ISSN 1330-3651(Print), ISSN 1848-6339 (Online)
DOI: 10.17559/TV-20131230163936

IMPLEMENTATION MODELS FOR ENERGY RECOVERY MEASURES OF EXISTING KINDERGARTEN FACILITIES IN SERBIA

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Original scientific paper

Investments in the construction of new kindergartens are at a low level in Serbia. On the other hand, the existing facilities are outdated, devastated and do not meet current regulations, especially in terms of energy efficiency. The attendance of children in such facilities represents a significant social issue and therefore, the refurbishment of these structures is necessary. This paper presents measures for energy recovery and methods of their implementation within the framework of a comprehensive revitalization of the existing kindergartens. Through a case study, an analysis of energy efficiency and cost effectiveness for three sets of measures has been conducted, the findings of which are presented and discussed. The advantages of the applied methods are listed, as well as the potential areas for the implementation of the results. In addition, some recommendations for the future research are given and the limitations in the application of the obtained results are emphasized.

Keywords: *cost effectiveness; energy efficiency; energy recovery measures; existing kindergarten; implementation models; Serbia*

Modeli implementacije mjera energetske sanacije postojećih dječjih vrtića u Srbiji

Izvorni znanstveni članak

Ulaganja u izgradnju novih vrtića su na nezavidnoj razini u Srbiji. S druge strane, postojeći objekti su zastarjeli, devastirani i ne ispunjavaju važeće propise, posebice u pogledu energetske učinkovitosti. Boravak djece u takvim objektima predstavlja značajan društveni problem te je stoga neophodna obnova ovih objekata. U radu su prikazane mjere energetske oporabe i metode za njihovu provedbu u okviru sveobuhvatne revitalizacije postojećih dječjih vrtića. Kroz studiju slučaja, provedena je analiza energetske i troškovne učinkovitosti za tri paketa mjera, a rezultati su prezentirani i diskutirani. Navedene su prednosti primijenjene metode, kao i potencijalna područja provedbi rezultata. Osim toga, dane su neke preporuke za buduća istraživanja, i naglašena su ograničenja u primjeni dobivenih rezultata.

Ključne riječi: *energetska i troškovna učinkovitost; mjere energetske oporabe; modeli provedbe; postojeći dječji vrtić; Srbija*

1 Introduction

The (re)construction of kindergarten facilities for our children is undoubtedly one of the most important tasks facing society today, despite declining birth rates - or perhaps precisely because of that. [1] However, investments in the construction of new kindergarten institutions have been at a very modest level, due to years of economic crisis in Serbia. Approximately 80 % of the existing facilities are between 25 and 35 years old [2], so that their condition is not at an advantageous level. The constructions of these buildings have been performed within a very restricted financial framework, with almost no application of modern technologies. As children are a particularly sensitive category of the human population, their longer stays in inadequate conditions, when it comes to positive psychological and physical development, represent a significant social problem. Taking into account all the above, the most rational approach in these circumstances is a comprehensive revitalization, which would extend the lifetime of these facilities, ensure proper conditions for childcare and, in terms of energy efficiency (EE) and sustainability, provide modern facilities that meet all applicable standards. The main objective of this study is the analysis of the requirements, development and determination of the optimal model of energy recovery within the process of a comprehensive revitalization of the existing kindergarten facilities, as well as its implementation in local conditions.

The paper is composed of a theoretical basis, digital modelling and computation works - calculations of heating energy needs for established models, by using the appropriate software packages. The program and the development of models for improving the energy quality of the envelope, with the tendency of switching to renewable energy sources are defined. The methods used in this survey include literature review, the method of modelling based on digital simulation of the representative existing facility, as well as local visits and interviews with relevant researchers, policy makers and kindergarten educators. The survey was conducted on a specific example, through a case study on the territory of the city of Niš. As part of the investigation, the current condition of the facility is given, with an analysis of the envelope structure and calculation of the annual heating energy demands. Further, based on prior consideration, three models for the implementation of energy recovery measures have been developed, with the calculation of the annual heating energy demands and achieved energy and cost savings for each of the featured models.

2 Existing kindergarten facilities and actual energy codes

Previous studies and analysis on preschool facilities in south-eastern Serbia, carried out by a group of authors, [2 ÷ 5] indicate that the largest number of existing kindergartens is characterized by overall obsolescence, huge energy consumption, and the fact that they do not comply with the stricter applicable building standards introduced in recent years. As such, the current state inevitably entails the implementation of certain measures, primarily in terms of energy recovery in buildings. Energy recovery involves construction works and other measures on the existing buildings in order to increase their energy efficiency [6, 7]. The sector of existing facilities is high on the priority list of possible energy savings and represents a significant generated resource, which is in danger of decay and devastation [8, 9]. One of the many ways in which energy consumption can be reduced is to recycle and re-use existing buildings as much as possible [10]. Providing new capacities for childcare that meet modern requirements through the reconstruction of redundant and obsolete facilities, represents a logical choice in the absence of available space for new development, particularly in urban areas. The importance of these measures is even greater if one takes into account the special sensitivity of the included population, since normal and complete development of the young requires thermally neutral spaces that do not cause discomfort or unpleasantness with children.

