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# ASSESSING THE ENERGY RENOVATION IMPACT ON PUBLIC BUILDING PERFORMANCE: A CASE STUDY OF THE FACULTY OF NATURAL SCIENCES AND MATHEMATICS IN BANJA LUKA

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# ASSESSING THE IMPACT OF ENERGY RENOVATION ON PUBLIC BUILDING PERFORMANCE: A CASE STUDY OF THE FACULTY OF NATURAL SCIENCES AND MATHEMATICS IN BANJA LUKA

***ABSTRACT***

Buildings in Bosnia and Herzegovina are among the largest energy consumers, and deep energy renovation is a key pathway to reducing consumption and costs. This paper presents a case study of an educational building in Banja Luka, renovated in 2016 through envelope improvements and optimization of the heating system. Energy bills from 2013–2015 and 2022 were analyzed, and an energy audit evaluated the corresponding conditions (design values), which were then compared with actual consumption based on the energy bills. Total energy savings amounted to 94.18 kWh/m², or 74.96%, while economic savings reached 28.56%. The renovation also replaced coal as the heating medium with biomass, improving energy efficiency and supporting decarbonization goals. This study contributes by providing data on final energy use for heating in educational and cultural buildings, thereby supporting future improvements to national energy efficiency regulations.

**Keywords:** Energy efficiency, Energy renovation, Legal framework, Public buildings, Bosnia and Herzegovina, Energy efficiency assessment

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## 1. INTRODUCTION

One of the most prominent methods for reducing energy consumption is the retrofitting of buildings[1]. The building sector itself represents a complex system that relies on limited natural and land resources for construction, while requiring significant energy throughout a building's service life. Extending this lifespan while improving indoor comfort for occupants is therefore essential. Energy renovations have proven to be highly valuable, not only for enhancing energy performance but also for increasing market value [2, 3]. Yet, despite this potential, a large share of buildings remains unrenovated due to financial constraints, limited awareness of the actual benefits, and underdeveloped support mechanisms and strategies.

Buildings account for 38% of total energy consumption in the EU and 36% of greenhouse gas (GHG) emissions [4–6]. In countries with high energy intensity, this share can exceed 50% [7]. Despite improvements in building codes, non-residential buildings in the EU still consume approximately 140 kWh/m² annually if newly built, and 180 kWh/m² if existing [8]. In Bosnia and Herzegovina, the situation is even more critical, with heating needs reaching 250–300 kWh/m² per year [9, 10]. National data indicate that the estimated energy need for heating (70,537.9 TJ) [10] is about 47% higher than the total energy consumption recorded in residential buildings (47,703 TJ) [11]. Based on the data from the Typology of Residential Buildings and the Typology of Public Buildings in Bosnia and Herzegovina, the total energy demand for heating in all buildings within the Republic of Srpska amounts to 8,421,652 MWh, of which 698,514 MWh is attributed to public buildings [1, 9, 10].

According to Directive 2010/31/EU, the cost-optimal level of energy performance is defined as the level that minimises overall costs over a building's economic life cycle [12, 13]. Bosnia and Herzegovina remains far from this benchmark. The Strategy for Adaptation to Climate Change and Low-Emission Development 2020–2030 highlights significant opportunities for energy savings and GHG reductions through measures such as envelope renovation, HVAC upgrades, improved office equipment and lighting, integration of renewable energy sources (heat pumps, photovoltaic panels), the construction of new low-energy buildings, and replacement of heating fuels [14].

Additionally, Bosnia and Herzegovina has adopted Nationally Determined Contributions (NDCs) with unconditional targets to reduce GHG emissions by 12.8% by 2030 and 50% by 2050, along with conditional targets of 17.5% by 2030 and 55% by 2050, compared to 2014 [15]. Achieving these goals, particularly the conditional ones, will require greater efforts and stronger support from international organizations and financial mechanisms. Deep energy renovation, therefore, emerges not only as a way to improve energy efficiency but also as a key strategy for addressing energy poverty.

