

The Urban Book Series

Milena Vukmirović
Aleksandra Đukić
Eva Vaništa Lazarević
Aleksandra Krstić-Furundžić *Editors*

Digital Dreams, Urban Realities

Crafting Sustainable, Inclusive, and Beautiful Cities

Springer

Chapter 18
Sustainable Modular Renovations of Buildings Envelope from the Prosperous Years for the Purpose of Energy Saving in Bosnia-Herzegovina and Serbia

Darija Gajić, Budimir Sudimac, Aleksandar Rajčić, Slobodan Peulić, and Jelena Kljakić

Abstract Following the concept of sustainability in the development of new building systems and envelopes based on renewable and natural materials, which is recently obligatory for the EU member countries through the new Renovation Wave Strategy, the authors present research on the topic of energy renovation of buildings using renewable materials in modular systems and its possibilities in two developing countries. This research presents energy savings through a case study of deep renovation of buildings using timber modular systems for envelopes on the characteristic example of residential buildings. Research focuses on the Prosperous Years of construction period between 1961 and 1980 due to a considerable number of modular buildings designed during the peak of the construction progress and promotion of prefabricated buildings. The total potential of energy savings for such building types was considered according to national typologies of residential buildings in Bosnia and Herzegovina (B&H) and Serbia. Through a comparative analysis of these countries, the research presents the parameters of buildings built in Prosperous Years, which indicate the energy condition of buildings before and after the renovation of the envelope using standard measures from national typologies and the application of wooden modular envelope systems, which have the potential for in-depth renovation of buildings.

Keywords Renovation strategies · Deep energy refurbishment · Residential buildings · Timber systems · Modular envelopes

D. Gajić (✉) · S. Peulić · J. Kljakić
Architecture Technologies Department, Faculty of Architecture, Civil Engineering and Geodesy, University of Banja Luka, Banja Luka, Bosnia and Herzegovina
e-mail: darija.gajic@aggf.unibl.org

B. Sudimac · A. Rajčić
Architecture Technologies Department, University of Belgrade—Faculty of Architecture, Belgrade, Serbia

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2025

M. Vukmirović et al. (eds.), *Digital Dreams, Urban Realities*, The Urban Book Series,
https://doi.org/10.1007/978-3-031-76353-3_18

18.1 Introduction

In countries with higher energy intensity (units of primary energy consumption per unit of GDP of the country), energy consumption in buildings is even higher than 50%, and that is why the greatest energy savings are expected when renovating buildings. The energy intensity was estimated at 0.42 for B&H (https://www.iea.org/countries/bosnia-and-herzegovina) and at 0.35 for Serbia (https://www.iea.org/countries/serbia) (tone of oil equivalent (toe)/1000 USD of GDP) according to data from the International Energy Agency from 2021. B&H and Serbia are even the countries with the highest energy intensity of all the countries of the former Yugoslavia, to which they also belonged together with North Macedonia [0.24], Montenegro [0.23], Croatia [0.15] and Slovenia [0.14].

In order to achieve the planned total reductions of greenhouse gas emissions in the EU of at least 55% by 2030, it is necessary to reduce emissions from buildings by 60% and their energy consumption by 14%, while the use of energy for heating and cooling must be reduced by 18%. The European Union Renovation Wave Strategy, published by the European Commission (2020), aims to reduce greenhouse gas emissions, increase material reuse and recycling, stimulate economic recovery after the COVID-19 pandemic, reduce energy poverty and support achieving the EU's goal of becoming climate neutral by 2050. The renovation of the building envelope, which is guided by organic materials, such as wood, was presented in this research through a case study of energy renovation of the existing buildings, which were built in the Prosperous Years from 1961 to 1980. The Prosperous Years refer to industrialisation and accelerated construction of residential buildings, which occurred in both countries after 1960.

In those years in B&H and Serbia, as prefabrication was already current in Europe, buildings were built from 1961 to 1970 with imitation of facade wall prefabrication because they have many of the same repeating elements on the facade of the building, and from 1971 to 1980 pure reinforced concrete prefabricated buildings are being built.

