Impact of U-Values in Evaluation of Implemented Energy Efficiency Measures and Energy Savings in Public Buildings in Context of Kosovo Legislation

KRESHNIK MUHAXHERI, BLETA BERISHA MUHAXHERI
Department of Energy Efficiency,
University for Business and Technology,
Magjistralja Prishtine - Ferizaj - Rrethi te QMI, Prishtina,
KOSOVO

Abstract: - The purpose of this paper is to articulate the immediate need for review and improvement of Kosovo Building Regulations and Codes in the field of implementation of EE measures and specifically reducing U-values for all building envelope elements, to be comparable to European Standards, and present a specific contribution for EE measures in public building stock in Kosovo as the real potential for huge energy savings.

In this paper the results of the several years' long research on the impact of implemented energy efficiency measures in the 70 selected public buildings are presented, in light of calculated U-values with a brief description of the constituent elements of the building envelope and their corresponding U-values, such as external walls, windows, doors, floors and roofs, comparing their impact in the phases before and after the implementation of Energy Efficiency measures.

A building designed to use the minimum quantity of thermal energy for heating and cooling to achieve a healthy environment and thermal comfort is considered an Energy Efficient building. The U-values of the building envelope are the dominant factors in its thermal performance and play an important role in reducing the energy consumption of buildings. Many studies confirm that in cold climates, from the total annual energy consumption for heating and air conditioning of public buildings, approximately 50% of the energy is consumed through the heat transmission of the building envelope.

The achieved results after implementation of EE measures have shown significant improvement of U-values for both opaque parts of building envelope and belonging fenestration compared with the referent values set in Kosovo Technical Regulation which is actually in use for designers in Kosovo.

Depending on wall thickness and installed insulation achieved, results of U-values for external walls were 0.31-0.35 W/m^{2}K, much lower than recommended in old technical Regulations, lower than recommended by ANA_IAE, but still higher than values from Finish and Norwegian building codes. Calculations have shown that in the case of implementation of improved U-values according to the Finish building code the impact of walls on U-values in overall energy savings is around 36.86%.

Windows and doors look the sensitive part of the building envelope and show that it is more than the required strengthening of requirements in future Kosovo Building code reducing the U-values for doors and windows at 0.8 W/m^{2}K. Analysis has shown huge improvement and potential increase of energy savings with 55.25 % for part of fenestration.

Detailed analysis of the collected U-values data for roofs has shown that there is sufficient space for improvements in Building codes and it is a highly recommended change of existing criteria and at least application of the values from EU building codes. With this change, potential energy savings in part of roof covers might be 44.24%.

Working as an EE expert in Kosovo Energy Efficiency Agency (KEEA) and World Bank (WB) and European Union (EU) projects, the author has identified the necessity of improvement of actual Kosovo legislation in the field of EE policies for public buildings, addressing the importance of the appropriate building envelope's thermal insulation to reduce its thermal losses and stipulating the impact of the U-values in the evaluation of implemented energy efficiency measures and energy savings in public buildings.

The overall energy savings with applied EE measures and potential energy savings in case of improvements of Kosovo Technical Regulation according to recommended standards and EU countries' experiences are presented in a separate table showing economic net savings, an average payback period and overall potential reductions of CO_2 emissions.

The presented results indicate a recommendation for further studies that may include other building typologies and may disclose additional differences between the energy performance criteria in the analysed building codes.

Key-Words: - U-values, building codes, public buildings, EE measures, energy savings.

Received: August 25, 2022. Revised: September 2, 2022. Accepted: September 10, 2022. Available online: September 28, 2022.

1 Introduction

This paper aims the review the results of achieved U-values of building envelope and fenestration after implementation of EE measures and to compare with actual regulation and codes and standards as well [1,3,27,28]. Moreover, the overall energy savings with applied EE measures and potential energy savings in case of improvements of U-values in the future Kosovo Technical Regulation, according to recommended standards and EU countries' experiences, are presented in a separate table showing economic net savings, an average of payback period and overall potential reductions of CO_2 emissions.

In Kosovo, as in most other countries, the energy with which the buildings are supplied as well as the activities in them, constitute an important part of the total energy consumption. According to the Energy Balance published by the Ministry for Economic Development, the primary energy supplied in Kosovo was 2,524.32 ktoe for 2020, which represents an increase of 15.6% compared to 2010 [30]. The final energy consumption for 2020 was 1,441.5 ktoe. In many cases, this means an increase of 30% in total fossil fuel consumption and almost 50% in total electricity consumption.

From this overall consumption, more than 50% is needed for covering thermal losses through building and the use of building materials with low significantly reduces the inefficient use of energy keeping the required level of thermal comfort [4].

The inefficient use of energy is one of the main concerns not only for Kosovo but for the region as a whole. Primary energy consumption per unit of GDP (GDP-Gross Domestic Product) is significantly higher than in EU countries (13 times higher than in Germany, 10 times higher than in France) [WB Statistics].

During the post-war years, Kosovo has made attempts to regulate the legal framework in the field of Energy Efficiency, starting with the Law on Energy No. 2004/8 in 2004. Later continued with the Law on Electricity No. 03/L201, Law on the Energy Regulator No. 03/L-185 and Law on Energy No. 03/L-184 which replaced the old version of the same Law from 2004! Law no. 06/L-079 establishes the legal framework necessary to promote and improve energy efficiency in Kosovo with the aim of defining energy efficiency targets and achieving these targets through the implementation of energy efficiency measures. Moreover, this Law is supposed to be accompanied by EE plans, national strategies, national objectives, targets and policy measures in the field of energy efficiency.

As a result of close cooperation with the former Ministry of Environmental and Spatial Planning (MESP) author worked in the transposition of EU Directive 2010/31/EU on Energy Performance in Buildings Kosovo, in 2016 issued Law no. 05/L-101 on Energy Performance in Buildings. This important Law is partly in accordance with Directive no. 2010/31/EU on the Energy Performance of Buildings; Directive 2012/27/EU of the European Parliament and the Council on Energy Efficiency According to the obligations of the law, the Ministry has drafted and enforced several regulations and codes for the implementation of the EPB law.

Taking into account that since 2021, all new buildings must be nearly zero-energy buildings (NZEB) and since 2019, all new public buildings should be NZEB [7,20,21,25], this indicates the need for significant review and amending of actual Kosovo legislation and accompanying regulations which can lead to benchmarking and improvement of the U-values as impacting factor in the evaluation of EEM and energy savings in public buildings [29].