It is essential to examine more closely the internal distribution of energy consumption in Bosnia and Herzegovina. Figure 1 illustrates the final energy consumption of residential, public and commercial buildings, together with other sectors. The data clearly shows that the residential sector dominates national demand, while public and commercial buildings maintain a smaller share over the years. Although their overall consumption has remained relatively constant, public and commercial buildings continue to exhibit high specific energy needs, highlighting the necessity of targeted renovation measures. To be precise, in 2023 the residential sector accounted for 42% of total final energy consumption, while commercial and public services accounted for 9.3% of the total share, together making up 51.3% of total final energy consumption in Bosnia and Herzegovina [16].

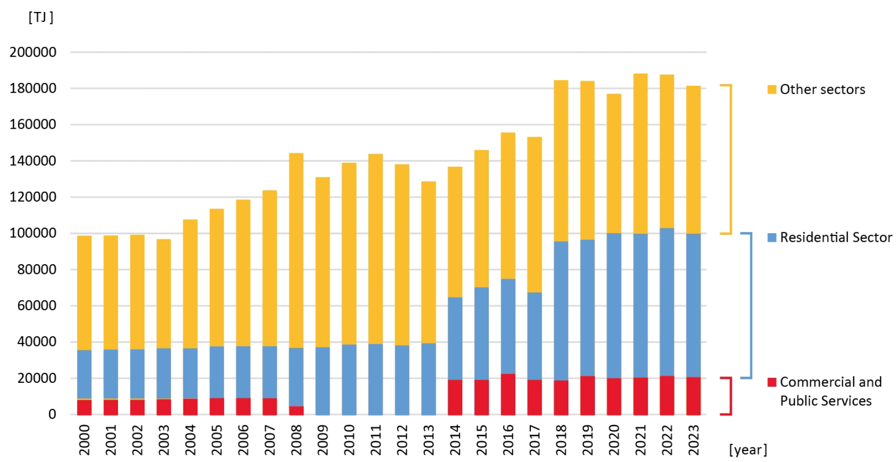



*Figure 1. Final energy consumption in Bosnia and Herzegovina for the Residential sector, Commercial and Public Services sector, and for other sectors together - according to data from IEA [16]*

The case study focuses on the historic building of the Faculty of Natural Sciences and Mathematics in the city of Banja Luka, located in the Republic of Srpska, Bosnia and Herzegovina. Constructed in 1931, the building is a stand-alone pavilion of significant historical and architectural value. At the time of its construction, it was one of several pavilions that symbolized the urban and institutional development of the city. From its earliest days, the building was designed to serve an educational purpose, a function that it continues to fulfil today, while also standing as a cultural and historical landmark.

To demonstrate both the challenges and the benefits of energy retrofitting, this paper presents a case study based on systematic monitoring of energy consumption. In this paper, such monitoring is illustrated through the analysis of energy consumption bills, and the calculation of energy needs for heating before and after the renovation measures. Delivered energy for heating during the heating season (October 1 – April 1) was analyzed for two periods: 2013–2015, representing the baseline conditions before renovation, and 2022, representing the post-renovation phase. Particular attention was given to the impact of a newly introduced heating medium procurement system, as such changes may influence both operational costs and heating quality. To ensure accuracy, the actual energy consumption was calculated by converting the procured quantities into energy units using calorific values obtained from the literature [17]. By comparing delivered energy data with estimated final energy needs, the methodology enables a critical assessment of the renovation's effectiveness and provides valuable insights into the building's energy performance.

## 2. LEGISLATIVE FRAMEWORK AND INFLUENTIAL PARAMETERS ON ENERGY RENOVATION

In order to apply for funding, develop and implement renovation projects, and monitor the results, a comprehensive database of current building stock, classified into groups and reference building types, is crucial. Member states of the European Union conducted the TABULA, EPISCOPE [18 – 20], and ASEIPI [21 – 22] projects, whose results led to the creation of national building typologies which produced a classification scheme grouping buildings according to their size, age and other parameters, together with an exemplary building representing the sourced building types [18 – 20]. By conducting such projects, a common methodological framework for segmenting and classifying building stocks [18] has been established and is similar to the one being used in the case of other countries. In Bosnia and Herzegovina, this was done in 2016 and 2018 by developing the National Typologies of Residential [9] and Public [10] Buildings. Typologies are divided into time periods and functional categories. The structure of the public buildings is divided into seven building function categories and six time periods.

