.3
Slavuj	68	17190	4.1	43	30700	7.7	46	47892	5.9
Svitac	53	8000	4.7	48	2920	2.8	51	37020	3.1
Vilin Grad	40	29600	5.7	37	37040	3.2	62	66640	4.0
Zvoncic	37	30400	6.6	42	37040	2.6	59	67440	3.6

Translated into liquid fuel saving: $m' = \frac{Q}{H_d}$ (9)

and corrected with calculated efficiency coefficient of boiler: $m = m' \cdot \eta$ (10)
Where Hd is lower heating value of liquid fuel

For a known cost of fuel used for heating preschools $g[€/\mathrm{kg}]$, resources saved by reducing fuel consumption can be calculated by the following formula: $C_g = g \cdot m$ (11)

For a known cost of adding new thermal insulation on façade, replacement and installation of new and external doors and windows Cp[€], viability period of the proposed investment is: $I_p = \frac{C_p}{C_g}$ (12)

The average market price in Nis is taken as the price for square meter of a window, including installation. In the same way, the price of thermal insulation material and the price of the installation of the new thermal insulation façade layers are calculated. The price of fuel is calculated based on average annual heating costs for certain buildings.

Table 8 shows that annual energy savings from reducing ventilation losses is from 40% to 70%, depending on preschool building. However, the return on investment does not depend on the percentage of annual savings. It depends on the way, type and cost of heating, the total space of the replaced windows, as well as on the quality of the existing windows. Cost-effectiveness is in the range of 4 years for smaller objects up to 18 years for larger preschool buildings which have well-preserved windows. It should be pointed out that the reduction of carbon dioxide emission, the product of the heating system, which has positive effect on the environment, has not been taken into consideration.

3. Conclusion

Nowadays there are a lot of types of intervention methods for better keeping and treatment of existing building fund. Adoption of the strategy and the principles of green design and construction / reconstruction can enlarge the economic, environmental performances of the buildings and also can contribute to the children more comfortable and stimulating stay in pre-school premises. 'Green' methods can be applied into buildings at any phase of upbuilding, starting from the phase of design and construction, to the reconstruction and demolition. In order to select the most appropriate treating measures, it is necessary to conduct previous researches and to gather information about certain building location (special microclimate conditions), physical structure, building condition, etc. Damage and imperfections to parts of the physical structure and the entire facility can be caused by numerous factors from outer surrounding, such as: natural-atmosphere influences, intentional acts of people, as well as internal factors, which aroused from the facility itself (type of applied materials). Mentioned influential factors have conditioned disturbing of children's comfort within facility and outer surrounding. Therefore, in these cases it is necessary to start with the implementation of revitalizing steps of the internal and external environment suited to children's needs.

The revitalization process of preschool buildings may have different aspects. Depending of the age and actual condition of the building, it may be suggested extensive reconstruction activities; otherwise the reconstruction can be focused on actions in the interior, equipment and furniture. In order to 'do more with the less', the problem of reconstruction must be considered through priorities. Major priority must always be the well-being of the occupants – children.

A greater part of building fund of preschool facilities in Serbia and region dates from the time when environmental and energy efficiency principles in architecture were not sufficiently present in the design and construction. This fact makes the preschool buildings as energy inefficient. Methodology of energy revitalization of buildings includes identifying and distinctly defining of primary and secondary factors of undue losses of energy, planning of future activities and realizing of planned steps leading to the elimination of major problems. Taking into account everything that has been researched and discussed in the monograph, one can make a conclusion that the use of highly efficient energy systems of heating, cooling, ventilating and lighting, increasing of thermal insulation of buildings envelop, different type of greening building, modification in human behavior habits, etc. may have a significant impact not only on upgrading energy efficiency in structures but also lowering the costs as well as reducing the negative effects on the environment. In addition the quality of children resides in preschool premises is raised to a higher level.

It is necessary that the space where children spend time is organized, equipped and colored in a manner to support a child and to provide privacy, shelter and isolation so that it could express its emotion and gain confidence. Revitalization of internal environment of preschool facilities includes the implementation of complex measures which affect improvement of physical, acoustic, aesthetic, light and air comfort. Considering pleasing children stay in preschool facilities, advisable is to raise comfort level by implementing new technologies, existing materials of improved quality and the introduction of new environmentally friendly materials and equipment in the area of internal environment.

The most important goals that need to be achieved by implementing of revitalization measures on preschool buildings are following:

- Firstly, providing comfortable and high-quality dwelling conditions for children and stuff in the pre-school buildings, as well as providing conditions and supporting environment criterion fulfilling so as to improve progress of children,
- Creating of ecological and high-quality outdoor and indoor surrounding,
- Preservation of non-renewable sources of energy, by introducing and applying renewable resources,
- Immediate environment protection.

With the aim to accomplish mentioned goals every step need to be applied in accordance with the general plan. These types of projects must be precisely and strategically planned and done, bearing in mind that children (main occupants of building) are in sensitive phase of development. The whole benefit from the revitalization project has been considered via three levels of sustainable development: social, economical and ecological development. When selecting the method of construction of building or revitalization, and when choosing architecture technologies, materials and elements, energy devices, installations and systems, optimal energy, economical and ecological requirements should be satisfied.

All preschools in the City of Nis were built before adoption of thermal protection regulations in construction industry. They are treated as energy-inefficient buildings, so there is a great need for their revitalization. Revitalization in terms of replacing old windows with poor thermal performance and adding new thermal insulation is the most efficient and cost-effective way to save energy. Previous research has shown that up to 50% of heat energy required to heat the building is lost through the old windows. The results of energy saving analysis of preschools in City of Nis show that by replacing the windows and adding new thermal insulation during one heating season savings of over 1,5 GWh of heat energy can be achieved. Each year, about 60% of fuel can be saved by replacing old windows and adding new layer of insulation. By increasing energy efficiency of preschool buildings, heating costs are reduced, and thermal comfort during the use of the facility is increased. Refurbishment and re-use of buildings will continue to represent a major and increasing component of construction activity in 21st century, especially taking into account legal obligations of energy efficiency improvements. In this regard, the contribution of this study is even greater, since its findings are useful for architects and engineers when it comes to choosing an approach for such and similar interventions.

Modernization of building façades is ideal opportunity for integration of passive and active solar energy systems into a new, reconstructed façade. Architectural predisposition of preschool facilities may represent the basis for designing a system that would be focused on the use of solar energy. Specific requirements that guide the development of building layout toward the south orientation are ideal prerequisites for adequate functioning of solar system. Basic characteristics of the functional organization of preschool facilities analyzed in terms of specific aspects of solar energy systems define main influencing predispositions of buildings: the position of architectural structure, size of architectural plan and architectural form and materialization, as factors that may directly affect the optimal operation of solar energy system.

Beside benefits that are directly related to increasing energy efficiency and utilizing renewable natural resources, it is important to note that the application of solar energy systems in preschool facilities is extremely important for children's education. In this way, children at early stage of their life become familiar with contemporary environmental problems and feel responsibility to protect their environment. Another important motif is promoting the use of energy efficiency systems in public facilities as one of the best ways to implement such systems in private households and multifamily buildings.

The main tendency of the research is to emphasize architecture revitalization praxis, based on the thoroughly developed and economically justified projects, as one of the ecological and energy "instruments" providing and preserving the life on the planet.

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