The basis of this study is the WB and EU-funded projects of implementation of Energy Efficiency Measures in public buildings in Kosovo, which since 2012 has involved the energy-efficient refurbishment of 70 public buildings across Kosovo (administrative buildings, schools and hospitals). The purpose of this investment was to encourage more effective use of energy across Kosovo with the major goal to implement energy efficiency improvement in public buildings and the verification of energy cost savings [1,13].

The detailed review of all U-values of building envelope elements in light of actual EU standards and recommended criteria from the developed countries has shown great potential for energy savings and CO_2 reduction. [8,9,10,11]

Some studies recommend doing comparisons of building energy performance criteria which may facilitate benchmarking of such criteria [6]. For example, benchmarking of Energy Performance of Buildings Directive applications in different countries, or issuing the new version of a national building code and/or regulation, comparing it with its older regulations and codes versions, as is the case in Kosovo.

Old Technical Regulation on Thermal Energy Saving and Thermal Protection in Buildings issued in 2009[18], regulates technical requirements for thermal energy saving and thermal protection, and U-values for envelope components. Requirements relate to both new building projects, and existing buildings adoption and reconstruction projects with internal heating temperatures of more than 12ºC. Despite all the shortcomings, this Regulation with few improvements [31] is still in force and frequently used by designers. Knowing that building codes and regulations are considered to be an effective policy tool to reduce energy use in buildings [6,20,21,22], this significantly increases the need for regulation of building codes adopting experiences from neighbouring countries and similar climates in European countries. Having in mind the actual energetical situation in Kosovo and worldwide, and the booming construction industry in Kosovo, improving the energy efficiency of the public buildings and in general building stock is highly impacted by a variety of legislative measures and improvement of actual legislation and building codes in the field of energy efficiency. This improvement can have a powerful economic and social impact.

2 Results and Discussions

Since 2016 Kosovo is attempting to establish legislation and required regulations [32], with provisions for the energy performance of the buildings with a further goal to reach nearly zero energy consumption building [24,25,26]. To achieve the goal and fulfil the requirements of the European legislation [20,21,22] a further attempt should be focused on interventions in codes such as lower U value limits in the opaque building elements of the building envelope and fenestration [2].

The transmission of heat from the exterior to the interior is one of the main mechanisms used for the calculation of heat losses of all audited buildings [5]. Understanding the energy performance of the building envelope was crucial for determining the amount of energy that was required for heating and energy savings. Therefore, once the building was characterized, the heat transfer through the main materials along the outer perimeter was calculated for all building opaque envelopes and fenestration.

The unit for determining heat losses through the materials of the building envelope elements defined in this paper as the U-value is used during the project analysis as a criterion for determining the energy performance of buildings. The U-value determines how well an element of the building envelope conducts heat from one side to the other, or how much heat is lost through a given element of the building envelope. These values are deterministic standards used in building codes to specify minimum Energy Efficiency values for walls, windows, doors, floors and roofs as building envelope elements. The U-values also determine the energy efficiency of the materials in a component or part of the building. A low U-value defines high energy efficiency. Combined, windows, doors, walls and roofs can absorb or lose heat and, as a result, energy consumption for cooling or heating increases. For this reason, the minimum values for achieving the energy efficiency of these components of the building envelope should be set and harmonized in the future revised building codes, to be comparable with Energy Performance of Buildings Directive (EPBD) recommendations.

Analysis of the energy consumption for all 70 public buildings before and after implementation of EE measures is done including potential net energy savings in case of improvement of building envelopes U-values. Based on these results are recalculated economic net savings and overall reductions of CO_2 emissions.

The required energy for heating in the winter period, needed to maintain the designed temperature difference to fulfil comfort criteria, can be calculated by the following equation:

$$P = \Delta T \cdot \sum U_{\mathrm{i}} S_{\mathrm{i}}$$

Where is:

ΔT temperature difference between inner and outer environment

U thermal transmittance for specific envelope element

S calculated area

The given equation, of course, is an approximation, because the temperature difference between the starting point and ending point gives a difference in form of sensible heat, stored in building materials [10,12,13,14].

Table 1. Results of implemented EE Measures

OVERALL RECAPITULATION		
Energy consumption before implementation of EE measures	51,248,451	kWh /year
Energy consumption after implementation of EE measures	33,429,687	kWh /year
Net energy savings after EE measures	17,818,764	kWh /year
Potential Net energy savings- U values in future Regulation	10,110,367	kWh /year
Potential Overall Net energy savings-after EE measures and applied new regulation	27,929,131	kWh /year
Economic net savings	18,064,136	€
Net savings	5,161,182	€/year
Investments in EE measures	18,680,487	€
Overall potential reductions of CO_2 emissions	20,303	[ton CO_2/year]
Average payback period/total investments	3.5	years

With possible improvements of Kosovo Technical Regulation related to the decreasing of U-values for all opaque building envelope elements and fenestration as well, by EU standards and EU countries regulations surveyed public buildings in Kosovo will reduce overall energy consumption by an additional 10,110,367 kWh/year which means an improvement from 56,74%.

In the continuation of this chapter, the results of measurements and calculations of U-values for each separate element of the building envelope before and after the implementation of Energy Efficiency (EE) measures will be presented, as well as discussed and presented in relevant tables and diagrams [1,15,16,17]. Moreover, a brief description of the constituent elements of the building envelope and their corresponding U-values, such as external walls, windows, doors, floors and roofs, is given, comparing their impact in the phases before and after the implementation of EE measures.

For comparison, U-values extracted from the two different countries' building codes, Finland and Norway, [6], were used and presented in various diagrams, while their impact on the reduction of energy consumption is calculated based on the recommendation of the Finish code compared with the Kosovo Technical Regulation.

Comparing the energy performance criteria used in different national building codes may provide opportunities to learn from different strategies for improving building energy performance and may facilitate actions towards such harmonization of Kosovo national codes.

2.1 External Walls

The most important element of the structure of the building must undoubtedly be the external wall. The external wall must be structurally strong, stable and durable, resistant to climatic conditions and humidity, heat transfer and the impact of sound from the external environment [2,9,13].

