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ENERGY AND ECONOMIC ANALYSIS OF THE RENOVATION OF THE KINDERGARTEN IN BANJA LUKA ACCORDING TO THE CURRENT RULEBOOK AND NZEB

Abstract

In the subject area, the term nZEB standard appears in 2011 in the legislative framework, but it never came to life, nor in the construction of new buildings, and completely unknown in the renovation of buildings. The reasons for this are insufficiently researched possibilities, i.e., unanalysed energy savings and economic profitability during the building renovation according to the valid regulations and the nZEB standard. This research analysed a specific type of building, a kindergarten, which must also respect the rules and does not have its own classification related to energy classes. Analysis has shown that, depending on the type of building, all possibilities for improving construction should be explored, not only in energy but also in redesign shape, since in this way, it is possible to reduce energy consumption to a minimum.

Keywords: nZEB, kindergarten, renovation, energy consumption, economic analysis

ЕНЕРЕГЕТСКА И ЕКОНОМСКА АНАЛИЗА ОБНОВЕ ВРТИЋА У БАЊОЈ ЛУЦИ ПРЕМА ВАЖЕЋЕМ ПРАВИЛНИКУ И nZEB-у

Сажетак

На предметном подручју термин nZEB стандарда, појављује се још 2011. године у законодавном оквиру, али никад није заживио, нити у изградњи нових зграда, а као концепт потпуно је непознат при обнови зграда. Разлози томе су недовољно истражене могућности, односно неанализирана енеретска уштеда и економска анализа при обнови зграда према важећем правилнику и према nZEB стандарду. Ово истраживање се води специфичним типом зграде, вртићем, који такође у важећем правилнику нема своју класификацију везану за енергетске разреде. Анализе су показале да у зависности од типа зграде, треба истражити све могућности унапређења зграде, не само у енергетском, него и у просторном и обликовном смислу, јер на такав начин могуће је потрошњу енергије свести на минималан ниво.

Кључне ријечи: nZEB, вртић, обнова, потрошња енергије, економска анализа

1. INTRODUCTION

The Energy Efficiency of Buildings Directive (EPBD) from 2010 [1] and Regulation EU No 244 from 2012 [2] require the Member States to establish minimum energy efficiency requirements for new buildings and existing buildings that need to be renovated. In line with these minimum requirements, the 2010 EPBD clearly states that all new buildings must be eligible for near-zero energy (nZEB) or have very low energy needs. Full implementation and enforcement of existing energy legislation are recognized as priorities in establishing an energy union [3]. Two critical requirements under this existing legal framework were to ensure that all new buildings are near-zero energy buildings by 31 December 2020 (two years earlier for public buildings) and to support the adaptation of existing buildings to near-zero energy buildings by setting zero-energy buildings as building standard from 2020. As Bosnia and Herzegovina (B&H) is signing the Energy Community Treaty, assuming the obligations of harmonizing the legal framework with the EU acquis in the energy sector [4], since 2016 on the entire territory of B&H (the first Rulebook was created in the Federation of Bosnia and Herzegovina in 2010) [5], which has been completely changed and is valid since 2019 on the territory of the Federation of B&H [6], and in the Republika Srpska, the Rulebook from 2016 is valid [7] legislation following European Union directives has come to life, but the above requirements have not yet come to life. The European Union has been focused on the objectives of the nZEB since 2010, while the legislation in B&H does not require the construction of nZEB, nor does it provide incentives for their construction, although this has been mentioned in legislative documents since 2011 [8]. As in the legislation of B&H, the energy efficiency indicator is guided by the numerical parameter of energy need for heating, and there are no primary energy indicators for the new construction of buildings. Numerical parameters for energy characteristics are based on cost-optimal analysis of B&H, led to the analysis of the nZEB of neighboring countries in the European Union, such as the regulations of the Republic of Croatia [9],[10],[11], and Slovenia [12],[13],[14].

It is interesting that in Austria, buildings are prescribed for nZEB four main energy indicators: energy need for space heating "*Heizwärmebedarf*" in [kWh/m^{2}a], primary energy demand in [kWh/m^{2}a], carbon dioxide emission in [kg/m^{2}a], and total energy efficiency factor fGEE [15].

