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# Cost-optimal thermal transmittance and energy performance of residential buildings in various cities in Kosovo

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## Abstract

In 2018, Kosovo approved two regulations that provide information on minimum requirements for calculating energy performance of buildings, and on methodology for calculating such performance. The aim of this paper is to clarify the thermal transmittance (U-values) according to local legislation, through a building model, and to find optimal U-values by simulating more than 540 combinations of building materials in five cities in the country which, as officially stated in its regulations, has one climate zone only. The modelling and simulation were conducted using the ARCHICAD software and the EcoDesigner Star add-on.

*Key words: heating and cooling energy demand, cost-optimal levels, building energy performance, residential building, dynamic simulation*

# Optimalni troškovi energetska učinkovitost stambenih zgrada u različitim gradovima na Kosovu

## Sažetak

Kosovo je u 2018 odobrilo dva propisa koja pružaju informacije o postizanju minimalnih zahtjeva za izračunavanje energetske učinkovitosti u zgradama i metodologiji njenog izračuna. Fokus ovog rada je razjašnjenje toplinske propustljivosti (U-vrijednosti) prema lokalnom zakonodavstvu, pomoću građevinskog modela, te pronalaženje optimalnih U-vrijednosti simuliranjem više od 540 kombinacija građevinskih materijala, u pet gradova u zemlji koja u uredbama službeno ima samo jednu klimatsku zonu. Modeliranje i simulacija provedena je pomoću ARCHICAD alata i dodatka EcoDesigner Star.

*Ključne riječi: potrošnja energije na grijanju i hlađenju, optimalni troškovi, energetska učinkovitost zgrade, stambena zgrada, dinamička simulacija*

## 1 Introduction

The Energy Performance of Buildings Directive (2010/31/EU) [1] requires definition of mechanisms for the regulation and reduction of energy consumption in buildings, including their certification. Even though Kosovo was not part of the European Union at the end of 2018, it has strengthened two regulations [2, 3] that partly correspond to this directive of the European Parliament. Based on [4], the energy demand of the residential building stock in Kosovo amounts to approximately 62 % of the total electricity consumption and, compared to the same period in 2019, the amount of electricity consumed has increased by 6.4 %. The fact that the municipality of Prishtina has considerable needs with regard to heating is also emphasized by Ahmeti et al. [5]. The results show that the daily heating energy consumption demand exceeds current production capacities. Heating demand data for other cities in Kosovo can be found in [6]. Faced with high demand and consumption of electricity, Kosovo seeks to strengthen relevant regulations to achieve the minimum required energy consumption and thermal comfort in buildings at optimum cost, based both on European legislation and climate conditions prevailing in the country. Although the two above-mentioned documents define maximum allowed values of thermal transmittance (U-values) for constituent elements of buildings, their application is still unenforceable. In the absence of relevant software, national calculation methodology for energy demand requirements in buildings is also inapplicable. According to [2, 3], these U-values are determined through the cost-optimal method but, until now, we do not have an official document with parameters to be used for these calculations. In recent decades, many studies have been undertaken to define the cost-optimal level in order to determine energy demands in buildings. Corgnati at al. [7] presented a general methodology for the creation of baseline buildings. They analysed an office building as a case study and then proposed new measures for simulation. In this respect, they created four types of buildings and each building was included in calculations that were conducted in three cities in Italy. In conclusion, twelve models were presented in the dynamic energy simulation for a cost-optimal energy analysis. Based on computer simulation, Ferrara at al. [8] established the cost-optimal level for the typology of a French building involving a single family house. Furthermore, they studied the French market and found that a cost function was created for each parameter, and the global cost methodology was adopted as an objective function for optimization. The optimization and cost-optimal methodologies in buildings are also considered in [9-11]. The cost effectiveness of energy renovation also depends on the existing envelope of the building. The return on investment is longer for buildings with higher quality of envelope compared to lower quality buildings. Bajraktari et al. [12] investigated the household sector in Kosovo by addressing the issue of energy efficiency and identifying the cost–optimal solution for typical masonry houses. The results show that the 20 to 30 year return on investment for renovation is cost-effective when targeting renovation of the building envelope at an average value of ~0.2 W/m²K for the case of an existing single family masonry building.