The main purpose of using energy efficiency measures in selected public facilities was part of the strategy proposed by Kosovo Government institutions, as a general solution to the problems related to the use of conventional energy in buildings. For this purpose, the author has systematically analysed the different constructions of external walls, identifying their U-values and comparing them with the values recommended in the Technical Regulation on Thermal Energy Saving and Thermal Protection in Buildings of the Republic of Kosovo (TRTES) [18,31] and those recommended by the International Energy Agency (ANE-IAE) for the best performance of buildings, as well the U-values extracted from the three different countries building codes, Finland and Norway[6].

For the selected 17 public buildings located in Pristina, the U-values of the walls before the implementation of the measures are spread over a wide range from 0.45W/m^{2}K to 3.63 W/m^{2}K, while the worst case was in the Technical Faculty in Pristina. A wall with the lowest U-value was identified in the newly reconstructed hospital building, so in that building and a few others, there were no further interventions on the external walls since the U-values were within the framework of the planned values.

After the implementation of the EE measures, the U-values have changed inherently way and with this, the consumption of thermal energy has also been proportionally reduced. U-values after measures have reached levels from 0.25W/m^{2}K to 0.57 W/m^{2}K, which are again lower values than recommended (0.60 W/m^{2}K) by ANA_IAE (The Eurima Ecofys VII study 2007), but lowest U-values very similar to Finish building code at 0.220 W/m^{2}K, and higher than Norwegian building code at 0.180 W/m^{2}K.

Table 2. Structure of the external walls of public buildings

EXTERNAL WALL TYPES AND THEIR THICKNESS								
External wall type	Thick clay blocks, plastered - without thermal insulation	with plastered blocks, insulated with perlit of 4cm	multi-layered, brick facades and eternite tiles containing asbestos, inside plasterboard	with blocks and plastering- without thermal insulation	with multi-layered clay blocks, EPS and plastering on both sides	of concrete, without plastering and without insulation	thin from solid bricks, facade bricks, plastered on both sides	Total
Number of buildings	4	2	2	5	1	2	1	17
Wall thickness	25-30 cm	25-30 cm	38 cm	25 cm	38 cm	25 cm	38 cm	

The analysis of the construction structure of the external walls shows that they also depended on the construction period. For the 25 schools with solid brick walls built in the period 1950-1980, the U-values before implementation of EE measures were between 1.12 W/m^{2}K, for only a few schools with external walls of 50 cm thickness, till 1.37 W/m^{2}K, for most of these schools with the thickness of the outer walls of 38cm. After the implementation of the measures, the walls in these schools have reached values between 0.31-0.33 W/m^{2}K, lower than recommended by ANA_IAE, but still higher than values from Finish and Norwegian building codes.

Our analysis has shown that in case of implementation of improved U-values according to the Finish building code the impact of walls U-values on overall energy savings is around 36.86%.

The U-values identified before the EE measures implementation for the other 26 schools, built with external walls from perforated blocks, of 25 cm thickness, without thermal insulation, built in the period 1980-2004, have values from 1.80 W/m^{2}K in most cases, and up to 1.92 W/m^{2}K, in rare cases, when the walls have been plastered. After the implementation of EE measures in these buildings, the U-values of the external walls were in most cases around 0.35 W/m^{2}K. In the two schools in which the external walls were previously reconstructed, the U-values calculated with the thickness of the insulation placed reached the values of 0.35 W/m^{2}K, therefore the intervention was not foreseen.

The following diagram in Fig.1, presents the average values identified before and after the implementation of EE measures.

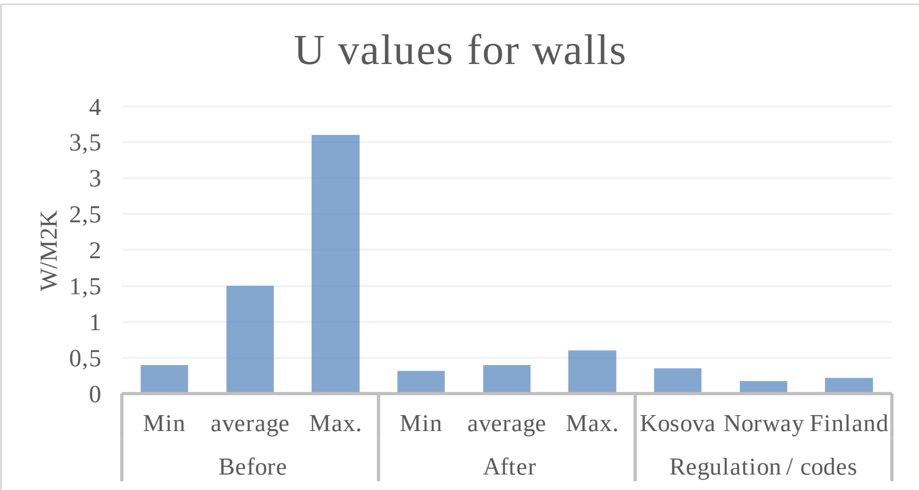

Fig. 1: U-values for external walls of public buildings compared with standards and codes

It is characteristic that on the external walls with a thickness of 50 cm, no big differences were observed in the achieved U-values (0.31-0.35 W/m^2K), compared to the external walls with a thickness of 38 cm and 25 cm, since the same thickness of thermal insulation of 8 cm, was installed. This articulates the need to optimize the thickness of the thermal insulation, depending on the type and thickness of the external wall.

Another factor that has been identified during the implementation of EE measures is the avoidance of thermal bridges to achieve the correct U-values after the implementation of the EE measures. This has been achieved through the complete insulation of the vertical facades, including the elements of pillars and beams, architraves and elements around doors and windows, balconies, consoles and other critical building elements. It was found that the transitions from the facade to the roofs were a critical part that should be treated with care.

In the following Fig.2 are given U-values for external walls for all buildings before and after the implementation of the EE measures.