Primary energy consumption might not be an adequate indicator for a cross-country comparison. Since additional steps from the energy need going through the energy use and the delivered energy involve additional parameters that change from country to country, the comparison becomes less transparent and therefore less meaningful. The intention of setting a national nZEB definition is not, first of all, a smooth cross-country comparison but rather the push of energy performance in the building stock. Nevertheless, we believe that a system that allows for cross-country comparison would lead to higher transparency and higher energy performance standards [16].

NZEB standard has not yet come to life in EU countries in the renovation of buildings, and recommendations EU8 (Focus of vulnerable groups) ZEBRA2020 project are that such a way of renovation could affect energy poverty [17].

In addition to the above requirements, the EU has established a new Directive since 2012, defining the need to develop and adopt a long-term strategy to encourage investment in the reconstruction. That refers to the housing and commercial buildings, public and private [18], because the existing fund of buildings are being renovated very slowly. The Directive requires that every three years, building renovation strategies be published, and in the latest European strategy from 2020 [19], it is emphasized that the renovation of buildings should be up to nZEB standards and, of course, following the promotion of green infrastructure and the use of organic building materials that can store carbon, such as sustainably-sourced wood.

This research aims to point out the usefulness of applying nZEB standards through energy and economic analyzes of kindergarten renovation by using the current Ordinance on minimum requirements for energy performance of buildings (designed solution) and applying nZEB standards in the Banja Luka area (improved solution). The "KI Expert Plus" program was employed to calculate individual energies. This research directly aims to provide an example of good practice in building renovation, such as kindergartens.

Kindergarten buildings are most often ground-floor free-standing buildings of relatively high value, building shape factors (f_o = 0.7-1.1 [m^{-1}]), which means that they belong to the categories of buildings with high energy need for heating [20].

Kindergartens are not implemented in any legislation in EU countries for a specific purpose, nor are they performed in the Recommendations of the European Commission for numerical benchmarks for NZEB primary energy use indicators where the purposes are classified into residential and commercial use [21].

2. NZEB AND TRENDS IN BUILDING RENOVATION IN THE EU

The nZEB concept was introduced in the early 2000s and has been well received and developed over the years. Thanks to global initiatives, it has spread rapidly worldwide, both in terms of concept and practical application. The nZEB offers a holistic approach in which the building is seen from energy, environment, and economic perspectives, bringing in close the built and natural environment and end-users [22]. Sweden (2006), Estonia (2007), Norway (2007), and Germany (2009) were among the first countries to incorporate this concept into national legislation in a certain way [23]. Zero energy buildings in the European Union are defined through the EPBD Directive, but due to differences in national laws, the possibility is left for each member to introduce additional parameters. That primarily refers to the calculation of primary energy consumption, but the system is so complex that it is challenging to set uniform limits due to the calculation itself. Nearly zero-energy buildings are buildings with very high energy efficiency, i.e., the consumption of electricity or heat from utility systems is reduced to zero or a very low amount of energy that should be significantly covered by energy from renewable sources. In addition, it is necessary for the nZEB building to produce this energy from renewable sources within or near the building.

It is not possible to establish a uniform definition for all EU countries at the moment, but the EBPD directive provides a framework, leaving member states the opportunity to adjust the definition according to their national laws.

Through the EPBD directives, the European Union has guided the entire building sector by setting zero energy buildings as the standard for construction from 2020. From the 2015 report [24], it can be seen that most countries have introduced in their national legislation that nZEB represents about 25-50% lower primary energy than that required by applicable regulations. In some countries, there are restrictions on primary energy indicators for nZEB, differing a lot from country to country. E.g., Denmark – 20 kWh/m^{2}a for residential and 20 kWh/m^{2}a for another purpose; France – 50 kWh/m^{2}a for residential and 20 kWh/m^{2}a for other buildings; Malta - 40 kWh/m^{2}a for residential and 60 kWh/m^{2}a for other purposes; Slovenia - 75 kWh/m^{2}a for a single-family house, 80 kWh/m^{2}a for the multi-family house and 55 kWh/m^{2}a for other purposes. It is even more interesting that in Slovenia, the established limit for the energy need for heating Qh,nd on 25 kWh/m^{2}a [24].