In the Republic of Srpska, an entity in which the city of Banja Luka is situated, together with this case study, the central document is the Law on Energy Efficiency [23, 24], which serves as the key document for promoting and regulating energy-saving measures in buildings, establishing standards and obligations for both construction and renovation to improve energy performance. Complementing this is the Law on Spatial Organization and Construction [25], which integrates energy-efficiency considerations into the broader framework of urban planning and construction. These laws are further elaborated through several subsidiary regulations in the form of rulebooks [26–28]. The Rulebook on Energy Survey of Buildings and Issuance of Energy Certificates specifies the procedures for conducting energy surveys and outlines the criteria and process for issuing certificates [26]. The Rulebook on Minimum Energy Requirements in Buildings sets the baseline energy performance standards that all buildings must meet, covering aspects such as thermal insulation, heating and cooling systems, and overall energy consumption [27]. Finally, the Rulebook on Methodologies for Calculating Energy Characteristics of Buildings provides detailed methodologies for calculating and assessing energy characteristics, including energy consumption and efficiency metrics [28].

According to the Rulebook on Minimum Energy Requirements in Buildings, maximum allowable U-values are prescribed for each building element following the implementation of renovation measures. For the case study building, the relevant requirements include: a vertical opaque envelope with a maximum U-value of 0.30 W/m²K, a pitched roof of 0.20 W/m²K, and a slab towards an unheated area ranging from 0.30 to 0.40 W/m²K. In addition, the prescribed limits are 0.30 to 0.50 W/m²K for a slab above an unheated area, 0.50 W/m²K for a vertical wall in contact with the ground, 0.60 W/m²K for a floor on the ground, and 0.60 W/m²K for a wall facing an unheated area [26].

In the Building Renovation Strategy of Bosnia and Herzegovina for the period until 2050, four renovation depths are defined: nZEB (nearly Zero Emission Building), deep, medium and shallow [29, 30]. Table 1 provides a detailed explanation of these depths according to energy consumption per square meter of the building.

*Table 1. Energy efficiency levels of residential and non-residential building renovations [29, 30]*

| Renovation depth | Energy efficiency (kWh/m²) | |
|---|---|---|
| | Residential Buildings | Non-residential buildings |
| Very deep/nZEB | 40 | 20 |
| Deep | 65 | 50 |
| Medium | 80 | 70 |
| Shallow | 90 | 100 |

For this research, it is useful to examine the educational buildings constructed before 1945. According to Table 2, average U-values are calculated for four types of buildings: educational, health-care, cultural, and office buildings. In this table, it is evident that U-values for the opaque facade (outer walls) range from 1.37 W/m²K to 1.63 W/m²K, windows range from 2.82 W/m²K to 4.01 W/m²K, the floor in contact with the ground range from 1.67 W/m²K to 1.70 W/m²K, and the ceiling or roof range from 1.18 W/m²K to 1.46 W/m²K [10].

*Table 2. Average U-values per building function constructed before 1945 [10]*

| U (W/m²K) | | Educational buildings | Health-care buildings | Cultural Buildings | Office buildings |
|---|---|---|---|---|---|
| Until 1945 | Wall | 1.52 | 1.37 | 1.63 | 1.41 |
| | Window | 3.06 | 2.82 | 4.01 | 3.52 |
| | Floor | 1.70 | 1.67 | 1.70 | 1.70 |
| | Ceiling/ Roof | 1.40 | 1.46 | 1.18 | 1.20 |

There are several aspects that must be thoroughly assessed before the design and implementation of energy renovation projects, including the existing building's energy consumption patterns and inefficiencies, as well as its structural integrity and age. The current U-value of the external opaque and transparent envelope can be precisely calculated using theoretical methods, or by applying experimental methods such as the heat-flow-meter method or surveying with an infrared camera. Airtightness must also be assessed to determine whether joints and locksmith elements are securely and snugly connected to the building's structure, or if gaps and loose fittings allow unwanted air infiltration. Another step is detecting thermal bridges, which may result from design flaws or material degradation and create linear pathways or localized areas with significant differences in thermal transmittance; to address this, the Quantitative Infrared Thermography (QIRT) method of surveying the building with an infrared camera can be particularly useful for detecting thermal anomalies and for measuring hard-to-reach areas [31 - 33].