It seems that all studies [5-12] aim to find the necessary energy demand, with the same or increased thermal comfort, through a cost-optimal procedure. Considering these studies, this research aims to compare the energy characteristics of model houses located in five cities of Kosovo in the same climate zone. The cost-optimal level and global cost analysis are determined through dynamic simulations of energy performance. Based on the EU regulation No 244/2012, cost-optimal U-values are analysed and compared with U-values according to [2, 3] in order to verify whether these parameters are achievable or whether they should be reviewed for current legislation.

## 2 Case Study: building characteristics, climatic conditions and energy evaluation

A typical local house was adopted by the design studio ArchiEDU [13] as a model for calculating physical parameters related to the heating and cooling energy demand. The baseline building contains information about the building geometry and materials currently used by Kosovar builders. This single-family house has two-storeys and a basement. It occupies a gross floor area of 267.29 m$^2$. The envelope of the existing building consists of autoclaved aerated concrete (25 cm). Approximately 43 % of the windows have the opening facing the south, while 10 % are oriented toward other directions. The window area occupies approximately 1/3 of the gross floor area. The insulation thickness at exterior walls is 9 cm, it is 8 cm on the roof, and 7 cm at the basement floor. The windows have double glazing and the space between panes is filled with argon (Ug-value is 1.5). These structural and functional parameters are in line with the legislation currently in force in Kosovo [14]. So, the baseline building or maximum U-values, were set to $U_{WALL}$: 0.35, $U_{ROOF}$: 0.3, $U_{GLAZING}$: 1.5, $U_{FLOOR}$: 0.3 [2, 3], while other 108 proposed U-value combinations were generated by combining the following U-values: $\mathbf{U_{WALL}}$ (0.15, 0.2, 0.35, 0.5), $\mathbf{U_{ROOF}}$ (0.15, 0.2, 0.3), $\mathbf{U_{GLAZING}}$ (0.6,1.1, 1.5) and $\mathbf{U_{FLOOR}}$ (0.15, 0.2, 0.3) (Figure 4). For energy performance analysis purposes, these buildings are located in various cities of Kosovo, i.e. in Prishtina, Prizren, Peja, Mitrovica and Gjilan, as shown in Figure 1. These cities lie in peripheral parts of the country and are characterized by their climatic conditions. Even though three of these cities have similar climatic conditions, the aim was to verify whether energy demand is different as a result of geographical position and differences in altitude.

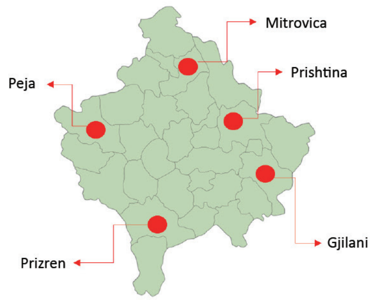


**Figure 1. Five cities where energy performance of buildings was analysed.**

Although the climate of Kosovo is mostly continental [15], the highest temperature of the country is around +29°C during the summer and the lowest around - 10°C during the winter, while average temperatures range from approximately +20°C during the summer to approximately 0°C during the winter [16]. So, all these cities have similar temperatures, but they differ by the number of sunny days throughout the year. The information about Heating and Cooling Degree Days (HDD, CDD), average solar radiation, altitudes and locations where the buildings are located, is presented in Table 1. Typical annual meteorological data are calculated using the data from the Strusoft Climate Server [17] for the five cities in Kosovo.