After that, as early as next year, the European Commission will issue Recommendations for the benchmark of primary energy indicator values, which member states should adhere to when formulating their definition. The amount of indicators is determined in relation to the technology price scenario for 2020. The proposed values are divided into residential and commercial buildings according to four climate zones (Mediterranean, Oceanic, Continental, Nordic). E.g., for Continental: — Offices: 40-55 kWh/m^{2}a of net primary energy with, typically, 85-100 kWh/m^{2}a of primary energy use covered by 45 kWh/m^{2}a of on-site renewable sources; — New single-family house: 20-40 kWh/m^{2}a of net primary energy with, typically, 50-70 kWh/m^{2}a of primary energy use covered by 30 kWh/m^{2}a of on-site renewable sources [21]. It is important to emphasize that these Recommendations of the European Union emphasize that benchmarks are usually provided in terms of energy needs. Underlying reasons are the fact that energy needs are the starting point for the calculation of primary energy, and therefore a very low level of energy need for heating and cooling is a vital precondition for nearly zero primary energy buildings. Very low energy needs are also a precondition to achieve a significant share of renewable energy sources and almost zero primary energy.

The further development of nZEB definitions and the setting of energy performance requirements in buildings can be improved through the lessons learned from the already in place nZEB buildings. Although it is shown that the climate condition is one of the main parameters that make a direct comparison of nZEB definitions among EU countries very difficult, an interesting outcome from a recent analysis shows differently [25]. The EU IEE ZEBRA2020 project [26] analyzed characteristics of 411 representative European high energy performance buildings (new and renovated, residential, and non-residential), mainly in mild-cold climates. It has been deduced that the climate conditions do not represent the main parameter affecting the definition of the technology package to achieve the nZEB target.

The share of energy for buildings in energy consumption is 40%. Today's annual building renovation rate is 0.4 to 1.2% in the Member States. This rate will need to be doubled to meet the EU's energy efficiency and climate goals. At the same time, 50 million consumers have difficulty adequately heating their homes. To address the dual issue of energy efficiency and affordability, the EU and Member States should engage in a "wave of renovation" of public and private buildings. Although increasing renewal rates is a challenge, renewal reduces energy bills and can reduce energy poverty [27].

Trends in the renovation of buildings can be followed through realized scientific research projects of the EU from 2009 until today. The first was guided by the concept of renovation of prefabricated panel cladding with renewable and organic materials such as [28],[29]. Later, this was followed by [30],[31],[32].

Research and design analyses of kindergartens were guided by the methodology presented in the research paper [33], where the authors expected that the presented methodology would stimulate evaluation of recent practice towards compatibility with future law legislative and strategic plans of EU research and innovation programs, Figure 1. NZEB standards in kindergartens are analyzed in many research papers, e.g. [34], [35], [36].

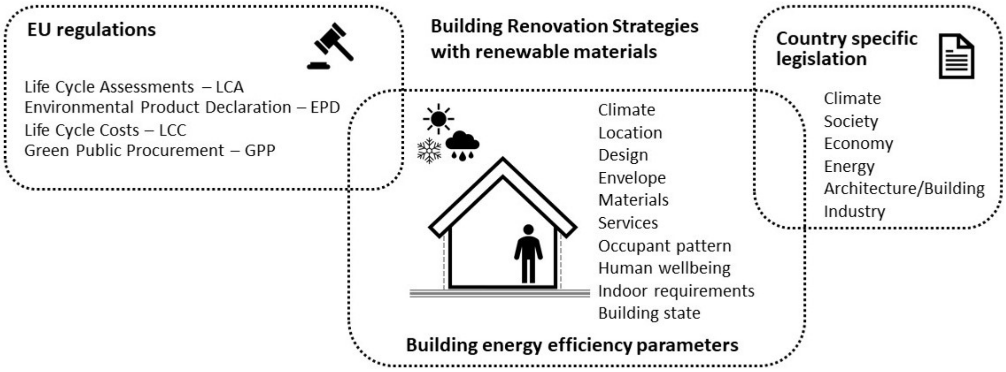

Figure 1. *Building renovation strategies with renewable materials. [33]*

3. POSSIBILITIES OF STANDARD AND IMPROVED RENOVATION OF KINDERGARTEN IN BANJA LUKA

The research analyzes a building in Banja Luka, constructed in 1962 when the Rulebook on thermal protection was not in force. One period, the building was devastated and abandoned, and in June 2020, at the initiative of investors from the City of Banja Luka and UNDP B&H, the reconstruction and rehabilitation of the kindergarten building were started, followed by the concrete realization.