Energy efficiency of buildings implies a high-quality building envelope (thickness of thermal insulation depending on the thermal conductivity of the material), reduction of air infiltration through the envelope (installation of windows and doors and penetrations for installations), and adequate sizing of HVAC systems (heating, ventilation, air conditioning, cooling). After renovation, monitoring the building's performance ensures that the upgrades deliver the expected results in efficiency and safety. Systematic monitoring gathers data to assess energy consumption, structural integrity, and overall functionality. This process involves continuous evaluation and analysis, aiming to identify any anomalies or improvements needed. Effective performance monitoring not only validates the renovation efforts but also enhances the building's operational sustainability over time.

## 3. QUALITATIVE OVERVIEW OF BUILDING RENOVATION: A CASE STUDY OF THE FACULTY OF MATHEMATICS AND NATURAL SCIENCES IN BANJA LUKA

As previously stated, the energy renovation of existing buildings is an important strategy for enhancing energy efficiency, reducing operational costs, and moving toward reaching energy efficiency standards and addressing environmental concerns. There are several case studies developed in the City of Banja Luka; however, only a few focus on public sector buildings. One notable example of good practice is the Faculty of Natural Sciences and Mathematics at the University of Banja Luka (UNIBL), which underwent the process of energy renovation in 2016.


*Figure 2. Position of the Faculty building in the Ensemble (borders are approximate; Google Earth background)*

Throughout the decades, the building has undergone continuous changes in property management and has housed several public services, including the School for Teachers, the Civil Engineering High School, and, now, a higher education building. Today, it is protected as part of the heritage ensemble along Kralja Petra I Karađorđevića and Mladena Stojanovića streets [34]. These changes were not accompanied by adequate upgrades in terms of property management and energy efficiency. Consequently, in 2016, the building was selected as a case study for a comprehensive renovation project aimed at improving its energy efficiency.

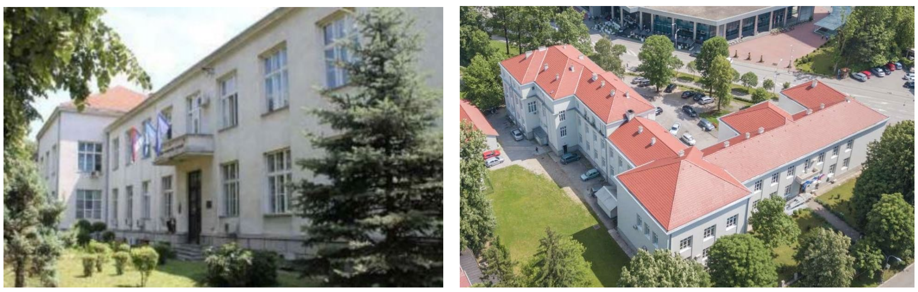
The building is a self-standing structure with a basement, ground floor and one upper floor. It has been reconstructed in the past when an extra floor was added to one part of the building. It has a robust structure with load-bearing facade walls made of solid brick, with thickness ranging from 30 to 75 cm. The roof is pitched and covered with tiles. The building envelope features individual windows, but due to the wall thickness, some rooms lack natural light. After the upgrades, and according to the Rulebook on Minimum Requirements for building energy characteristics [26], the building meets Energy grade C, which is, in the first place, the minimum requirement for educational buildings after renovation (Table 3).

*Table 3. Energy grades for educational and cultural buildings [26]*

| Educational and cultural buildings | | New | | Educational and cultural buildings | | New |
|---|---|---|---|---|---|---|
| Energy grade | $Q_{H,nd,rel}$ (%) | $Q_{H,nd}$ [kWh/(m$^2$a)] | | Energy grade | $Q_{H,nd,rel}$ (%) | $Q_{H,nd}$ [kWh/(m$^2$a)] |
| A + | ≤ 15 | ≤ 10 | | D | ≤ 150 | ≤ 98 |
| A | ≤ 25 | ≤ 17 | | E | ≤ 200 | ≤ 130 |
| B | ≤ 50 | ≤ 33 | | F | ≤ 250 | ≤ 163 |
| C * | ≤ 100 | ≤ 65 | | G | > 250 | >163 |
| * Minimum requirement after the renovation of the building | | | | | | |

The building's energy renovation considered a holistic approach, focusing on upgrading the thermal performance of the facade (including both opaque and transparent envelope); replacing the previous heating medium (coal, Class I wood, Class II wood, and wood chips) with a single medium (pellet); and replacing the boiler since it was not efficient and optimized for the wood-based fuels. According to the Heating Medium Procurement bills over a three-year period (2013 – 2015), coal was the primary heating source, followed by wood products (Class I, Class II, and wood chips), including associated transport costs.