Since the 1970s, the importance of providing adequate insulation has been reflected by several changes to the building regulations, which now demand considerably greater amount of insulating material in the building envelope. New regulations [6, 7, 11] made compulsory for all buildings to be classified into energy classes (from best A+ to worst G) according to the annual heating energy consumption, as well as to have energy performance certificates. These changes in energy codes will play a considerable role in the improvement of the construction quality, modernisation of existing buildings, and will significantly contribute to the reduction of energy consumption.

2.1 The scope of energy recovery measures

Within the [6] it is also specified that "after performing the works on reconstruction, extension, renewal, modification, repair and energy rehabilitation of the existing buildings, the energy class must be improved for at least one grade." Since it is expected that the current EE standards will be even stricter in accordance with EU directives, [12] and due to the rapid development of new technologies, the current criteria may change several times during a building lifecycle, and thus the above mentioned legal clause should be regarded as a minimum goal. A review of the EU directives and the modes of their implementation indicate that the reduction in the energy performance indicator value, which expresses the annual consumption of energy for one square metre of a building, is one of the essential goals [13]. According to some other authors, energy recovery measures should be chosen to have the greatest effect on the energy balance, with the aim of achieving higher standards, such as low-energy or passive-house [14]. If such EE measures are applied on an existing building with an average energy consumption of about $200 \div 300$ $\mathrm{kW \cdot h/m^2}$, as is commonly the case with kindergartens, savings of up to 90 % are possible [5]. The question now in the minds of many experts and building users is no longer whether insulation should be used, but rather which type, how, and how much [15]. Should EE activities be related only to the current standards, or should they aim at achieving the lowest possible energy consumption, taking into account the economic efficiency as well?

3 The benefits of energy recovery

In addition to the environmental and economic benefits, the justification for undertaking energy recovery measures of such a large scale is reflected in other numerous facts. Improved energy performance of the building envelope has a large positive effect on the improvement of indoor physical and thermal comfort [15, 16]. This is of great importance in the nursery buildings, because it has a significant effect on the performance of building occupants. The learning effect, motivation and performance are closely related to the indoor environment quality, and are greatly affected by air temperature in particular [17].

Despite all of the aforementioned, additional benefits include noise reduction, prevention of condensation, better fire protection, preventing damage of the building structure by minimizing temperature fluctuations and undesirable thermal movements, etc. The façade reconstruction contributes to the architectural and visual identity and integrity improvement in terms of achieving contemporary architectural expression, but also to a sense of pleasantness, development of positive feelings, and the need of children to more easily accept the environment in which they spend a substantial part of the day.

4 Case study analysis of energy recovery measures

In this chapter the results of a case study carried out on a representative example of this type of buildings in the city of Niš are presented. The approaches adopted are:

- to identify a representative example of a kindergarten building in the city of Niš and perform a short presentation of its technical characteristics,
- to establish three possible levels of energy efficiency improvement: through the implementation of standard measures, common to the Serbian market, and advanced measures which require a larger scope of intervention and investment,
- to perform computational analysis and evaluate thermal and energy performance of the facility before/after the implementation of envisaged measures in terms of achieved heat losses and gains, required annual energy for heating and realized energy class,
- to analyse and compare the obtained results in terms of realized energy savings, costs of the applied measures, as well as cost effectiveness.

This survey and its findings are presented in the following sections, and the implications of applying these energy recovery measures are considered and discussed.

4.1 Identifying the representative example

Surveys of existing kindergarten facilities in the city of Niš and in one part of southern Serbia were conducted from 2011 to 2013, within the framework of the scientific project "Revitalization of preschool facilities in Serbia: the program and methods of improving environmental, functional and energy qualities", financed by the Serbian Ministry of Education, Science and Technological Development. The aim was to gather information regarding the general condition of this type of buildings, including construction details, buildings area and number of floors, year of construction, type of the building envelope, thermal and energy performance etc. The data were obtained mainly through local contacts on site and/or within the architecture design practices, and are presented in Tab. 1 below.

Table 1 Basic construction characteristics of kindergartens in the urban area of the city of Nis

Kindergarten	Const. year	Obj. type	Fl.	Façade type	Roof/ attic	Joinery
Petar Pan	2005	Freestanding object	2	Brick	Sl./attic	Al
Bambi	1978		2	Brick	Flat	Al
Leptirić	1978		2	Brick	Flat	Al
Palčić	1963		2	Plaster	Sl./attic	PVC
Pinokio	1979		2	Brick	Sl./attic	PVC
Cvrčak	1983		2	Brick	Sl./attic	Wood
Bajka	1977		2	Brick	Sl./attic	Wood
Kolibri	1977		2	Br/plaster	Sl./attic	Al/PVC
Vilin Grad	2000		2	Brick	Sl./attic	PVC
Bubamara	1963		1	Plaster	Sl./attic	W/PVC
Plavi Čuperak	1983		2	Br/plaster	Sl./attic	PVC
Maslačak	1976		2	Brick	Sl./attic	PVC
Zvončić	1992		2	Brick	Sl./attic	Al
Neven	1976		2	Br/plaster	Sl./flat	Wood
Crvenkapa	1976		2	Brick	Sl./attic	Al
Slavuj	1970		2	Plaster	Sl./attic	PVC
Pepeljuga	1980		2	Plaster	Sl./attic	Wood
Svitac	2002		2	Brick	Sl./attic	PVC
Cvetić	2012		3	Plaster	Sl./attic	PVC