**Table 1. Various factors that affect heating and cooling energy demand**

| Altitude | | Latitude | Longitude | HDD | | CDD | | Avg. Solar radiation [Wh/m²] |
|---|---|---|---|---|---|---|---|---|
| **PRISHTINA** | 672 m | 42° 40’ 11.7610” | 21° 11’ 18.8732” | 3372.88 | (66 %) | 1702.38 | (34 %) | 450.44 |
| **PRIZREN** | 438 m | 42° 13’ 8.7060” | 20° 44’ 45.9312” | 3783.79 | (72 %) | 1443.57 | (28 %) | 459.00 |
| **PEJA** | 505 m | 42° 39’ 19.2312” | 20° 17’ 44.2392” | 4024.71 | (76 %) | 1276.62 | (24 %) | 459.26 |
| **MITROVICA** | 505 m | 42° 53’ 16.1520” | 20° 51’ 31.4424” | 3372.88 | (66 %) | 1702.38 | (34 %) | 450.44 |
| **GJILAN** | 501 m | 42° 27’ 42.0192” | 21° 28’ 30.9396” | 3372.88 | (66 %) | 1702.38 | (34 %) | 450.44 |

StruSoft’s software - VIPcore calculation engine integrated in ARCHICAD [18], complying with ANSI/ASHRAE Standard 140-2007 [19], was used because the energy performance could not be calculated through Kosovo national calculation methodology due to lack of relevant software. ARCHICAD with EcoDesigner STAR add-on was selected as it is considered to be a detailed simulation approach, because all parameters are related to physical specifics of the materials generated by the 3D model of the building. More approaches relating to building energy simulations can be found in [20]. All the spaces of this model house, functioning as separate areas in the ACHICAD software, were generated automatically as thermal blocks using software for the dynamic simulation of buildings, as presented in Figure 2. These thermal blocks evaluate the temperature and control the heat exchange from one area to another, thus calculating thermal bridges as well. Each thermal block provides specific information on energy performance through EcoDesigner STAR and as such is controlled and calculated separately enabling achievement of desired energy demand targets.

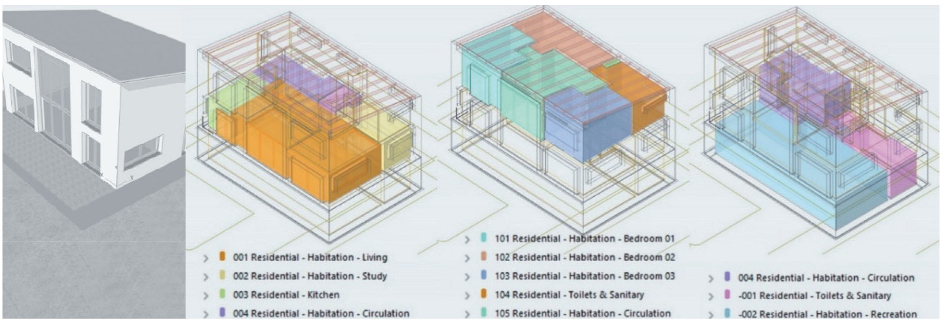


**Figure 2. Thermal blocks and their geometry**

## 3 Determination of cost-optimal levels through financial calculation

Since the regulation on the national calculation methodology [2, 3] does not specify the way in which cost-optimal levels or financial implications for different time periods should be defined, the calculation methodology was adopted based on the Guideline [21] accompanying the regulation No. 244/2012 [22]. According to [23], cost-optimal levels are defined as **"***the energy performance level which leads to the lowest cost during the estimated economic lifecycle***".** The calculation is made through the Global Cost Methodology, which is known in the regulation as "the lifecycle cost analysis". Using an appropriate financial calculation, the Global Cost analysis considers the investment itself for the period of 30 years as defined in the regulation for residential buildings. However, since the results for all cities give the same investment option, the Global Cost calculation was also conducted for a 20-year period. In this paper, various combinations of the model building envelope were tested and compared with respect to their global cost, by relating the calculations of the initial investment cost, annual cost and energy cost, to the starting year (2020) of the calculation. Global Costs were calculated by summing various types of costs and the discount rate was set to 4 %. In addition, all applicable taxes and fees were included in the calculation.
The equation of Global Cost is defined as follows:

$$C_g(\tau) = C_I + \sum_j \left[ \sum_{i=1}^{\tau} \left( C_{a,i}(j) \cdot R_d(i) \right) - V_{f,\tau}(j) \right] \quad (1)$$