*Table 4. Design values of all parameters that affect the calculation of the energy need for heating ($Q_{h,nd}$) before and after applied renovation measures at the Faculty of Natural Sciences and Mathematics in Banja Luka*



Building before renovation (left) [35] and after renovation (right) [36]

| | | | | |
|---|---|---|---|---|
| Period | | 1930 | | |
| Heated Space Area | | 3770 m² | | |
| Number of Floors | | Po+P+1 | | |
| Heated Space Volume | | 13603 m³ | | |
| heat capacity | Wh/m²a | 72 | | |
| metabolic heat from a person | W/m² | 7 | | |
| Orientation | | NW -NE | | |
| | | Before | After | Maximum Permitted values according to Rulebooks [26, 27] |
| U-value of the Facade walls | W/m²K | 1.52 | 0.26 | 0.30 |
| U-value of the Windows | W/m²K | 3.06 | 1.30 | 1.60 |
| U-value of the Pitched roof | W/m²K | 1.40 | 0.19 | 0.20 |
| U-value of the Floor | W/m²K | 1.70 | 0.30 | 0.30 - 0.60 |
| g-value | - | 0.77 | 0.62 | Not prescribed |
| A/V – Area/Volume ratio | - | 0.34 | | |
| Percentage of window area | % | 15.64 | | |
| Infiltration | 1/h | 0.70 | 0.50 | 0.50 |
| Internal temperature | °C | 20.0 | 20.0 | 20.0 |
| Setback temperature | °C | 16.7 | 19.0 | Not prescribed |
| Internal heat gains | | | | |
| Ventilation | kWh/m²a | 0.0 | 0.0 | 10 |
| Lighting | kWh/m²a | 5.6 | 5.6 | |
| Various equipment | kWh/m²a | 4.1 | 4.1 | |
| $Q_{H,nd}$ – Energy need for Heating | kWh/m²a | **173.19** | **41.62** | ≤ 65 |

Table 4 presents the building's energy performance both before and after the renovation measures. It has a heated area of 3,770 m², with the primary facades oriented northwest-northeast. The thermal transmission coefficients (U-values) of the main envelope elements, indicating their thermal performance, were improved as follows: (1) facade walls, from 1.52 W/m²K to 0.26 W/m²K; (2) windows, from 3.06 W/m²K to 1.30 W/m²K; (3) pitched roof, upgraded with new covering and thermal insulation, from 1.40 W/m²K to 0.19 W/m²K; and (4) floor in contact with the ground from 1.70 W/m²K to 0.30 W/m²K.

According to Table 5, the largest funding and energy production originated from sources that are environmental pollutants. Also, while reviewing the bills, it was difficult to understand the necessity for a large number of small procurements. It is necessary to point out that the procurement process was conducted in multiple stages and from different sources and locations, resulting in an inconsistent process. This scenario leaves room for inconsistent product quality due to different suppliers and missing product certificates. An important point is that the bills do not specify the physical characteristics of the product. Moisture content, density, and form of the delivered product are completely absent from the available documents. This study is guided by the average values from previous studies [17] and the current market in Bosnia and Herzegovina, to calculate the delivered energy. For coal, an average energy value of 27.6 mJ/kg is used. For the wood, it is assumed to be beech logs, with an assumed moisture content of M15% in stacked form, and for the wood chips, the moisture content is assumed to be M20%.