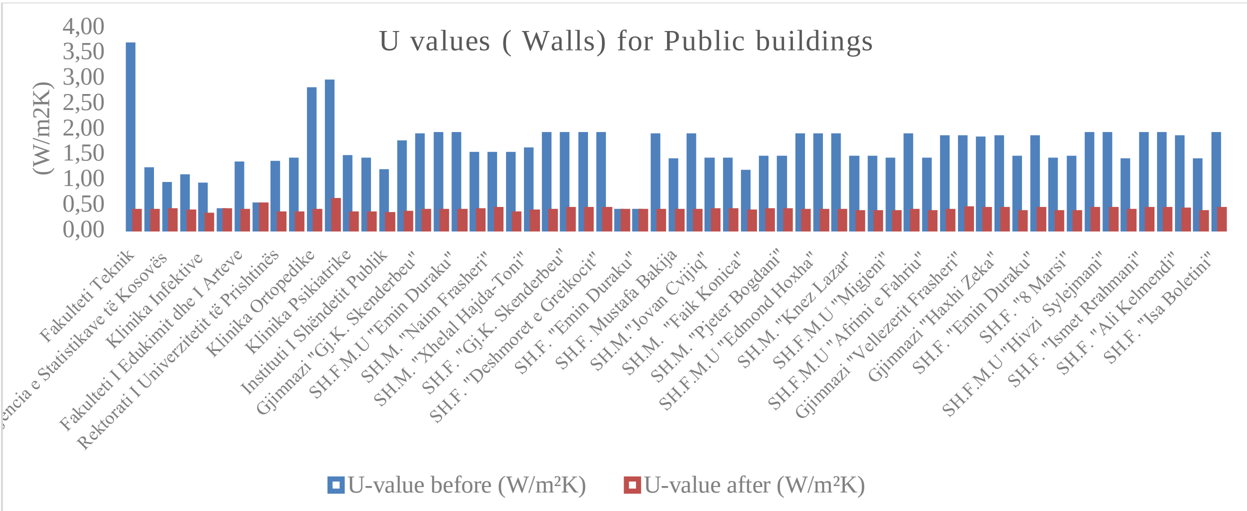

Fig. 2: U-values for external walls for all analysed public buildings before and after EE measure

2.2 Windows

In many of studies of the impact of energy efficiency measures in public buildings and their energy requirements have been treated as a black box, leaving room for architects and engineers to act on improvements [2,9,11]. The role of the window is not explicitly specified, but the treatment was holistic and integrated as a combined effect of energy efficiency measures in the building envelope, such as higher levels of thermal insulation, better windows and better sealing, high-quality spacers, heat recovery from flue gases, etc. In separate studies, the importance and role of windows in public buildings have been addressed [9]. It has been found that the cooling energy needs in the summer period are influenced by the glazing size, orientation, ventilation rate, internal thermal load and light penetration. On the other hand, heating requirements are mainly influenced by the degree of ventilation, climatic zone, orientation and type of glazing.

However, the annual heating is mainly influenced by the windows' U-values and not only by the solar transmittance. Thermal comfort is largely influenced by glazing [23]. In the summer season, the size of the glazing and the transmittance of solar energy are important parameters, while the size of the glazing and the U-value are important for the thermal loads in the winter season. With this motivation, the author has approached the detailed analysis of all types of windows in the treated public buildings and the possibility of intervention within the EE measures, not forgetting the need for significant revision of the current regulation and codes.

The window U-values highly depend on the characteristics of the frame, glazing and their current condition. The standard window U-value calculation includes the average U-value of the glass (window frame value (U_f), and the linear transmittance due to the combined thermal effect of the glazing, sealant and frame (Ψg value).

The European standard EN ISO 10077-1, Part 1, defines the calculation of windows U-values based on the four components of the overall transmittance - the thermal transmittance of the glazing, of the panels, of the frame and the linear thermal transmittance of the frame and glazing connections. The reference values to compare the U-values for windows before and after the implementation of the EE measures are referred to the European standards for windows in the public sector, EU member states codes, as well as the Technical Regulation of Kosovo, mentioned above.

In the school buildings, the U-values of the windows before the implementation of EE measures varied from 2.5-5.2 W/m^{2}K; of which in 2 schools it was 2.5 W/m^{2}K, in 4 schools it was 2.8 W/m^{2}K, in 28 schools it was 3.5 W/m^{2}K, in 6 schools 3.8 W/m^{2}K, in 7 schools it was 4.0 W/m^{2}K, in 3 schools 4.5 W/m^{2}K, and in the last 4 schools it was 5.2 W/m^{2}K.

Table 3. U-values for window- before and after implementation of the EE measures and compared with standards

. Description	U-values before the EE measures [W/m^{2}K]	U-values before the EE measures [W/m2K]	U-values after the EE measures [W/m2K]	U – values according to Kosovo Technical Regulation [W/m2K]	U – values according to the 2017 Finish building code [W/m2K]	U – values according to the 2017 Norwegian building code [W/m2K]
17 public buildings in total	1.8-4.5			≤ 1.8	≤ 1.2	≤ 0.8
7-without implemented EE measures		1.8				
10- Complete new			1.4			
53 school buildings in total	2.5-5.2			≤ 1.8	≤ 1.2	≤ 0.8
4–without implemented EE measures		2.5 - 2.8				
8-complete renovation			2.2 - 2.8			
11–New and complete reparation						
30–Complete new						

The U-values of the windows after the implementation of EE measures have been substantially reduced, varying from 1.8-2.8 W/m^{2}K. In 30 schools completely new windows have been installed and in 11 others the old windows have been partially replaced with new ones with a U-value of 1.8 W/m^{2}K.

Collecting all U-values for new and repaired windows for all 70 public buildings and comparing them with the data from the Finland building code we have concluded that is more than required strengthening of requirements in future Kosovo Building code reducing the U-values for doors and windows at 0.8 W/m^{2}K. Analysis has shown room for huge improvement and potential increase of energy savings with 55.25 % for part of fenestration. The following diagram in Fig. 4 describes best the average U-values of windows of public buildings before and after implemented EE measures, compared with Kosovo Regulation and two EU states' building codes.

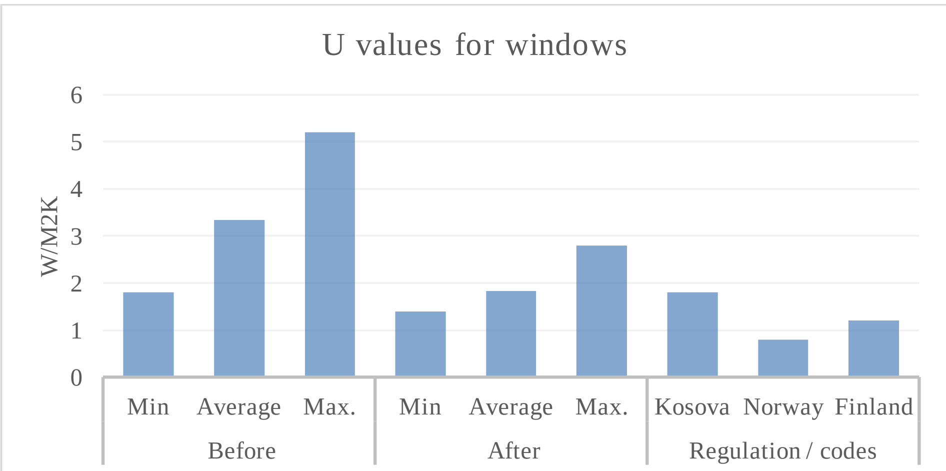

Fig. 3: U-values for windows for all analysed public buildings

2.3 Doors

As with the windows, the U-values of doors depend on the characteristics of the frame, glazing and their current condition [2,9,10,14]. The standard door U-value calculation includes the average U-value of the glazing (U_g), the U-value of the door frame (U_f), and the linear transmittance due to the combined thermal effect of the glazing, sealant, and frame (value Ψ_g).