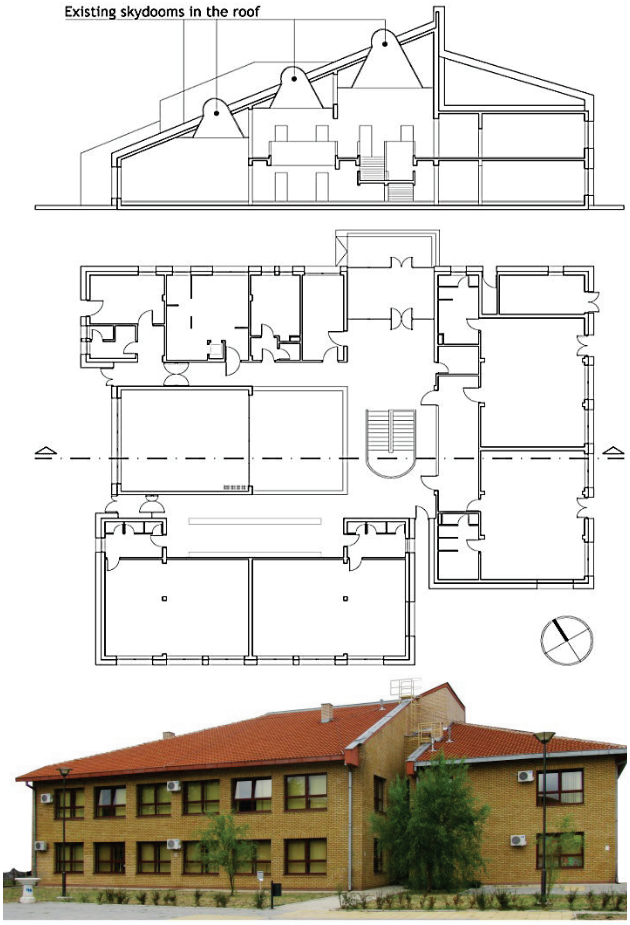

Figure 1 Kindergarten "Zvončić" - cross section, ground floor plan and the current appearance

Based on the collected data shown in Tab. 1, it was concluded that kindergarten "Zvončić" can be selected as a representative example of those facilities located in an urban area of the city of Niš (Fig. 1) on the following grounds:

- Besides the kindergarten "Zvončić", there are two more in the city, which were built on the basis of the same design ("Vilin Grad" and "Petar Pan"),
- The facility is of the average age, compared to the others in the table,
- Most of the buildings have the same type of façade walls (brick block 25 cm, 5 cm insulation of mineral wool, and façade brick 12 cm), uninsulated floor on the ground, the roof type (sloped roof with unheated attic, and isolated ceiling, with mineral wool 5 ÷ 10 cm thick) and external joinery type (aluminium profiles and double glazing),
- All of them are free-standing type facilities, located on the flat ground, and in most cases are two-storey buildings (ground floor and first floor).

4.2 Energy efficiency improvement measures

For the representative kindergarten facility selected, considered measures of energy recovery are given for two possible levels of EE improvement of the building, through three established models, different in scope of intervention. Thermal insulation of the building envelope and joinery replacement are among the most implemented measures. They represent major contributions in this process because they bring the greatest effect. Thus, they are usually set as the first step towards higher EE level in the process of energy recovery of existing facilities. An adequate insulation of the building reduces an unwanted heat loss or gain, decreases the 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 CO_2 emissions [18]. Experience shows that the use of various energy efficiency measures can result in energy savings up to even 80 % [19]. The objective is to determine which of the presented sets of energy recovery measures will yield better results in practice, taking into account the invested assets, achieved level of thermal comfort, realized energy and financial savings and savings-to-investment ratio. Implementation models for energy recovery measures have been described and analysed in this section.

1. Medium investment set (standard energy recovery measures) without changes in dimensions and volume of the building, with moderate efficiency increase, where a medium decrease of heating energy demand is expected,
2. High efficiency set (advanced energy recovery measures) without changes in dimensions and volume of the building, with large efficiency increase, where a large decrease of heating energy demand is expected,
3. High efficiency set (advanced energy recovery measures) with the increase of floor surface area and volume of the building, and identical energy recovery measures as in the second established model.

It is assumed that the application of standard measures can lead to savings of up to 50 % of the current heating energy demands, and that advanced measures, which imply significant investment costs, would result in savings of even 70 % of the current annual heating energy needs. It is also estimated that it would be possible to upgrade the energy balance of the building and bring it to the energy class A only by improving the insulating properties of the building envelope.

The scope of intervention between the medium and high efficiency set of measures differ in terms of the thickness of insulating layers in the façade walls, ground floor and attic, as well as different systems of external joinery used. Standard measures of energy recovery, characteristic for the first established model, include improving the thermal properties of the walls by adding rock wool of 12 cm, insulation of the ceiling by placing rock wool of 10 cm, installing of 8 cm thick XPS styrodur in the ground floor construction, as well as the installation of joinery that has a better energy performance [20]. As in this case the existing installation of district heating system is retained, it is necessary to complement existing air conditioning (AC) split system, in order to provide conditions for normal functioning of the object in the summer period. The objective of the implementation of standard measures is to improve the energy class of the facility for at least one energy level, which is in accordance with the current regulations.