The standard solution for the renovation of the building was guided by the main project of reconstruction and rehabilitation of the building, based on the current Ordinance on minimum requirements for energy performance [37] and the Rulebook on pedagogical standards and norms for the field of preschool education [38],[39]. The goal is to review the standard solution, identify possible shortcomings and opportunities for improvement, and offer a new design solution for improvement, i.e., to meet the energy characteristics of nZEB. The part of the building that has already been built is the starting point for both variants. The standard solution is a variant that would otherwise occur in the real sector. The second improved variant is led by nZEB under the condition that lower values of U-values are applied to the cladding elements than in the standard solution. The building shape factor is improved, and more than 30% of the annual energy delivered for the operation of technical systems in the building is reconciled with energy from renewable energy sources. The concept of renovation using renewable materials was also applied to the improved solution. In both solutions, the thermo-technical heating and cooling systems are heat pumps with central hot water preparation and a ventilation system with 75% efficiency recovery.

3.1. STANDARD RENOVATION OF KINDERGARTEN

The current Rulebook on minimum requirements for energy performance of buildings in the Republic of Srpska was created by cost-optimal analyses in numerical indicators related to the building envelope, i.e., heat transfer coefficients - U-values. As an indicator of energy efficiency of the building, energy need for heating, already during the renovation of the complete envelope it is possible to achieve the stated reduction of energy need for heating, which is different depending on the construction period (existence of thermal insulation on the envelope and its thermal characteristics and thickness) and building shape factor (the ratio of the envelope surface and the volume of heated space).

The kindergarten has an "L" shape. The vertical dimension of the building is defined by the ground floor (Figure 2). According to the existing condition, the elevation of the building with respect to the terrain is raised by 50 cm or, according to the designed solution, by 60 cm. Stairs and a ramp overcome this height difference. There are two entrances for users on the north and east sides and two economic entrances on the north side.

Figure 2. *Standard renovation of kindergarten was realized in May 2021. Source: authors*

The building is made in a classic masonry system with brick walls 25 cm thick and brick reinforcements in the form of extensions 38 cm thick, about 100 cm long. At the corners and half of the span of the sides, there are vertical circles 25x25 cm connected by horizontal beams 30 cm wide and 25 cm high, i.e., 40 cm, along the facade walls. The ceiling is made of wooden beams - ceiling tiles 18/20 cm; there is a board edging and the reed plaster on the lower side. A wooden plank was also made towards the attic on the upper side. Designed solution - standard renovation envisages construction of a contact facade with expanded polystyrene insulation (λ=0.042 [W/mK]) 15 cm thick and a final layer of silicate-silicone precious plaster, then windows with plastic frames and three-layer thermal insulation glass with low-E coating and filled with Argon (average U_w=1.10 [W/m^{2}K]). The floor is covered with waterproofing with 10 cm of extruded polystyrene (λ=0.035 [W/mK]) over which the protection from PVC foil is placed, and then the cement screed with the final layer of epoxy. As the roof structure is above the unheated attic, the installation of mineral wool was planned and carried out (λ=0.038 [W/mK]) in a thickness of 20 cm on the mezzanine structure under the unheated attic, Table 1.

Table 1. U-values of characteristic elements of the facade cladding - designed solution

Construction element	**A [m^2]**	**U [W/m^{2}K]**	**U_{max} [W/m^{2}K]**
Façade wall	477.54	0.23	0.30
Windows	79.31	1.10	1.60
Floor	392.06	0.32	0.30
Roof	392.06	0.17	0.20

The designed solution retains the basic concept of the building, which means that the geometric characteristics have not changed. During the works, it was noticed that the thermal bridges and the tightness were not adequately resolved, so the expected airflow was reduced to the volume of heated air, with a pressure difference between indoor and outdoor air of 50 Pa estimated at n_{50} = 2.00 h^{-1}. Table 2.

Table 2. Geometric characteristics of the designed solution – standard renovation

The envelope surface of the heated part of the building	A [m^2]	1426.33
The volume of the heated part of the building	Ve [m^3]	1800.10
Heated air volume	V [m^3]	1368.07
Shape factor - A/V ratio	-	0.79
The useful floor area of the heated part of the building	A [m^2]	397.08
Windows factor	%	20.23
Number of air changes at a pressure difference of 50 Pa	n_{50} [h^{-1}]	2.00

The capacity of groups for children under three years of age is 36 children, two groups of 18 children each, and the group of 3 to 6 years old is 25 children. So the total capacity according to the projected solution was 86 children. The building met the prescribed U-values and the transmission loss coefficient per unit of the heated part of the building, according to the designed solution for which the building permit was obtained. Annual energy need for heating per unit of usable area of the heated part of the building $Q''_{H,nd}$ amounts 91.88 kWh/(m^{2}a), which according to the Rulebook [40] brings the building to D class. Although the building has lower U-values than the prescribed, the permitted coefficient of transmission loss does not reach the permitted energy class C for buildings for education and culture and other offered categories of buildings.