*Table 5. Analysis of Funding and Energy produced for heating in the period from 2013 to 2015*

| Heating medium | Energy value | Density | Quantity | Price | Energy | |
|---|---|---|---|---|---|---|
| Units | mJ/kg | kg/m³ | | BAM | mJ | kWh |
| Heating medium / month | 2015 | | | | | |
| COAL | 27.6 | | 50 t | 8,478.26 | 1,380,000 | 383,333.3 |
| Wood beech log, stacked (M15%) | 15.3 | 445 | 57.638 m³ | 2,685.29 | 392,428.32 | 109,007.8 |
| Wood chips (M20%) | 14.4 | 328 | 5 m³ | 409.5 | 2,3616 | 6,560 |
| Transport | | | | 468 | | |
| Heating medium / month | 2014 | | | | | |
| COAL | 27.6 | | 48 t | 6,960 | 1,324,800 | 368,000 |
| Wood beech log, stacked (M15%) | 15.3 | 445 | 51.312 m³ | 3,107.69 | 349,357.75 | 9,7043.8 |
| Wood chips (M20%) | 14.4 | 328 | 1 t | 260 | 14,400 | 4000 |
| Transport | | | | 2,400 | | |
| Heating medium / month | 2013 | | | | | |
| COAL | 27.6 | | 50 t | 8,640.75 | 1,380,000 | 383,333 |
| Wood beech log, stacked (M15%) | 15.3 | 445 | 29.87 m³ | 2,101.43 | 203,369.9 | 56,491.6 |
| Wood chips (M20%) | 14.4 | 328 | 10 m³ | 588 | 47,232 | 13,120 |
| Transport | | | | 6,183.09 | | |
| **Average funds spent per year** | | | | **14,094** | | |
| **Average Energy Production per year per square meter (kWh/m²a)** | | | | | | **125.63** |

For the most precise calculations, the only possible way to consistently calculate the delivered energy is to either empirically evaluate the physical properties of the heating medium if it is still present at the location, or to request the certificates retrospectively and compare the real values with the theoretical ones in the certificate. However, this scenario is difficult to confirm since most of the medium has already been used, and moisture levels change over time depending on storage conditions. According to energy bills from the procurement of the medium, and considering the average values over three seasons (2013 – 2015), the calculations indicate that the final energy for heating was estimated at 125.63 kWh/m$^2$a.

One of the key objectives of the energy renovation was to optimize the heating system, including the procurement of the heating medium. The decision was made based on local production and availability, as well as the ecological benefits of wood pellets. Table 6 shows how the current procurement works: it is consolidated into a single period of the year, from one supplier, and for one type of medium. Compared to the previous scenario, this allows better quality control and easier assessment of the energy production. When analyzing the winter season of 2022, a significant drop in delivered energy was observed. The final energy for heating is estimated at 31.45 kWh/m$^2$a for the winter season of 2022.

*Table 6. Analysis of funding and energy produced for heating in 2022*

| Heating medium | Energy value | Density | Quantity | Price | Energy | |
|---|---|---|---|---|---|---|
| Units | mJ/kg | kg/m$^3$ | t | BAM | mJ | kWh |
| Wood Pellet, bulk (M8%) | 11.115 | 650 | 38.4 | 10,067.4 | 426,816 | 118,560 |
| **Total funds spent** | | | | **10,067.4** | | |
| **Total Energy Production** | | | | | 426,816 | 118,560 |
| **Average Energy Production per year per square meter (kWh/m$^2$a)** | | | | | | **31.45** |

In this context, Figure 3 compares the shares of heating media used for energy production across two time periods.

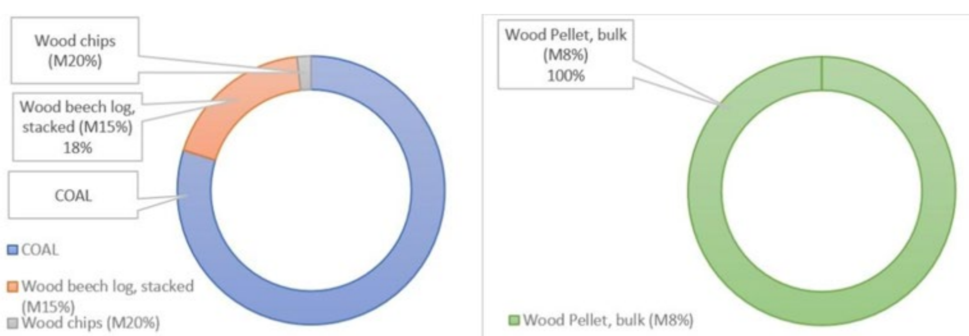



*Figure 3. Comparison of the energy produced based on the medium energy value in 2015 (left) and 2022 (right) (Authors' figure)*

When examining Figure 4, the positive outcomes of the renovation become evident. Figure 4 illustrates a decline in the energy consumption for heating, which dropped from an average of 473,629 kWh in the period 2013 – 2015 to 118,560 kWh in 2022. This represents a reduction of approximately 74.96% in heating energy use.