Advanced energy recovery measures, characteristic for the second and third established models, are those which greatly improve the energy performance of the building, raising its energy class to B or A. These measures include the installation of much thicker layers of the insulating material in walls (30 cm), ceilings (40 cm) and floors (25 cm), compared to those described within the framework of standard measures, as well as the installation of specialized high quality joinery systems for passive house standards [20]. Further increase in the thickness of the insulating material would not be rational in any respect. For advanced measures, it is also necessary to introduce some non-constructional measures of energy recovery, and this is primarily related to the installation of sophisticated, more efficient heating and cooling systems, which use renewable energy sources. The model of the possible appearance of the building for 1st and 2nd set of measures is presented in Fig. 2.

Figure 2 The proposed remodelling of the kindergarten [21]

The previously described high efficiency package is used identically in the establishment of 2nd and 3rd implementation models. The maximum range of this approach is conditioned, to a large extent, by the characteristics of the building on which the interventions are carried out. These characteristics primarily include the building shape factor, type of facility (freestanding, double or in a row), percentage of the façade glazing, etc. Further improvements in relation to the described advanced measures are only possible through the improvement of the shape factor by the extension of the facility in order to become more compact, and by the formation of large glazed roof surfaces in the gym and multi-purpose hall, which would increase heat gains during the winter. Passive use of solar energy for heating during the winter means the direct use of renewable solar energy with the use of architectural and construction measures, without any special installation [22]. By implementing such construction interventions the 3rd model was established, so that it has the same thermal characteristics of the envelope as the 2nd model, but it has a larger useful floor area and volume, as well as a higher share of glass surfaces in the envelope. Cross section, ground floor plan and the possible appearance for 3rd model are presented in Fig. 3, where the implemented construction measures can be seen.

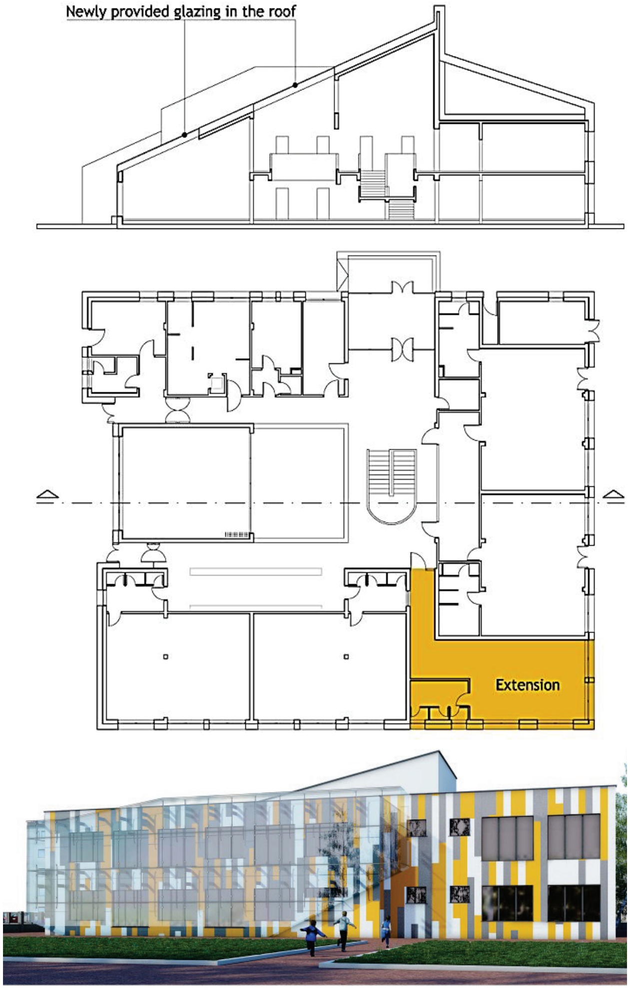

Figure 3 Extension of the kindergarten and new glazing in the roof

4.3 Evaluation of the energy performance

Based on the previously described models for the implementation of energy recovery measures, evaluation of thermal and energy performance was conducted in this section, both for the current state of the building and for all three models presented. Given that the national software package has not been adopted yet, calculations and determining the energy class were carried out using the software package "URSA Building Physics 2" [23].

The use of such building simulation tools is very common nowadays, since it not only helps the users evaluate the energy features of the buildings, but also enables them to analyse the design options in order to ensure the optimum performance throughout their service life [24].

Calculations were performed on the basis of Regulations on energy efficiency in buildings, [7] and the values of all relevant parameters (U-coefficients, vapour diffusion, specific transmission heat loss, specific annual heating energy demands, etc.) were obtained in compliance with all standards specified in this Regulation. Thermo-physical material properties provided in the Regulations were used, as well as characteristics of URSA thermal insulating materials. For input parameters in the calculation the following values were taken:

- External design temperature $Q_{H,e}$ −14,5 °C
- Number of heating days 179
- Average temp. of heating period $Q_{H,mn}$ 5,4 °C
- Indoor design temperature for winter T_i 20 °C
- Indoor design temperature for summer T_i 26 °C
- Outdoor relative humidity φ_e 90 %
- Indoor relative humidity for winter φ_i 55 %
- Indoor relative humidity for summer φ_i 65 %
- Condensation in winter/drying in summer 60/90 days.