3.2. IMPROVED RENOVATION OF KINDERGARTEN

The improved solution, which aims to reach the nZEB standard, was primarily driven by changing the shape factor because the standard design solution showed that it was impossible to achieve the required energy need for heating, i.e., energy class C. The shape factor was improved by upgrading the gallery. Following the trends in the EU and the potential of B&H in this construction material, it is planned to renovation the envelope and upgrade it with a wooden structure. Enhancement of the envelope was guided by a cross wooden substructure filled with thermal insulation, Figure 3, which was placed alternately in order to reduce the thermal bridges to a minimum.

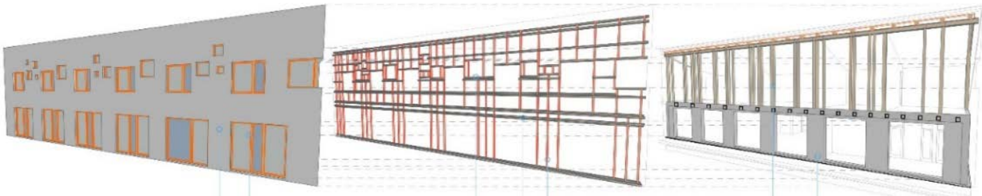

Figure 3. *Improved renovation of kindergarten, 3D view - facade diagram according to TES principles. Source: authors*

According to the improved solution, a single-pitched pitched roof was designed with a slope from south to north. The complete load-bearing structure is wooden. Transverse posts are attached to the massive wooden rafters from the upper side with thermal insulation installed between them and between the rafters as well, thus reducing the thermal bridges in the roof. According to the improved solution, it was planned to demolish the parapet and maximize the opening on the south and west sides, achieving a direct connection with the courtyard of the building, improving both the spatial and functional solution of the kindergarten. Gallery upgrading was planned so that the building on the south side has two floors and opens to the south to the maximum, and closes to the north, lowering the roof again to the level of one floor. In the extended part, i.e., the gallery, the play of dimensions and position of the opening was used as an architectural-visual element, creating a playful facade, contributing to the atmosphere of the interior space, Figure 4.

Figure 4. *Improved renovation of kindergarten, 3D view. Source: authors*

The improved renovation includes the construction of a wooden substructure with expanded polystyrene insulation ($\lambda = 0.034$ [W / mK]) 30 cm thick and a final layer of silicate-silicone precious plaster. In addition, the renovation envisages windows with wooden frames and three-layer thermal insulation glass with low-E coated and filled with Argon (U_w=0.90 [W/m^{2}K]). The floor is covered with waterproofing and 20 cm of extruded polystyrene (λ = 0.035 [W / mK]) over which the protection from PVC foil is placed, followed by cement screed and epoxy as the final layer. As the roof structure is above the heated gallery space, the installation of mineral wool (λ = 0.034 [W / mK]) in the thickness of 35 cm on the roof structure was planned and carried out. Table 3.

Table 3. U-values of characteristic elements of the facade cladding - an improved solution, Source: author's analysis

Construction element	**A [m ^{2}]**	**U [W/m ^{2} K]**	**U_{max} [W/m ^{2} K]**
Façade wall on ground floor	427.66	0.12	0.30
Façade wall on the gallery	311.93	0.07	0.30
Windows	137.86	0.90	1.60
Floor	392.06	0.16	0.30
Roof	529.23	0.08	0.20

An improved solution has changed the geometric characteristics of the building. The research was conducted with properly resolved thermal bridges and sealing with the help of RAL window installation, so the expected airflow was reduced to the volume of heated air, with a pressure difference between indoor and outdoor air of 50 Pa was estimated atn_{50} = 1.00 h^{-1} Table 4. According to the improved solution, it was noticed that the usable area per child is small, and in the improved solution, it was kept with a minimum area of 2.75 m^2 per child, and for groups from 3 to 6 years, the usable area per child is 3.3 m^2. The estimated total capacity is 120 children. In addition to increasing the accommodation capacity, additional rooms have been organized on the upgraded gallery, such as the administration office, meeting and presentation room, and storage.