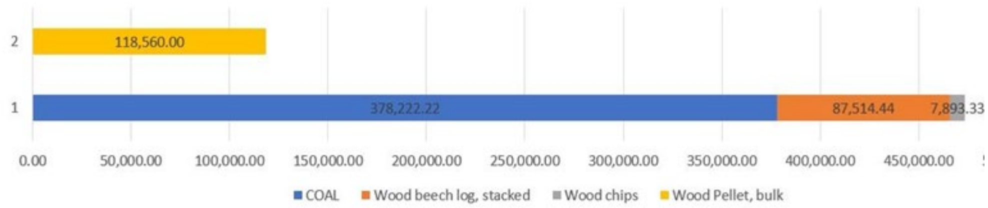



*Figure 4. Comparison of the total energy produced for heating in 2022 (up) and 2015 (down) (Authors' figure)*

The substantial reduction in energy consumption can be attributed to several factors. Firstly, improvements to the building's insulation have reduced heat loss, ensuring that less energy is required to maintain comfortable indoor temperatures. Secondly, the installation of a new heating system has led to overall better use of the heating medium. Overall, the significant drop in heating energy consumption demonstrates a successful implementation of renovation strategies that enhance energy performance.

After calculating the benefits visible from an energy-intensity perspective, a comparison of funding expenditures was also made. As shown in Figure 5, it is evident that the amount of funds spent in 2022, compared to the average annual funding from 2013 to 2015, decreased from 14,094 BAM to 10,067.4 BAM. This represents a decrease of approximately 28.6% in public spending.

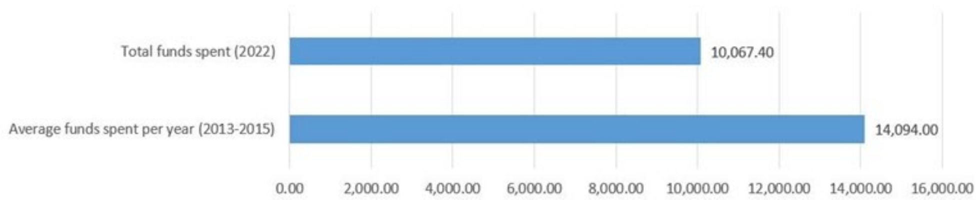



*Figure 5. Comparison of the total funding spent for heating in 2022 (up) and 2015 (down) (Authors' figure)*

Final energy for heating is compared for the design values and the actual values. Looking at Table 7, it is evident that the design value of final energy for heating is 78.37% higher than the actual value calculated from heating-medium bills. Also, the defined design value of the final energy for heating after the renovation is still 71.27% higher than the real-time value.

*Table 7. Comparison of the final energy for heating in design values and in actual energy consumption according to the bills*

| FINAL ENERGY FOR HEATING | | **Before renovation** | **After renovation** |
|---|---|---|---|
| Design value - with heating system losses | kWh/m²a | **224.12** | **53.86** |
| According to the bills | kWh/m²a | **125.63** | **31.45** |

After everything is considered, a significant step towards more efficient energy management and consumption has been taken; however, it remains necessary to monitor performance over the coming years and to conduct assessments at 5- and 10-year intervals to determine whether the use of a new heating medium is justified. Further studies could examine the environmental impact of interventions and new types of heating medium, where a deep analysis of GHG emissions should be conducted.

## 4. CONCLUSION

This paper provides an overview of energy intensity and regulatory policies in Bosnia and Herzegovina, with particular attention to the rulebooks applied in the Republic of Srpska entity, and underscores the importance of energy renovation as one of the most effective pathways to reduce energy consumption in the building sector. As outlined in the introduction, buildings represent complex systems that rely heavily on limited natural and land resources, while demanding substantial energy throughout their life cycle. In this context, extending the lifespan of buildings while improving thermal comfort and energy performance is not only desirable but also essential.