The values of specific annual energy required for heating ($Q_{H,an}$) were obtained as the final results of the calculations, upon which the determination of the energy class was made for the current condition of the building and for all three models. According to [6], a building energy class is defined as "an indicator of the energy performance of the building, expressed by the relative value of the annual final energy consumption for heating and represents the percentage ratio of specific annual thermal energy required for heating and maximum allowable energy for heating, for a specified category of building." Also, the values of annual CO_2 emissions were obtained. Technical features (geometrical features, heat transfer coefficients, thermal and energy features) of the object current condition and of all three established models, as well as the results of the conducted calculations are presented in Tab. 2.

Table 2 Technical characteristics of the building (1), established models (2 ÷ 4) and the obtained results

a) Geometrical features							
		A_N (m^2)	V_e (m^3)	V (m^3)	f_s (m^{-1})	A_e (m^2)	Z (%)
1.	Current	1258	5373	4048	0,49	2652	6,22
2.	1st model	1258	5492	4048	0,49	2686	6,14
3.	2nd model	1258	5673	4048	0,51	2781	5,93
4.	3rd model	1415	6419	4615	0,44	2835	6,55
b) Heat transfer coefficient U for all elements of the envelope							
		U (W/(m^2·K))					
		W	R	C	F_g	F_h	A_{av}
1.	Current	0,49	0,38	0,37	3,43	0,98	3,76
2.	1st model	0,34	0,19	0,37	0,38	0,37	1,99
3.	2nd model	0,108	0,107	0,105	0,131	0,26	1,22
4.	3rd model	0,108	0,107	0,105	0,131	0,26	1,22
c) Thermal and energy features							
		H'_t (W/(m^2·K))	Q_g (kW·h)	$Q_{H,nd}$ (kW·h/a)	$Q_{H,an}$ (kW·h/(m^2·a))	C	CO_2 (kg)
1.	Current	1,13	44 239	173 336	137,79	E	73 764
2.	1st model	0,50	40 280	75 698	60,17	C	80 790
3.	2nd model	0,27	39 504	35 236	28,01	B	28 968
4.	3rd model	0,31	54 146	26 129	18,47	A	28 731

Symbols in Tab. 2 are as follows: A_N, useful floor area of the structure; V_e, gross heated volume of the structure; V, net heated volume of the structure; f_s, shape factor; A_e, area of the thermal envelope; z, share of transparent surfaces in the thermal envelope; W, façade wall; R, sloped roof over the part of the structure; C, ceiling; F_g, floor on the ground; F_h, floor above an unheated space; A_{av}, aluminium joinery; H'_t, specific transmission heat loss of the structure; Q_g, total annual heat gains; $Q_{H,nd}$, annual energy required for heating; $Q_{H,an}$, specific annual energy required for heating; C, energy class of the structure.

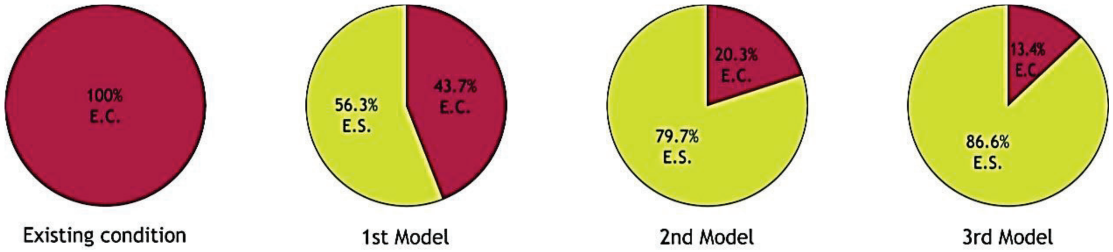

Figure 4 Energy consumption (E.C.) and energy savings (E.S.) achieved after the implementation of energy recovery measures

Heating energy consumption, before/after the implementation of the introduced energy recovery measures, and energy savings achieved are graphically presented in Fig. 4. The results shown in Tab. 2 indicate that an increase in heat gains within the 3rd model, in comparison to the 2nd, contributed to the upgrade from the energy class (B) to a better (A), although it has a less favourable coefficient of the specific transmission heat loss (H'_t). This anomaly is due to the fact that calculation and determining the energy class is carried out on the basis of the heating energy needs only [6, 7]. It is certain that such increased heat gains will result in a great increase of the energy required for cooling in the summer, which is completely neglected in the above-mentioned regulations. Therefore, it can be underlined (as one of the conclusions of this study) as a necessity for the legislature to make changes of the existing regulations in order to eliminate such anomalies. It is obvious that determining of the energy class on the basis of the required final (instead of heating) energy would provide more appropriate results of the calculations.