The European standard EN ISO 10077-1, Part 1, defines the procedure of the calculation of U-values for doors based on the four components of the overall transmittance - the thermal transmittance of the glazing, of the panels, of the frame and the linear thermal transmittance of the frame joints and glazing.

The reference values to compare the U-values for doors before and after the implementation of the measures are referred to the European standards for windows in the public sector, national codes of two EU states, as well as the Technical Regulation of Kosovo, mentioned above.

In the 17 selected public buildings, the Audit Report has identified the U-values of the existing doors, which ranged between 1.8 W/m^{2}K in the three public buildings in which no intervention was planned and from 2.80 W/m^{2}K to 4.50 W/m^{2}K in the other group of buildings in which the intervention was carried out with the complete replacement of doors, replacement of glazing or door joints and handles to reach the required level of U-values < 1.8 W/m^{2}K according to the criteria of the Technical Regulation for Thermal Energy Saving of Kosovo.

In cases when the complete replacement of the doors was required, the U-value reached the level of 1.40 W/m^{2}K, lower than recommended by TRTES, but higher than Norwegian and Finish building codes, while in the facilities where there were no interventions, it remained at 2.80 W/m^{2}K, higher than recommended by Regulation as initial reference.

In school buildings, U-values for doors varied from 2.8 – 5.2 W/m^{2}K; of which 9 schools had a U-value of 2.8 W/m^{2}K, in 23 schools it was 3.5 W/m^{2}K, in 6 it was 3.8 W/m^{2}K, in 7 schools it was 4.0 W/m^{2}K, in 6 schools it was 5.0 W/m^{2}K, and in 2 schools was 5.2 W/m^{2}K.

After the implementation of the EE measures, the U-values of the doors changed a lot depending on whether the measures were implemented or not, and varied in the values of 1.8 -2.8 W/m^{2}K; of which in 47 school's new doors with a U-value of 1.8 W/m^{2}K were installed, in 3 schools there were small interventions in glazing and sealing and gloves and the U-value reached 1.8 W/m^{2}K while in 3 schools without EE measures the doors have remained as before with a U-value of 2.8 W/m^{2}K.

Table 4. U-values for doors- before and after implementation of the EE measures and compared with standards

Description	U-values before the EE measures [W/m^{2}K]	U-values before the EE measures [W/m^{2}K]	U-values after the EE measures [W/m^{2}K]	U – values according to Kosovo Technical Regulation [W/m^{2}K]	U – values according to the 2017 Finish building code [W/m^{2}K]	U – values according to the 2017 Norwegian building code [W/m^{2}K]
17 public buildings in total	1.8-4.5			≤ 1.8	≤ 1.2	≤ 0.8
3-without implemented EE measures		1.8	1.8			
1- Complete repaired		2.8	1.4			
13- Complete new		2.8	1.8			
53 school buildings in total	2.5-5.2			≤ 1.8	≤ 1.2	≤ 0.8
3–without implemented EE measures		2.8				
3-complete renovation			1.8			
30–Complete new			1.8			

The following diagram in Fig. 5 clearly describes the average U-values of doors in public buildings before and after implemented EE measures, compared with the actual Kosovo Regulation and two EU states' codes.

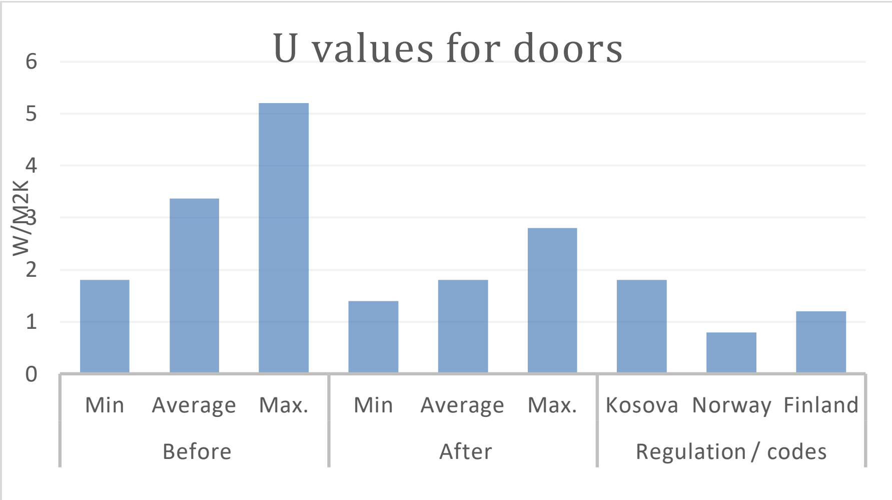

Fig. 4: U-values for doors for all analysed public buildings

2.4 Roofs

By definition, the roofs are the constructive elements of the envelope of the building which close the building from the upper part to protect it from climatic conditions - rain, snow, wind, sun, temperature changes, etc. [12]. The analysed public buildings have different constructions and based on the technical solutions, EE measures have also been proposed to reduce heat losses and reduce energy consumption.

Thermally poor, uninsulated roof constructions, have been identified in some buildings, such as sloping roofs with wooden timbers and concrete beams, without thermal insulation and leaking during rains. In some others, the flat roofs are covered with a sloping roof as a superstructure to avoid rain penetration, but in the thermal aspect, they are very weak. In hospitals, other roof structures have been identified - sloping with concrete and on the side parts, bricks with holes. The coverings of these buildings have also varied—from asbestos sheets to uninsulated metal sheets.