The case study of the Faculty of Natural Sciences and Mathematics in Banja Luka demonstrated the practical outcomes of such renovation measures. The Energy Efficiency Study suggested a theoretical reduction of 75.97% in heating energy demand (Qh, nd). Considering the defined depths of energy retrofit, the energy need for heating of 41.62 kWh/m²a indicates the building underwent a deep energy retrofit (Table 1), while achieving an energy grade C (Table 3). However, the results revealed important discrepancies between design values and actual consumption. Before renovation, the Final energy for heating (design value - with heating system losses) was 224.12 kWh/m²a (Table 7), while actual average energy consumption calculated according to the bills in the period 2013–2015 (Table 5) was significantly lower at 125.63 kWh/m²a, indicating possible factors such as inadequate room temperatures, unheated areas, or use of additional heating sources. After renovation, the final energy for heating (design value - with heating system losses) is 53.86 kWh/m²a (Table 7), while the actual average energy consumption calculated from the 2022 bills (Table 6) was significantly lower at 31.45 kWh/m²a. Despite these discrepancies, the renovation led to substantial improvements.

In addition, poor-quality coal was eliminated as the primary heating medium and replaced with biomass in the form of wood pellets, aligning the building's energy profile with broader EU and national decarbonization strategies. The introduction of a structured procurement system further enhanced transparency, tracking accuracy, and control over heating quality, while generating financial benefits by reducing annual public heating expenditure from 14,094 BAM to 10,067.4 BAM.

By comparing energy consumption based on utility bills from 2013–2015 and 2022, it is observed that total energy savings amount to 94.18 kWh/m², or 74.96%, while economic savings amount to 4,026.6 BAM, or 28.56%.

Taken together, these findings confirm the central argument presented in the introduction: the building sector in Bosnia and Herzegovina, while one of the largest energy consumers, holds vast potential for energy savings through targeted and well-monitored renovation measures. The case study demonstrates that a combination of envelope renovation, optimized heating systems, and procurement reforms can significantly reduce energy demand, operational costs, and environmental impact, while also contributing to national and international decarbonization goals (NDCs and EU directives).

Rulebooks in the Republic of Srpska use the indicator of energy need for heating when calculating the minimum energy performance and in the energy certification of buildings.

The contribution of this research lies in the inclusion and presentation of the final energy for heating for educational and cultural buildings. Furthermore, such research contributes to future improvements to the Rulebook on Energy Audits of Buildings and Issuance of Energy Certificates and the Rulebook on Minimum Requirements for Building Energy Characteristics in the Republic of Srpska.

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## ПРОЦЈЕНА УТИЦАЈА ЕНЕРГЕТСКЕ ОБНОВЕ НА ПЕРФОРМАНСЕ ЈАВНЕ ЗГРАДЕ: СТУДИЈА СЛУЧАЈА ПРИРОДНО-МАТЕМАТИЧКОГ ФАКУЛТЕТА У БАЊОЈ ЛУЦИ

**Сажетак:** Зграде у Босни и Херцеговини спадају међу највеће потрошаче енергије, а дубока енергетска обнова представља кључни пут за смањење потрошње и трошкова. У раду је приказана студија случаја образовне зграде у Бањалуци, обновљене 2016. године кроз побољшања омотача зграде и оптимизацију система гријања. Поред анализе рачуна за енергију из периода 2013–2015. и 2022. године, извршен је енергетски аудит стања прије и након обнове (пројектне вриједности), који је затим упоређен са стварном потрошњом из рачуна. Укупна уштеда енергије износила је 94,18 kWh/m², односно 74,96%, док су економске уштеде достигле 28,56%. Реновирање је такође замијенило врсту огрева – угаљ са биомасом, побољшавајући енергетску ефикасност и усклађеност са напорима у декарбонизацији грађене средине. Рад додатно доприноси приказивањем финалне енергије за гријање у образовним и културним зградама и будућем унапређењу националних правилника о енергетској ефикасности.

*Кључне ријечи: Енергетска ефикасност, Енергетска обнова, Правни оквир, Јавне зграде, Босна и Херцеговина, Процјена енергетске ефикасност*