Table 4. Geometric characteristics of the improved solution – improved renovation

The envelope surface of the heated part of the building	A [m^2]	1814.07
The volume of the heated part of the building	Ve [m^3]	2946.00
Heated air volume	V [m^3]	2238.96
Shape factor - A/V ratio	-	0.62
The useful floor area of the heated part of the building	A [m^2]	624.04
Windows factor	%	22.09
Number of air changes at a pressure difference of 50 Pa	n_{50} [h^{-1}]	1.00

According to the improved solution, the building met the prescribed U-values and the transmission loss coefficient per unit of the heated part of the building. Annual energy need for heating per unit of usable area of the heated part of the building $Q''_{H,nd}$ amounts 27.93 kWh/(m^2a), which according to [37] reaches the permitted energy class B for buildings for education and culture, as well as for all other offered categories of buildings.

With an improved solution, a canopy was designed to improve protection from the summer sun, which also served as a carrier for photovoltaic panels. The projected production of energy from renewable sources is 45.41%, and the consumption of primary energy per unit of usable area of the heated part of the building is 41.30 kWh/m^2a.

4. ENERGY AND ECONOMIC ANALYSIS OF THE RENOVATION OF THE KINDERGARTEN IN BANJA LUKA

In the comparative presentation, we see that by improving the geometric characteristics, i.e., appropriate upgrades, the usable area of the building can be increased by about 64%. At the same time, the amount of annual energy need for heating is reduced by about 70%. The energy need for cooling has been reduced by almost 50% by introducing external blinds on the windows and creating a canopy in the south as protection from the sun.

At nZEB Croatia, it is necessary to meet the conditions that for new buildings at least 30%, and for reconstructed / significantly renovated, 10% of the annual energy delivered for the operation of technical systems in the building is provided from renewable energy sources. As the design solution uses the same technical heating and cooling systems as the improved one, it reduced the total delivered energy to 38.11 [kWh/m^2a], and primary energy on 61.51 [kWh/(m^2a)], which also indicates a very energy-efficient building, Table 5.

Table 5. Comparative presentation of geometric and energy characteristics of the designed and improved solution for the renovation of the kindergarten

	DESIGNED	IMPROVED
The envelope surface of the heated part of the building	A = 1426.33 [m ^{2}]	A = 1814.07 [m ^{2}]
Volume of the heated part of the building	V_e = 1800.10 [m ^{3}]	V_e = 2946.00 [m ^{3}]
Shape factor - A/V ratio	f_o = 0.79 [m $^{-1}$]	f_o = 0.62 [m $^{-1}$]
Useful area of the heated part of the building	A_k = 397.08 [m ^{2}]	A_k = 624.04 [m ^{2}]
Annual energy need for heating	$Q_{H,nd}$ = 39335.57 [kWh/a]	$Q_{H,nd}$ = 17431.69 [kWh/a]
Annual energy need for heating per unit of usable area	$Q''_{H,nd}$ = 91.88 (max = 81.77) [kWh/m^{2}a]	$Q''_{H,nd}$ = 27.93 (max = 72.90) [kWh/m^{2}a]
Annual energy need for cooling	$Q_{C,nd}$ = 9821.03 [kWh/a]	$Q_{C,nd}$ = 10263.49 [kWh/a]
Annual energy need for cooling per unit of usable area	$Q_{C,nd}$ = 25.47 [kWh/m^{2}a]	$Q_{C,nd}$ = 16.45 [kWh/m ^{2} a]
Total energy delivered	E_{del} = 14942.37 [kWh/a]	E_{del} = 9204.57 [kWh/a]
Annual delivered energy per unit of usable area	E''_{del} = 38.11 [kWh/m^{2}a]	E''_{del} = 14.75 [kWh/m^{2}a]
Total primary energy	E_{prim} = 24116.99 [kWh/a]	E_{prim} = 25772.79 [kWh/a]
Total primary energy per unit of usable area	E''_{prim} = 61.51 (max = 90.00) [kWh/m^{2}a]	E''_{prim} = 41.30 (max = 55.00) [kWh/m^{2}a]
Coefficient of transmission heat loss per unit of heated part of the building	$H'_{tr,adj}$ = 0.44 (max = 0.50) [W/m^{2}K]	$H'_{tr,adj}$ = 0.20 (max = 0.54) [W/m^{2}K]