$C_g(\tau)$ - global cost over the calculation period (referring to starting year $\tau_0$)
$C_I$ - initial investment costs for a measure or a set of measures j
$C_{a,I}$ (j) - annual cost during year i for a measure or a set of measures j
$V_{f,\tau}$ (j) - residual value of a measure or a set of measures j at the end of calculation period (discounted to the starting year $\tau_0$).
$R_d$ (i) - discount factor for year i based on discount rate r to be calculated

Current prices for materials and construction, relating to measurement of the heating and cooling energy demand, are presented in Table 2. To calculate the initial investment cost, real selling prices of these construction materials are provided by two local construction companies, and average prices including VAT are taken into account. Prices for thermal insulation of building envelope, roof and floor are given per square meter, while fixed prices are given for doors and windows. These prices reflect the current situation on the market and should therefore be updated on a regular basis.

**Table 2. Prices of materials used in building envelope**

| Type | U-value [W/m²K] | Building material | Width [cm] | Qty | Unit | Price [€/m²] incl.VAT | Total price [€] | Total price (gross floor area) [€/m²] |
|---|---|---|---|---|---|---|---|---|
| Wall | 0.15 | Expanded Polystyrene (EPS) | 25 | 277.27 | m² | 26.50 | 7,347.66 | **27.49** |
| | 0.2 | | 18 | | | 19.50 | 5,406.77 | **20.23** |
| | 0.35 | | 9 | | | 10.50 | 2,911.34 | **10.89** |
| | 0.5 | | 6 | | | 9.00 | 2,495.43 | **9.34** |
| Roof | 0.15 | Mineral wool | 20 | 98.01 | m² | 66.50 | 6,517.67 | **24.38** |
| | 0.2 | | 14 | | | 50.00 | 4,900.50 | **18.33** |
| | 0.3 | | 8 | | | 34.00 | 3,332.34 | **12.47** |
| Glazing | 0.6 | Wood window, triple-glazed, argon fill, clear, low-e | | 52.68 | m² | 180 | 9,482.63 | **35.48** |
| | 1.1 | Wood window, double-glazed, argon fill, clear, low-e | | | | 150 | 7,902.20 | **29.56** |
| | 1.5 | Wood window, double-glazed, argon fill, clear | | | | 130 | 6,848.57 | **25.62** |
| Floor | 0.15 | Extruded Polystyrene (XPS) | 18 | 71.83 | m² | 22.50 | 1,616.18 | **6.05** |
| | 0.2 | | 12 | | | 16.50 | 1,185.20 | **4.43** |
| | 0.3 | | 7 | | | 10.00 | 718.30 | **2.69** |

The price of electricity is calculated based on local rates with 1 kWh costing 0.0532 EUR. In addition, a fixed monthly fee of 1.74 EUR should be added as well at the 8 % VAT. Annual costs include the sum of all costs for each year and the final value. Replacement and maintenance costs are not considered because their lifetime is assumed to be equal to the calculation period.

## 4 Results and discussion

Five cities in Kosovo with the same climate have been selected for analysis in this paper. The case study involves comparison between baseline buildings and their envelope properties. The energy of the model building was simulated using the EcoDesigner STAR software. The heating and cooling energy demand of the baseline building is presented in Figure 3 for each of the five cities. This demand varies from 23.97 kWh/m$^2$a to 32.70 kWh/m$^2$a for heating and from 35.75 kWh/m$^2$a to 47.13 kWh/m$^2$a for cooling. Therefore, the demand for cooling is higher than that for heating. However, it is interesting to note that Kosovo needs more energy for heating than for cooling. The cooling energy demand is high due to high g-value of the double pane glazing, and also because the south façade has approximately 43 % of glazed surface. Energy saving measures were established by comparing the model of the house using various performances of its envelope, taking into account the heating and cooling energy demand only.