4.3.1 Heating and cooling system

Energy efficiency promotion and the adoption of renewable energy sources are techniques used in modern society to deal with problems that arose by the start of the first industrial revolution [25]. In our case, further improvements within the advanced measures for energy recovery could be obtained by including renewable energy sources, using the heat pump (HP) instead of the district heating system for heating. A heat pump is an environmental option in various European countries for reducing the consumption of energy sources, primary energy and indirect CO_2 emissions [26]. They satisfy the needs of heating and cooling for various purposes by utilizing the renewable energy from the environment and sources of waste heat in the most efficient manner [27]. By switching from a high temperature heating system with a high emissive value to a more efficient low-temperature system, the emission of harmful substances is significantly reduced. In addition to the environmental benefits, this measure is also considered to be rational because the existing district heating system will become multiply oversized for the facility with such high energy performances achieved. Low-temperature systems of this kind have a high degree of utilization, because they always produce more energy than invested in the form of mechanical work [22]. Values of primary/heating energy ratio range from 1:3,5 to 1:4,5 (utilization level) with the latest modern systems. A heat pump can also be used in the summer period for cooling, so an additional air conditioning system is not required, as is the case for the medium investment package. Another advantage of installing this system is reflected in the fact that the operating mode can be adapted to the specific needs and working time of kindergartens, as opposed to the district heating system through which heat energy is supplied from 6 am to 9 pm, seven days a week, during the whole year. This is why the application of HPs in these and objects of a similar purpose is becoming a growing market in Serbia.

In our case study, the fan coil heating/cooling system with HP is adopted, because the distribution of energy through the underfloor system is inappropriate for this type of a facility. Cooling via the underfloor system in the summer period is not appropriate for childcare facilities, and underfloor distribution of heat energy in the winter causes rising of micro-dust from the floor. Since the winter operating mode is more intense than the summer one, the heat capacity of HP is adopted on the basis of heat losses in the winter mode and calculated according to Eq. (1):

$$Q_h = H'_t \cdot A_N \cdot \Delta t, \tag{1}$$

where Q_h, heat capacity of HP; H'_t, specific transmission heat loss of the structure; $A_{N,}$ total heated area of the structure; $\Delta t = T_i - Q_{H,e} = 34{,}5$ °C, difference of internal and external design temperature.

The following heat pumps have been adopted based on the Eq. (1): HP with heat capacity of 12 kW and 3,67 kW of supply power for 2nd model; HP with heat capacity of 16 kW and 3,81 kW of supply power for 3rd model of energy recovery measures (high efficiency packages). Heat pump is an air-cooled inverter type, with its own hydro-module, for installation in the outdoor and indoor environment. It consists of two parts, the outdoor and indoor unit, connected by copper tubing through which the refrigerant R410A flows.

4.4 The scope and cost of the investment

As mentioned in the introductory section of this paper, the process of energy recovery is observed as part of an integrated, comprehensive revitalization of the building. Such an approach, where these two processes take place simultaneously, is considered to be the most rational in terms of cost effectiveness, because such measures of energy recovery are not feasible without performing a complete reconstruction of the building envelope. In terms of construction works, besides the above mentioned EE measures, the scope of the investment also implies complete replacement of the façade cladding and the floor structure on the ground, up to the reinforced concrete slab. Instead of the current brick façade, installation of a modern system of ventilated façade is provided, with a final coating of fibre-cement "Eternit" panels. As a final floor covering, the porcelain stoneware floor tiles are specified for lobbies and hallways, PVC floors for classrooms and dressing rooms, and ceramic tiles for sanitary and utility premises. Types of building materials are the same for all three models formed. Tab. 3 provides a detailed description of all construction and works on heating and/or cooling installations, with the unit prices and total cost of the investment for all three considered cases. Unit prices are based on the literature review [28] and the practical experience of authors.

Table 3 Total investments cost and costs of EE measures

	Description of work (units)	U. price (€/u.)	1st MODEL		2nd MODEL		3rd MODEL	
			Quantity	Total (€)	Quantity	Total (€)	Quantity	Total (€)
	Demolition and removal							
1.	Removal of brick façade (m^2)	6,5	813	5285	813	5285	813	5285
2.	Removal of mineral wool from the façade wall (m^2)	0,5	813	407	813	407	813	407
3.	Removal of window sills (m^2)	1,25	97	121	97	121	97	121
4.	Removal of insulating layers from the attic (m^2)	0,75	480	360	480	360	480	360
5.	Removal of floor - clinker tiles (m^2)	4	151	605	151	605	151	605
6.	Removal of floor - ceramic tiles (m^2)	3,5	213	745	213	745	213	745
7.	Removal of floor - vinflex tiles (m^2)	0,9	65	60	65	60	65	60
8.	Removal of PVC floor (m^2)	0,75	864	648	864	648	864	648
9.	Removal of cement screed (m^2)	3,5	726	2540	726	2540	726	2540
10.	Forming new openings in the roof	240					2	480
	Total demolition and removal			10 771		10 771		11 251
	Construction works							
1.	Ventilated façade – "Eternit" on substructure (m^2)	83	813	67 479	843	69 969	852	70 716
2.	Façade rock wool t =12/30 cm (m^2)	8/18	813	6504	843	15 174	852	15 336
3.	Vapour-permeable waterproof sheet - façade (m^2)	2,5	813	2033	843	2108	852	2130
4.	Vapour-permeable waterproof sheet - attic (m^2)	2,2	480	1056	480	1056	550	1210
5.	Moisture barrier - attic (m^2)	2	480	960	480	960	550	1100
6.	Rock wool t=10/40cm - attic (m^2)	5/15	480	2400	480	7200	550	8250
7.	Porcelain stoneware floor tiles (m^2)	27	91	2457	91	2457	103	2781
8.	Ceramic tile flooring (m^2)	18	164	2952	164	2952	174	3132
9.	PVC flooring (m^2)	18	545	9810	545	9810	606	10 908
10.	Cement screed t = 4,5 cm (m^2)	8	800	6400	800	6400	883	7064
11.	PVC sheet (m^2)	1	800	800	800	800	883	883
12.	XPS styrodur t =10/25 cm (m^2)	12/23	800	9600	800	18 400	883	20 309
13.	Cement-based hydro insulation (m^2)	7,5	800	6000	800	6000	883	6623
14.	Aluminium joinery with window sills	total		31 130		47 420		49 750
15.	Total cost of building extension							41 500
	Total construction works			149 581		190 706		241 692
	Heating and cooling installations							
1.	Air conditioning (AC) split system	total		4400				
2.	Fan coil heating/cooling system with heat pump	total				20 505		25 720
	Total investments costs			**164 752**		**221 982**		**278 663**
	Investments costs of EE measures			**59 420**		**114 085**		**124 991**