The use of photovoltaic cells in the improved solution created a difference in the delivered energy being greater than 60% and about 33% in the total primary energy compared to the designed solution. In addition, the nZEB of Croatia and Slovenia has the highest permitted annual primary energy per unit of usable area of the heated part of the building E_{prim} = 55.00 [kWh/(m^{2}a)], and an improved solution with 41.30 [kWh/m^{2}a] satisfies the stated condition of the nZEB in the neighboring countries of the European Union.

Economic analysis based on current electricity prices (0.1229 BAM), being one of the lowest in Europe, indicates the cost-effectiveness of the improved, i.e., nZEB solution. The initial investment of the improved solution is 20% higher, while the delivered energy is 38% lower, Table 6.

Table 6. Comparative presentation of parameters that affect the economic analysis of the designed and improved solution for kindergarten renovation

	DESIGNED	IMPROVED	DIFFERENCE
E_{del} [kWh/a]	14942.37	9204.57	5737.80
Total price (according to 0.1229 KM / kWh) in BAM	1836.41	1131.21	705.20
Total capacity	86	120	34
Total price of the stay (according to 165 KM / child / month)	170280.00	237600.00	67320.00
Initial investment	555139.39	697977.86	142838.57

The cost-effectiveness of the difference between the initial investment in designed and improved building renovation solutions is estimated at three years and eight months. In addition to energy savings, increasing the capacity of the number of users is also taken into account.

5. CONCLUSION

Regulations in Bosnia and Herzegovina have to undergo major changes, as energy efficiency indicators are not well set. The minimum energy performance requirements used for the representative kindergartens show that it is impossible to reach the energy need for heating of reference class C ($Q_{H, nd} \leq 65$ kWh/m^{2}a) as defined for residential buildings or buildings for education and culture. This research proved that kindergartens must be introduced as a special category of buildings with very low average U-values achieved (U_{wall} =0.23 W/m^{2}K, U_w=1.10 W/m^{2}K, U_{floor}=0.32 W/m^{2}K, and U_{roof}=0.17 W/m^{2}K), and a shape factor of 0.79, achieved the energy need for heating Q" $_{H,nd}$ = 91.88 kWh/m^{2}a should be in energy class between B and C.

It was once again confirmed that the recommended EP indicator ($Q_{H, nd}$ - energy need for heating) for the permitted energy class C for kindergartens should be between 70.00 kWh/m^{2}a ≤EP < 150.00 kWh/m^{2}a [20].

NZEB standard for buildings in the kindergartens' category requires lower heat transfer coefficients than prescribed by the current Rulebook. In addition, research has shown that in addition to the U-values, the sealing of the building and the building shape factor are very important. To achieve the value of the energy need for heating at the nZEB standard below 25 kWh/m^2 (a requirement in Slovenia), U-values must correspond to the passive standard (below approx 0.1 W/m^{2}K), the envelope must be well sealed (n_{50} = 1.00 h^{-1}) and the shape factor must be below 0.60 [m $^{-1}$]. To reach the value of the energy need for heating at the nZEB standard between 50-70 kWh/m^2, following other research in this field, it is enough that the U-values reach the current Rulebook, that the casing is well sealed (below n_{50} = 1.50 h^{-1}) and that the shape factor is below 0.77 [m $^{-1}$].

Since the requirement for primary energy is not defined in B&H, and knowing that most countries have introduced in their national legislation that nZEB represents about 25-50% less primary energy than needed, the renovation of the building followed Croatian regulations. According to Croatian regulations, in both cases (designed E "prim = 61.51 [kWh/m^{2}a]) and improved (E" prim = 41.30 [kWh/m^{2}a]), kindergarten solutions in the subject area had designed technical systems that generate very low primary energy values.

Although the improved solution is nZEB and such a standard requires primary energy per unit of usable area of the heated part of the building E"$_{prim}$ = 55.00 [kWh/m^{2}a], the solution is less primary energy than required. Although an example of renovation/reconstruction of kindergartens using renewable materials, extending to the latest strategy of renovation of EU buildings, the improved solution exceeded the requirements of the Croatian nZEB for new buildings in delivered energy for technical systems in buildings with renewable energy.

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