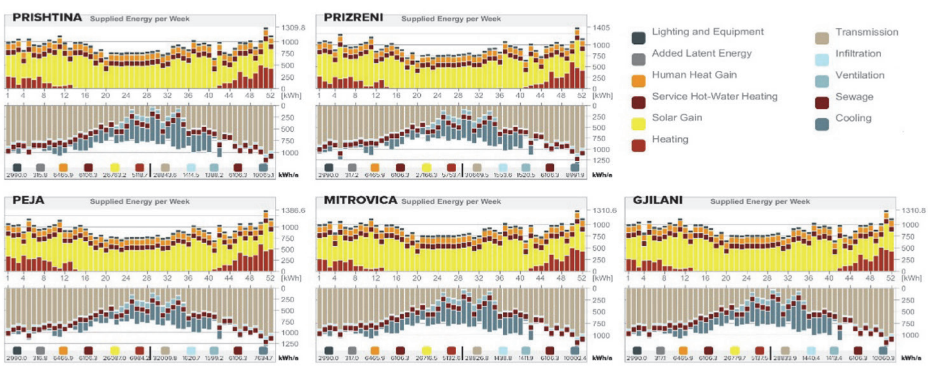


**Figure 3. Energy balances presented via EcoDesigner STAR**

After many simulations between U-value combinations, the cities with small heating and cooling energy demand differences have been identified. This curve shows linearity for all cities but with a difference of about 7.31 % for the same thermal performance. 108 combinations of U-values, and the total heating and cooling energy demand, are presented in Figure 4 for each of the analysed cities.

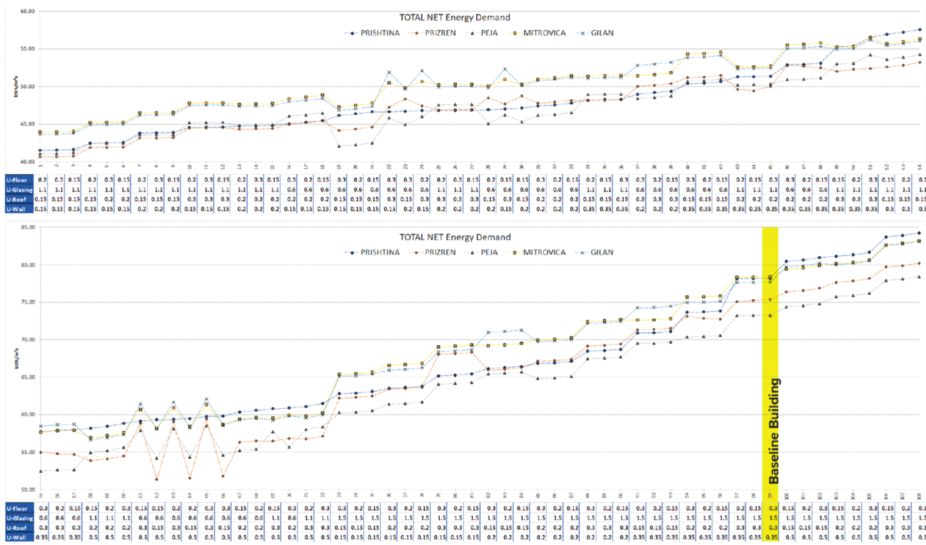


**Figure 4. Total heating and cooling energy demand based on 108 combinations of U-values for five cities**

Based on the final data from the EcoDesigner STAR software, it was established that characteristics of the cities located in the north-eastern part of the country, i.e. Prishtina, Mitrovica, and Gjilan, differ from those of the cities located in south-western Kosovo, i.e. Prizren and Peja. The north-eastern cities exhibit mostly similar total energy demand values because they have the same HDD, CDD and Average Solar radiation values, while the altitude is higher in Prishtina only. On the other side, the cities of Peja and Prizren present a slightly better performance in terms of lower heating and cooling energy demand compared to other cities. It seems that similar buildings located in different cities exhibit small differences in energy performance, which is why it can be confirmed that only one reference climate is acceptable in Kosovo.