4.4.1 Cost effectiveness analysis and repayment

Investments made in energy conservation should be balanced by the cost savings they achieve. The repayment (amortisation) must be completed during the life expectancy of the components in question (30yrs for insulation systems, 50yrs for aluminium joinery and 25yrs for glazing) [29]. The potential savings of EE measures are often underestimated due to incorrect economic assessments, often with the result that potentially beneficial investments are not done. Frequently, the costs of necessary routine maintenance work are included in the cost estimations, increasing the amount to be amortised through energy savings. This is incorrect and the effect is to imply that the EE measures are uneconomic [30]. If a differentiated approach is taken, the maintenance and repair costs must be determined separately from the costs for the EE improvements and should be financed from the funds provided for that purpose [29]. For instance, in case of the refurbishment of a composite façade system, this means that new façade cladding is classed as "maintenance", whereas the insulation should be included under EE improvements. Only the costs for the actual insulation improvement should be amortised through energy savings. In this sense, an option of a comprehensive revitalization, combining maintenance works and EE measures, is gaining in importance.

Investments in energy saving measures are expensive and long-term measures, with payback period of 15 ÷ 40 years [31]. With potential energy savings obtained by computations and building simulation tools, annual heating energy costs and financial savings can be calculated according to the Eq. (2) for the district heating and Eq. (3) for a system with a heat pump. District heating price consists of a fixed (0,38 €/m^2 of heated area) and a variable part (0,05 €/(kW·h)) [32]. Price of electrical energy per kWh supplied by the national power company is about 0,045 ÷ 0,055 €/(kW·h) on average [33].

$$C = A_N \cdot p_f \cdot 12 + Q_{H,nd} \cdot p_v, \tag{2}$$

$$C = P \cdot h_d \cdot n_{hd} \cdot p_e, \tag{3}$$

where C, annual heating energy costs; A_N, floor area; $Q_{H,nd}$, annual heating energy needs; p_f, p_v, price for fixed and variable part of district heating; P, supply power of HP; h_d= 12, operating hours per day; n_{hd}= 179 – 26 = 153, annual number of heating days reduced by number of non-working days; p_e = 0,05 €/(kW·h), power energy price.

When considering the period for assessing whether an investment is worthwhile, the life expectancy of the investment plays an important role. It is defined as the period during which the behaviour and properties of structures remain preserved at the level which fulfils essential requirements [30]. For instance, technical installations must amortise over a period of 15yrs because then they must be replaced due to wear and tear, failure or the introduction of technically more advanced systems. As life expectancy of structural measures is almost twice as long, it is suitable to assume a30-year payback period. If the sum of the savings with added interest is higher than the costs of the investment calculated on an annuity basis, the investment is worthwhile (Tab. 6).The annuity for the investment and repayment period are calculated according to the Eq. (4) and (5).

$$A_o = \frac{K_o \cdot q^n \cdot (q-1)}{q^n - 1}, \tag{4}$$

$$TA = \frac{ln(1 - K_o(q-r)/R)}{ln(r/q)}, \tag{5}$$

where A_o, annuity for the investment; K_o, amount to be invested; n, life expectancy; q, interest rate (if 5 %, q = 1,05); TA, payback period; r, price increase of annual savings (e.g. r = 1,08); R, savings during the first year [29].

The invested capital must be restored during the determined life expectancy of building components that are replaced.

5 Results and discussion

The costs of annual energy required for heating and achieved cost savings during the first year of operation are calculated based on Eq. (2) and (3), and the results are presented in Tab. 4. The annuity for the investment and payback period, both for costs of EE measures and for total costs are presented in Tab. 5.