Table 5. Types of roof covers

Type of roof covers						
	Clay tiles	Metal sheet	Asbestos	Bitumen tiles	Flat roof	Total
Public buildings	29	26	5	2	8	70

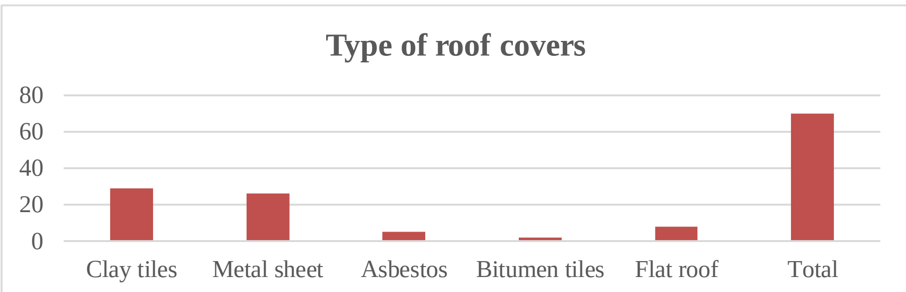

Fig. 5: Types of roof covers for all analysed public buildings

In 17 selected public buildings, different U-values of the roof constructions have been determined by the type of construction of the roof, covering, and thermal insulation has been identified and differs from the value of 0.39 W/m^{2}K for the student dormitory building, which is a new building with the pitched roof with a small slope, with thermal insulation of the thickness of 10 cm covered with a corrugated sheet, up to the value of 4.37 W/m^{2}K for the roof of the Faculty of Dentistry as a pitched roof covered with corrugated metal sheet without thermal insulation.

In school buildings, similar to findings from different studies [19], different U-values have been identified depending on the type of construction and the period of construction, and they vary from 1.1 W/m^2K for roofs with the construction plate "Avramenko", to 2.04 W/m^2K, 1.1 W/m^2K for the "Monta" construction, and values of 3.3–4.0 W/m^2K for structural concrete slabs without thermal insulation and with an average U-value for school roofs of 2.6 W/m^2K.

Based on the recommendations from the Kosovo Technical Regulation, the buildings were designed so, that the U-value of the roofs after the implementation of the EE measures should be <0.7 W/m^2K! In all public buildings, this objective has been achieved, moreover, in 17 public buildings, it reaches the lowest value of 0.36 W/m^2K for reconstructed objects and up to 0.60 W/m^2K for the roofs without EE measures.

After the implementation of EE measures in most of the school buildings, the U-value has been improved up to 0.2 W/m^2K, except in cases where the roofs have met the criteria according to the Kosovo Technical Regulation. The table below shows significant differences between some achieved U values after implementation of EE measures and recommended U values by Technical Regulation, and is very similar to the U values from EU states' building codes. This indicates the necessity for improving the building codes impacting directly buildings' energy efficiency. The achieved U-values after a complete renovation and/or for new roof constructions were between 0.17-0.2 W/m^2K, much lower than recommended by Kosovo Technical Regulation and very similar to Finish and Norwegian Building Codes.

Table 6. U-values for roofs- before and after implementation of the EE measures and compared with standards

Description	U-values before the EE measures [W/m^2K]	U-values before the EE measures [W/m^2K]	U-values after the EE measures [W/m^2K]	U – values according to Kosovo Technical Regulation [W/m^2K]	U – values according to the 2017 Finish building code [W/m^2K]	U – values according to the 2017 Norwegian building code [W/m^2K]
17 public buildings in total	1.47-4.37			≤ 0.7	≤ 0.18	≤ 0.13
3-without implemented EE measures		0.39-0.60	0.39-0.60			
14- Completely repaired	1.47-4.37		0.20			
53 school buildings in total	0.4-3.80			≤ 0.7	≤ 0.18	≤ 0.13
3–without implemented EE measures		0.4-0.5	0.4-0.5			
43-complete renovation			0.17			
30–Complete new			0.20			

Through detailed analysis of the collected U-values data for roofs in all 70 public buildings, these new and partially repaired, we have concluded that there is sufficient space for improvements and it is a highly recommended change of existing criteria and at least application of the values from Finish building code. With this change, potential energy savings in part of roof covers might be 44.24%.

The following diagram in Fig. 6 clearly describes the average U-values of roofs in public buildings before and after implemented EE measures, compared with Kosovo Regulation and two EU states' codes [6,10,17,18].