It is not always possible to select the best energy performance option based on software simulations. The information about the heating and cooling energy demand, financial cost, and energy consumption, was obtained through optimisation for the 20 and 30 year periods. All simulated variants for heating and cooling energy demand of the model building, based on the investment cost and required energy, are presented in Figure 5. According to the cost-optimal methodology, financial calculation diagrams were obtained based on the lowest cost and optimum energy consumption. As can be seen in Figure 5, energy performance points vary from 40.64 kWh/m$^2$ to 84.27 kWh/m$^2$. The values shown in the global cost diagram range from 83.93 EUR/m$^2$ to 208.82 EUR/m$^2$. For the period of 30 years and for all cities, the cost-optimal level for this model building resulted in the most favourable combination ($U_{wall}$ -0.15, $U_{glazing}$ -1.1, $U_{roof}$ - 0.2 and $U_{floor}$ - 0.3) with the thermal insulation thickness of 25 cm in wall, 14 cm on the roof, and 7 cm in the floor, and with the double-glazed, argon filled, clear, low-e wooden window. Cost optimal levels from global-cost diagram are presented for 30 and 20 years in Table 3.

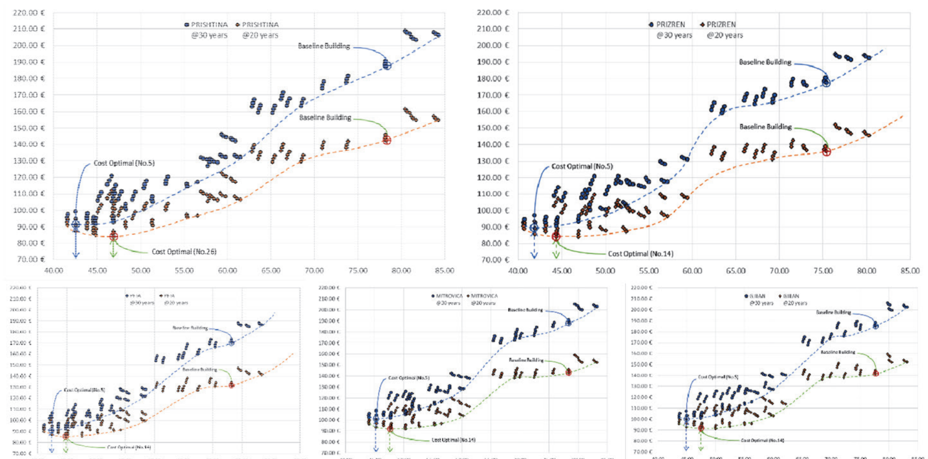


**Figure 5. Cost-optimal levels for five cities and the baseline building**

**Table 3. Cost-optimal levels for 30 and 20 years in five cities**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **30 years** | kWh/m²a | **Prishtina** | 42.51 | **Prizren** | 41.91 | **Peja** | 42.45 | **Mitrovica** | 45.22 | **Gjilan** | 44.94 |
| | EUR/m² | | 91.42 | | 89.37 | | 91.22 | | 100.7 | | 99.74 |
| **20 years** | kWh/m²a | **Prishtina** | 46.83 | **Prizren** | 44.36 | **Peja** | 44.86 | **Mitrovica** | 47.68 | **Gjilan** | 47.41 |
| | EUR/m² | | 83.93 | | 84.15 | | 85.29 | | 91.74 | | 91.12 |

The combination of U-values of $U_{wall}$ -0.2, $U_{glazing}$ -1.1, $U_{roof}$ - 0.2 and $U_{floor}$ - 0.3 may also be a suitable option for the city of Prishtina and so the thickness of thermal insulation in the wall is 18 cm, and is equal to 44.76 kWh/m$^2$a for a global-cost of 91.94 EUR/m$^2$, which is more applicable in the Kosovo market. Therefore, the differences in money seem to be more significant compared to those in energy savings.