The Strategy for the Renovation of Buildings in B&H (by entities, the Strategy for the Renovation of Buildings in The Republic of Srpska until 2050 and Directive 2012/27/EU) has not yet been officially adopted. Strategies of B&H and Serbia are guided by cost-optimal analyses prescribed by Regulations No 244/2012 (European Union Parliament and Council 2012). However, they do not emphasise the refurbishment of building envelopes with renewable and organic products and materials, but only the use of renewable energy sources (Government of the Republic of Serbia, Ministry of Civil Engineering, traffic and infrastructure (MGSIRS) 2022; Sudimac et al. 2022). The starting point for the formation of the Strategy in B&H is the cost-optimal analyses for residential and non-residential buildings done during 2016–2017. The B&H Strategy states that the greatest energy savings, about 60%, will be when we apply all valid new U-values on the envelope (Rulebook on energy efficiency; Rulebook on minimal requirements on Energy Efficiency in Buildings). By applying all measures to the building envelope, the price of the investment is twice as high, while energy consumption has been reduced by five times. In Serbia, the formation was

based on residential and non-residential buildings done during 2019–2020, developing five potential renovation scenarios according to the level of energy-saving potential—Scenario 4 in Serbia is considered a deep renovation because Scenario 5 is intended for nZEB, and as B&H requires deep renovation of the entire building envelope resulting from cost-optimal analysis and following the requirements of the New Renovation Wave Strategy, it is necessary to point out possible deep renovations envelope of buildings with organic materials that will reduce the value of the energy indicator, the energy need for heating, by 60%.

18.2 Modular Envelope Renovations for Residential Buildings

Over the years, renewable materials have not found a path towards serious use in analysed countries. The reason for this lies in three main factors: higher price of renewable materials, poor industrial capacity and lack of knowledge, and lack of public awareness on the importance of natural, bio-based materials in energy renovation (Gajić et al. 2021). Traditional systems with contact façades are most accepted because they are the cheapest and most often used; however, over time, the question of the durability of such solutions, maintenance and certainly extremely bad impact on the environment arose. On the surging side, ecologically acceptable solutions are not represented in the analysed countries (B&H and Serbia), mainly due to the lack of interest, but also legislation that defines the carbon footprint of materials used in construction or missing understanding and rules on life cycle analysis. Building stock in both countries has become old and in a condition that is already questionable as to whether it is suitable for renovations; however, national programs should enhance processes and funding for energy renovations. These programs can be based on four main renovation models adjusted on a specific case-by-case basis: external composite insulation system, ventilated system, partially prefabricated systems and modular systems (Peulić et al. 2023). When it comes to the selection of the most adequate solution, there are several influential factors—the state of the building envelope, the time frame for the execution of works, the complexity of the details, i.e. the existence of modules in the building envelope, the development of the local construction industry and financial structures, etc. (Peulić and Gajić 2022).

Developed EU countries succeeded in implementing these solutions in AEC practice. The topic of modular prefabrication has gained serious attention through several projects developed in the EU. One of the pioneering projects was TES—Timber Energy Systems, where a systematic typological classification of facilities suitable and in need of deep renovation, design methodology, factory production and installation of modules was presented. This project advanced to additional study on the extension of buildings or their segments with the help of prefabricated spatial structures. Further research developed in recent years promoted different approaches to methodological solutions with emphasis on several key points presented in Table 18.1.

Considering the pedigree of the projects and participant countries (Finland, Germany, Norway), it is possible to note similar approaches with different outcomes.