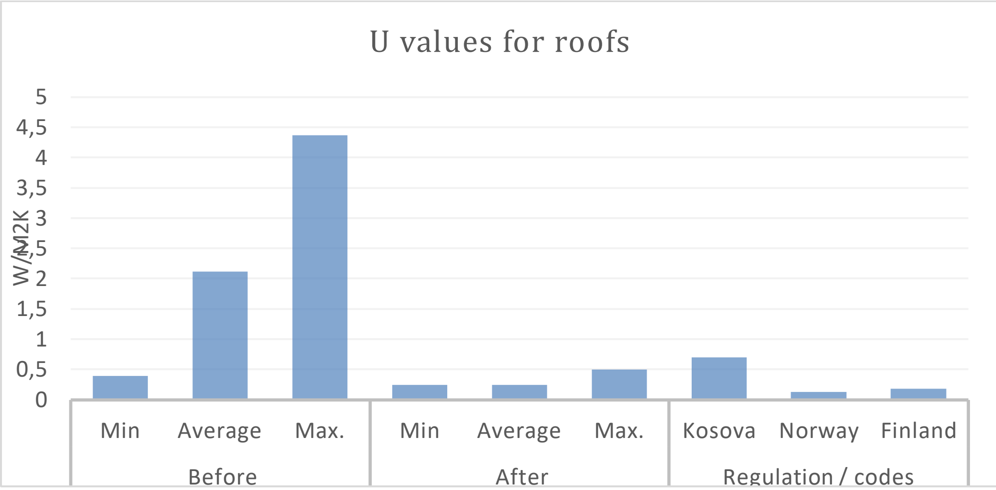

Fig. 6: U-values for roofs for all analysed public buildings

2.5 Floors

In many of reports of the International Energy Agency and studies related to the energy performance of buildings [3,12] it is confirmed that floors as a constructive part of the building, can be a great source of energy savings as part of the building envelope. Qualitative and careful insulation of the floors in public buildings can significantly affect thermal energy savings. Floors can be designed in different ways and techniques: as concrete slabs and prefabricated slabs on typical floors, somewhere there were raised floors where cables and technical equipment are placed, and concrete floor monolith connected with walls, which is usual in basements. These types of constructions were the basis for applying the final floor layers for floors in schools and public buildings to increase their thermal performance. In schools, we found damaged wood flooring, hardwood flooring on gymnasium floors, and ceramic tiles in corridors and sanitary parts of buildings, while in public buildings situation was improved with better quality floors from laminated wood, Vinyl Composition Tiles (VCT), linoleum and sometimes even covered with carpets. The problem of humidity is a very sensitive issue that should be handled more carefully. On the floors of public buildings, significant deficiencies were observed in terms of thermal insulation and finishing materials. Despite these remarks, for financial reasons, the implementation of EE measures for floors has not been recommended for most buildings. Therefore, the U-values before and after the EE measures in most of the 17 public buildings are still far from the criteria defined by the Technical Regulation and European norms, especially compared to the codes of European countries. The weak structural details were the connections between the finishes and angles of the floors and the external vertical walls which were usually presented as thermal bridges.

The U-values in these public buildings, before the implementation of the EE measures, ranged between 0.63-0.91[W/m^{2}K], while in most of the buildings, they remained the same after the implementation of the measures and in the range between 0.55-2.91 [W/m^{2}K] even though the values of recommended according to the Kosovo Technical Regulation were <0.65 [W/m^{2}K].

In the school buildings, the U-values before EE measures, varied between 1.0 – 2.3 [W/m^{2}K], depending on the structure of the floor layers. In 25 schools, the new floor has been installed, but only in 12 of them, the thermal insulation has been extended. The U-value of these floors before the EE measures was 1.72-2.3 [W/m^{2}K], while after the implementation of the EE measures these values reached values 0.93-0.96 [W/m^{2}K].

More than 42 public buildings were left without EE measures on floors because of a lack of investments. Our internal analysis for both public buildings and schools has shown the need for both technical and economic analysis when a decision for EE measures for floor refurbishment is required. The solution should be feasible and the Finish building code is quite rigid.

Table 7. U-values for floors- before and after implementation of the EE measures and compared with standards

Description	U-values before the EE measures [W/m²K]	U-values before the EE measures [W/m²K]	U-values after the EE measures [W/m²K]	U – values according to the Kosovo Technical Regulation [W/m2K]	U – values according to the 2017 Finish building code [W/m2K]	U – values according to the 2017 Norwegian building code [W/m2K]
17 public buildings in total						
14- without implemented EE measures	0.63-2.91	0.63-2.91	0.63-2.91	≤ 0.7	≤ 0.18	≤ 0.10
2- Finalized floor with thermal insulation	1.21-2.97		0.54-0.57			
53 school buildings in total						
28-without EE measures	1.0-2.30	1.0-2.3				
13–New PVC floor without thermal insulation	2.3		2.1	≤ 0.7	≤ 0.18	≤ 0.10
7- New PVC floor with thermal insulation	1.72-2.3		0.93-0.96			

The following diagram in Fig.7 describes the average U-values of floors in public buildings before and after implemented EE measures, compared with Kosovo Regulation and two EU states' codes.

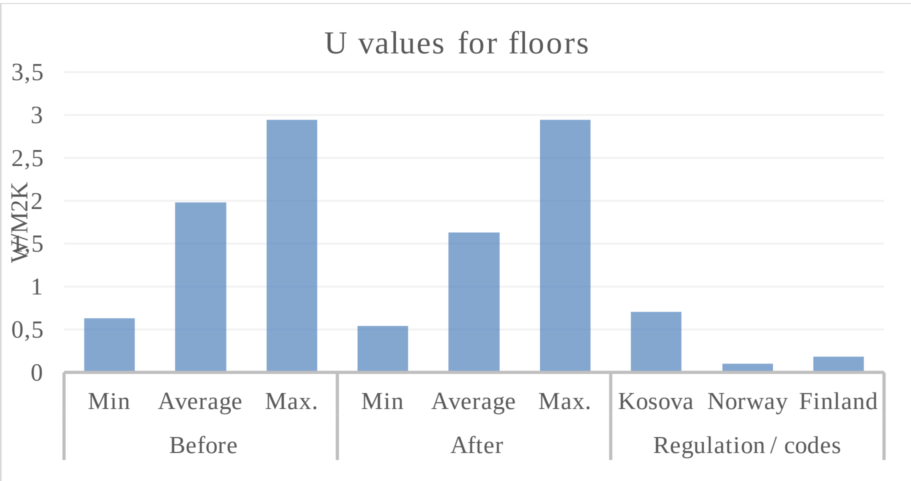

Fig. 7: U-values for floors for all analysed public buildings

3 Conclusion

Findings from this study project, undoubtedly show that, both from the early design phase and from the phase of later building main renovations, energy savings can be greatly influenced by the correct design of the building envelope and the proper selection of building envelope materials with low U values. This suggests a necessity for significant review and strengthening of actual building codes and regulations in Kosovo. This approach must be holistic, especially related to the Kosovo Technical Regulation on Thermal Energy Saving and Thermal Protection in Buildings, reviewing not only actual recommended U-values, but also new building requirements which should be in line with requirements that since 2021, all new buildings must be nearly zero-energy buildings (NZEB) and since 2019, all new public buildings should be NZEB. In this context, to produce comparable evaluation values, the standard input data for climate, building and thermal comfort should be provided in detail in future building codes.

It is confirmed that after the implementation of the EE measures, the U-values of all building envelope elements, external walls, windows, doors, roofs and floors have changed inherently way and with this, the consumption of thermal energy has also been proportionally reduced. In some cases, much lower values are reached compared with the Kosovo Technical Regulation and/or recommended values by ANA_IAE (The Eurima Ecofys VII study 2007).

Our findings suggest a potential for more demanding energy performance criteria in the Kosovo building code and regulations. To achieve this goal, it is recommended to consult building codes and regulations of neighbouring countries, because as we presented in this paper, EU countries, in our case Finnish and Norwegian building codes have relatively very strict requirements on the energy performance of the building envelope.

Achieved U-values for external walls, after implementation has changed essentially, and are close to the EU standards and much better than Kosovo Regulation, but the thickness of the thermal insulation needs to optimize depending on the type and thickness of the external wall.

U-values for windows and doors for all 70 public buildings after implementation of EE measures are compared with EU standards and we have concluded that is more than required strengthening of requirements in future Kosovo Building code reducing the U-values for doors and windows at 0.8 W/m^2K.