If these cost-optimal U-values are compared with values that come from legislation or baseline building, big differences can be seen both in financial terms and in energy consumption. If the example of Prishtina for a thirty-year period is considered, the energy consumption can be reduced from 78.22 to 42.51 kWh/m$^2$a, and the global cost from 187.39 to 91.42 EUR/m$^2$, or by about 50 %. Results seem to be quite similar for the other cities as well. As to the period of 20 years, the energy consumption can be reduced from 78.22 to 46.83 kWh/m$^2$a, and the global cost from 142.51 to 83.83 EUR/m$^2$, which is the difference of approximately 40 %. In the 20 year-period, the most favourable combination of the cost-optimal level for all cities except Prishtina is $U_{wall}$ -0.2, $U_{glazing}$ -1.1, $U_{roof}$ - 0.2 and $U_{floor}$ - 0.3, while for Prishtina this combination is $U_{wall}$ -0.2, $U_{glazing}$ -1.1, $U_{roof}$ - 0.3 and $U_{floor}$ - 0.3). Taking into consideration all these results, the legislation in force should be reexamined and possibly changed, since the global cost analysis shows opportunities for improvement. Also, this building can be used as a reference for all buildings that have the same characteristics such as size, shape, occupancy, and climate. Although these cities exhibit some variations in the heating and cooling energy demand, the same optimal U-values can be adopted. The same calculation methodology can be used to find the optimal U-values and energy demand for all other types of buildings.

## 5 Conclusions

The aim of this paper was to provide detailed calculation of the heating and cooling energy demand for the purpose of finding optimum U-values in the building envelope and to compare these values with those proposed in the regulation. In addition, the paper takes into account the current regulation, analyses its elements, and offers possible combinations for the purpose of improving the deficiencies arising from the current legislation. The study is assessed as necessary, due to lack of Kosovo's literature in this field. Moreover, it presents some combinations of U-values for changing thermal properties in the model building envelope and finding which U-values are optimal for five cities in Kosovo (Prishtina, Prizren, Peja, Mitrovica, and Gjilan). The building model is located in continental climate that requires mixed heating and cooling for each city. The modelling of this building was conducted by means of the ARCHICAD program, while detailed simulations were performed using the EcoDesigner STAR add-on, by executing hourly dynamic energy analysis for input data in order to produce energy simulation results. The calculations were made only for the heating and cooling energy demand in the building, taking into account parameters such as solar gains, orientation, building materials and structures, openings, and natural ventilation. Construction materials adopted for the basic model of the house include materials that are most often used in Kosovo. Based on the achieved results, it can be concluded that there is a difference in the required energy demand for heating and cooling for the baseline building, with the cooling demand of around 56.22 kWh/m$^2$a and the heating demand of about 29.20 kWh/m$^2$a. After many different combinations of U-values were tested, the simulations show that the same building located in different cities exhibits small differences in energy performance. Concerning the sample results from the perspective of cost-optimal methodology, it can be stated that, in the period of 30 years, the same optimal U-values are presented in the diagram, and that these values are the same for the analysed five cities in Kosovo. The exception on the global-cost diagram for the period of 20 years is Prishtina only. After the global cost analysis, the optimal U-values were compared with the U-values of the baseline building, and the results showed that the current legislation needs to be reviewed. In addition, the legislation should specify energy requirements for different types of buildings, rather than only provide maximum allowable U-values. This model building can be used by central and local authorities as a reference building for the calculation of optimal U-values building types with similar characteristics. Furthermore, the demand for heating is higher than that for cooling in Kosovo although the opposite case is shown in the paper. It can thus be concluded that modification should be made in subsequent work in terms of architecture so as to enable the necessary reduction of cooling demand, which will result in improvement of an overall performance of the building, and in reduction of initial investment in the building envelope.

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