Smart-TES EXTENSIONS is the continuation of the previous project (TES Energy) and is a step forward to building extensions rather than classic renovation

Table 18.1 Overview of the key outputs from projects developed in the European Union

Project	Type of improvement	ECBCS	BERTIM	More connect	TES energy façade	Smart-TES
Thermal comfort improvements	Opaque envelope	+	+	+	+	+
	Transparent envelope	+	+	+	+	+
Layout improvements	Elevator	−	−	−	−	+
	Balconies and/or terraces	−	−	+	−	+
	Extending window area	−	−	+	−	+
Structure survey	3D laser scanning	+	+	NA	+	NA
	Total station	−	+	NA	−	NA
Developed system	Prefabricated vertical panels	+	+	+	+	+
	Prefabricated horizontal panels	+	−	−	−	+
	Prefabricated volumes	−	−	−	−	+
Building services	Integrated ventilation systems with heat recovery	+	+	+	+	+
	Panels pre-equipped with HVAC systems	−	+	+	+	+
Software	Automated panel distribution	−	+	−	−	−
	Off-site fabrication	+	−	+	+	+
	Robotic manufacturing and new algorithms	−	+	−	−	−

(usually narrowed to the envelope level), Table 18.1. The project results booklet showed several types of these extensions—horizontal, annexe, vertical annexe, terrace/balconies annexe, etc. Since the name is about the extensions, often several stories high, this project explained load transfer—via TES facade and extensions, via extensions, via extensions and existing building, via existing building loadbearing structure (Heikkinen et al. 2009). In addition, functional differentiation is considered since horizontal annexes typically affect existing flats and rooms (layout, ventilation, insolation, etc.), compared with vertical annexes that can perform independently. Prefabricated space modules require special attention to the transport requirements of different countries.

ECBCS (Prefabricated Systems for Low Energy Renovation of Residential Buildings) is a project of 7 countries (Austria, Czech Republic, France, Netherlands, Portugal, Sweden, Switzerland) where combines best approach in both on-site and software approaches, going with the case-by-case methodology rather than unification of overall process, Table 18.1 (Mark 2012). Reduce energy consumption needs to the range of 30–50 kWh/m^2 per year for heating and domestic hot water. Thus, panels can be slightly optimised accordingly, which can result in better overall building performance and economic benefit of the investment. The project resulted in 6 successful demonstration sites (*until the 2012 report) in Austria, the Netherlands and Switzerland. Energy consumption goals were fully achieved; furthermore, with solar installations, these demands were reduced to almost zero.

In the desire to bring to life the deep renovation of buildings, again using wood as a substructure, six countries (France, Spain, Sweden, Germany, Norway, and Poland) in the period from 2015 to 2019 created the project BERTIM (Building Energy Renovation through Timber Prefabricated Module), Table 18.1. This project tries to automatise the surveying process, as well as modular coordination and communication. An algorithmic approach is a step forward in thinking about modular coordination. However, there are certain gaps between different processes, such as tolerances ranging from 5 to 10 mm in surveying, compared with 3 mm tolerance in prefabricated panel production, which can mislead the results to be adjusted manually and on-site. Robotic manufacturing and RENO BIM software were developed to quickly design the optimal panel shape and distribution. During this project, an algorithm was developed to reduce the time needed to manually design and arrange modules. As in the previous project, prefabricated modules are designed to be pre-equipped with heating, cooling, ventilation and domestic hot water systems (BERTIM 2019).

MORE CONNECT (MOdular REtrofitting and CONNECTions) sets a number of user-friendly criteria to influence users' everyday life during renovation as little as possible and tries to solve the aforementioned problems by developing prefabricated, multifunctional renovation elements for the total building envelope (façade and roof) and installation/building services, from period 2015–2018 participated seven countries (Latvia, Estonia, Czech, Netherlands, Denmark, Portugal, Switzerland). The project has been launched to develop energy efficiency, hygrothermal performance and aesthetics of buildings and demonstrate technologies of prefabricated modular

renovation elements, including the prefab integration of multifunctional components, e.g. for climate control, Table 18.1 (Volf et al. 2018). A set of basic modular facade and roof elements including renewable energy production and integration of HP insulation.