Although investments in the implementation of measures for roofs have been limited, we have concluded that there is sufficient space for improvements and it is a highly recommended change of existing criteria and at least application of the values from the Finish building code. With this change, potential energy savings in part of roof covers might be 44.24%.

The achieved U-values after a complete renovation and/or for new roof constructions were between 0.17-0.2 W/m2K, much lower than recommended by Kosovo Technical Regulation and very similar to Finish and Norwegian Building Codes.

Contrary to the importance of EE measures impact, the investment on public buildings floor remained the weakest part of the project, because of a lack of investments. It is highly recommended that in future studies this part of the building envelope should be seriously improved and U-values changed to be close to the EU standards.

Presented results in tables and diagrams show great potential for energy savings through the strengthening of criteria for U-values in future technical regulation and Building codes and are very useful for practical applicability for designers and building constructors. Implementation of these new criteria will significantly improve energy savings and increase construction quality reducing building system energy costs.

Decreasing the U-values in a technically and economically feasible way for all building envelope elements will significantly impact reducing of overall energy consumption in public buildings. Results from our study show an energy reduction from 56.74% for the overall consumption of 70 public buildings and schools in Kosovo, reducing proportionally CO_2 emissions through more strengthening of the building codes and in alignment with international standards.

Presented findings are done for a limited number and types of public buildings, and taking into account that we in KEEA (Kosovo Energy Efficiency Agency) and KEEF (Kosovo Energy Efficiency Fund), in recent years, have implemented EE measures in hundreds of public buildings, it is highly recommended to made new holistic studies which may include other building typologies and may disclose additional differences between the energy performance criteria in the analysed building codes.

References:

[1] Muhaxheri, K. Nepravishta, F., “Evaluation of implemented energy efficiency measures in public buildings in Kosovo “IJARET 9 volume 4, pp. 333-342, 2018

[2] E. Giama. E. Kyriaki. and A. Papadopoulos “U-Value: A Key Role Parameter for Sustainable Buildings”, JSAC 3/16, pp. 20-31, 2020

[3] B. Carlsson, A Elmroth, P.Å. “Engvall, Airtightness and thermal insulation: building design, solutions” Spanbergs Tryckerier AB, Stockholm, 1980

[4] D. Holm F.A. Engelbrecht, “Practical choice of thermal comfort scale and range in naturally ventilated buildings in South Africa” South African Institution of Civil Engineering (SAICE), Volume 63, , Issue 4, pp. 11–23, 2021,

[5] L.S. Sorensen. L.S, “Heat Transmission Coefficient Measurements in Buildings Utilizing a Heat Loss Measuring Device” Sustainability, Volume 47, Pages 14, 2013

[6] I. Allard. G. Nair., T. Olofsson,, “Energy performance criteria for residential buildings: A comparison of Finnish, Norwegian, Swedish, and Russian building codes”, Energy& Buildings, 250(2021)

[7] J.Kurnitski et al., “ How to define nearly net zero energy buildings nZEB – REHVA

proposal for uniformed national implementation of EPBD recast" REHVA Journal, 2013

[8] Emmitt.S., "Barry's Introduction to Construction of Buildings", 4th Edition, Wiley-Blackwell, November 2018

[9] H. Biilow-Hiibe, Energy-Efficient Window Systems. Effects on Energy Use and Daylight in Buildings, Division of Energy and Building Design Department of Construction and Architecture Lund University Lund Institute of Technology, 2001 Report TABK--Ol/l 022, 2001

[10] *EURIMA-Ecofys* "U-values For Better Energy Performance of Buildings" VII report, pp. 1-65

[11] T. Boermans, C. Petersdorff, "U-values for Better Energy Performance of Buildings", Report established by Ecofys for EURIMA, 2007

[12] E. Abel, A. Elmroth "Building and Energy" Formas, Stockholm 2007

[13] ISBN 978-9 79-35999-6, "Technical Guidance-Financing of Energy Renovation of Buildings"- EU Commission, Final Report, Bruxelles,2014

[14] J. Ratnieks, A. Jakovics, S. Gendelis, "Wall assemblies U-value calculation in test buildings using constant power heating" Energy Procedia, Volume 147, August 2018, pp 207-213

[15] EU Commission, DG Energy "Energy performance certificates in buildings" Final Report, 2013

[16] Implementation of Energy Efficiency Measures (EEM) in schools and hospitals in Kosovo, Final Report,2016

[17] EU Commission, DG Energy, "A Guide to the Energy Efficiency Directive,2013

[18] Technical Regulation nr.03/2009 for thermal Energy savings and Building Thermal Protection

[19] BS Department for Education "Guidelines on ventilation, thermal comfort and indoor air quality in schools" Building Bulletin 101, June 2016

[20] Directive 2010/31/eu of the European Parliament and of the Council of 19 May 2010 on the Energy Performance of Buildings (recast)

[21] DIRECTIVE 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the Energy Performance of Buildings

[22] EN 13829, Thermal Performance of Buildings, ISO Energy 9972:1996, modified

[23] J.M Daisey, Indoor air quality, ventilation and health symptoms in schools, Indoor Environment Department, Lawrence Berkeley National Laboratory, 2003

[24] D.L.D Harvey, "Energy Efficiency and the Demand for Energy Services", Earthscan, Washington DC,2010

[25] P.A Torcellini, and D.B Crawley, "Understanding zero-energy buildings", ASHRAE Journal, vol.48, pp. 62-69, 2006

[26] A.K Elsadig,., "Energy Efficiency in Commercial Buildings" MSc Thesis, Faculty of Engineering, University of Strathclyde, 2005

[27] S Stankovic, "Evaluation of energy efficiency measures applied in public buildings (schools & hospitals) in Serbia, Spatium IR, pp.1-8, 2009

[28] K Johnsen, "Energy Conservation in the Built Environment"; Session 4 – Design for Low Consumption.

[29] EPEC, "Guidance on Energy Efficiency in Public Buildings",2010

[30] KEEA "Fourth Annual Report under the Energy Efficiency Directive", October 2020, Kosovo

[31] Regulation MESP no 04/2018 for minimum requirements for the Energy Performance of Buildings, GoK

[32] Law No. 05/L-101 on "Energy Performance of Buildings", Official Gazette of The Republic of Kosova / No. 42 / 22 December 2016, Pristina.

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

No funding was received for conducting this study.

Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.