Table 4 Costs of annual heating energy and achieved cost savings

	Costs (€)	Savings (€)	Savings (%)
Current state	14 403		
1st model of en. recovery	9521	4882	33,89
2nd model of en. recovery	340	14 063	97,64
3rd model of en. recovery	350	14 053	97,57

All results of this survey were obtained for ideal experimental conditions. Aggravating circumstances, inevitable in real conditions of the building exploitation (negligence of object users, decrease in the performance of applied materials over the years, etc.), are not considered. More studies are needed to address these issues.

Table 5 Annuity for the investment and payback period

	EE measures costs		Total costs	
	Annuity (€)	Payback (yrs)	Annuity (€)	Payback (yrs)
1st model	3865	11,05	10 717	24,82
2nd model	7421	7,73	14 440	13,76
3rd model	8131	8,40	18 127	16,57

Table 6 Savings-to-investment ratio

	EE measures costs	Total costs
1st model	1,33	0,48
2nd model	1,99	1,02
3rd model	1,81	0,81

The previous economic analysis of energy recovery measures implemented through the three established models and savings-to-investment ratio obtained indicate that the investment is worthwhile for all three models, if only the EE measures costs are considered. The values of this ratio are presented in Tab. 6, implying that the 2nd model (high efficiency set of measures without extension of the object) is the most efficient in terms of the relation between invested funds and cost savings achieved. Furthermore, if the calculation is carried out for total costs, only the 2nd model is cost effective. In both cases, the worst results were obtained for the 1st model (medium investment set of measures). When it comes to the repayment period, both for EE measures and total costs, invested capital would be restored during the determined life expectancy for all three models. The worst payback period is for 1st model, and the most favourable for 2nd model. The 3rd model gave slightly worse results than the 2nd in both analyses, but it should be noted that in this case the usable area is increased, which can be considered as another major contribution.

It is indicative that the 1st model proved to be the most inefficient regarding the obtained repayment period and cost/savings ratio. This is primarily the result of inadequate pricing policy of PUC "Gradska Toplana", which delivers heating energy to final consumers. Since a fixed part of the heating price is not negligible in relation to the total price, the percentage of price reduction (33,89 %) is significantly lower than the percentage of energy savings achieved in the 1st established model (56,3 %). Such a pricing policy has a disincentive effect on potential investments in EE of new and existing buildings connected to the district heating system, so that the change in the method of price calculation is needed as soon as possible.

6 Conclusion

The initial assumptions about energy savings through the implementation of energy recovery measures are not only confirmed, but the expectations in terms of achieved percentage of savings are significantly exceeded. On the other hand, the assumption that it would be possible to upgrade the energy balance of the building and bring it to the energy class A only by improving the insulating properties of the building envelope (2nd model of energy recovery), proved to be incorrect. The energy class A for this specific facility could only be reached by improving the shape factor and increasing heat gains, through the extension of the facility and increasing glass surfaces (3rd model). Nevertheless, despite a significant investment, it is the 2nd implementation model that has proven to be the most rational and gave the best results in energy savings, repayment period and the cost/savings ratio. Unfavourable results of the economic analysis for the 1st implementation model imply that the existing district heating system is highly non-effective in terms of cost/benefit ratio due to the bad pricing policy and unsustainability in the long term. Based on all the aforementioned, it can be concluded that the installation of the environmental-friendly and highly efficient heat pump system, in combination with the best energy performance of the building envelope, is crucial for achieving such great energy savings and cost effectiveness, despite the large initial investment.

The refurbishment and re-use of buildings will continue to represent a major and increasing component of construction activity in the 21st century, especially taking into account legal obligations of EE improvements. In this regard, the contribution of this study is even greater, since its findings are useful for architects and all engineers when it comes to choosing an approach for such and similar interventions. The applicability of the obtained results in practice is reflected in the establishment of a methodological and systematic framework for management of energy recovery measures within the process of comprehensive revitalization of kindergartens. An implemented system can be offered to stakeholders, such as relevant ministries, local communities and administrations of preschool institutions, with the aim of creating optimal, healthy and environmental-friendly conditions for child care.

As this case study was performed for the building on the territory of the city of Niš and its specific conditions, the obtained results are applicable predominantly in southern and south-eastern part of Serbia, but also to all major cities, with minimal adjustments related to the local parameters. In this regard, the inability of application of the discussed methods on the facilities in different climatic conditions, with dispersed geometry and a higher prevalence of the façade glazing, may be emphasized as a limitation of this study. Another limitation arises from the applicable legal framework, since all the calculations are carried out only on the basis of the heating energy needs. This important issue remains unsolved. Therefore, it is necessary to adopt a new and better legislation, more suitable for real conditions of use of the facilities, primarily in terms of changing the method for determining the energy class.

All of the discussed topics, especially the use of unconventional sophisticated EE technologies, represent a broad and unexplored field in our circumstances, convenient and inexhaustible material for future studies in this field. Such solutions certainly represent the future in the management of EE measures, both in the new constructions and energy recovery of the existing buildings.

Acknowledgements

This paper is realized within the framework of the national scientific project at the University of Niš, the Faculty of Civil Engineering and Architecture, financed by the Ministry of Science and Technological Development of the Republic of Serbia 2011-2014: "Revitalization of preschool facilities in Serbia – The program and methods of environmental, functional, and energy efficiency improvement" (No. 036045: leader of the scientific and research project Danica Stanković, PhD).

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