The presented projects show a variety of methodologies in research on the renovation of prefabricated modules. It is interesting to see different approaches in setting typologies, how to classify them in categories, ways to survey buildings, do building construction and envelope analysis, and see how to set exact aspects that renovation should accomplish. Some of the projects were answered affirmatively. However, some remained unclear on the methodology of surveying or building typology classification. Each of the projects gave some interesting conclusions, and this research will try to present a similar methodology that could possibly be implemented in the case studies in Bosnia-Herzegovina and Serbia.

18.3 Energy Savings Potential in Modular Envelope Renovations of Prefabricated Residential Buildings in B&H and Serbia

Data on the comparison of residential building stock in B&H and Serbia were collected through the methodological framework for researching the typology of residential buildings, based on the European international research project "TABULA" (EPISCOPE.EU 2023; EPISCOPE.EU 2023) Both project Typologies of Residential Buildings in B&H (Arnautović-Aksić et al. 2016) and Serbia (Popović et al. 2013) showed absolute and specific energy need for heating was calculated for the total of 29 representative residential buildings in B&H and 39 representative residential buildings in Serbia, which represent six categories of buildings classified into six and eight periods of construction. For the purpose of comparing countries according to the TABULA methodology (Loga et al. 2016), it was reduced to 22 buildings for B&H divided into four categories and six periods, and for Serbia, 31 buildings divided into four categories and eight periods. Adequate buildings for the application of prefabricated timber panels are selected according to three criteria: layout, which allows modular division of the facade envelope; the period of construction and amount of such buildings. Multi-family residential buildings (MFH and AB), in contrast to individual residential buildings (SFH and TH), have larger envelope area which needs to be renovated and can be heat-upgraded with the same pre-fabricated elements of organic materials, which are also the subject of this analysis.

18.3.1 Existing Residential Building Stock for Energy Renovations Modular Envelope

The potential of construction period between 1961 and 1980 was investigated. The construction of prefabricated reinforced concrete systems in the EU began in 1960 (Giebeler et al. 2009), while in B&H and Serbia after 1970, but the influence of EU construction leads to the imitation of prefabrication on buildings made of cast concrete and masonry construction in Bosnia and Herzegovina, (see Fig. 18.1).

Today, such buildings are adequate for renovation with modular panels, which would be made in industrial conditions and installed on site in its entirety on the existing casing. The characteristics of such residential buildings are that they were built as free-standing (MFH) or lamellas (AB), (see Fig. 18.2), and that their number of floors is 4 or more with at least 20 apartments within such structures.

In addition, they are usually connected to inefficient district heating. Building renovation strategies usually refer to buildings whose renovation can generate energy savings of 60% or more, but priority must be given to buildings where renovation would solve health and energy poverty problems for users (https://energy.ec.europa.eu/system/files/2015-07/INSIGHT_E_Energy%2520Poverty_Appendices_0.pdf). From the Typology, we can see how many buildings there are free-standing (MFH) and slats (AB) and what their ratio is compared to other types of buildings. The potential building stock over which the building envelope could be upgraded has been examined through a comparative analysis of data on the building stock of both countries. Periods 1961–1970 and 1971–1980 for the



Fig. 18.1 Residential buildings of Bosnia and Herzegovina (left—cast concrete building period 1961–1970, right—prefabricate concrete building period 1971–1980)



Fig. 18.2 Typology of residential buildings of Bosnia and Herzegovina (left) residential building typology of Bosnia and Herzegovina (EPISCOPE.EU 2023)

residential buildings (MFH and AB) have mutually in B&H 9355 buildings, while in Serbia, this number, 2.5 times higher than the number of buildings in B&H, is 24,372 buildings. However, looking at the number of dwelling units within these buildings, the ratio decreases because the number of dwellings in individual buildings is 66.47% in B&H and 73% in SRB, respectively, which is shown in Table 18.2.

Comparative analysis indicates that although Serbia has a larger number of buildings of all types. In B&H, the number of dwellings in types MFH and AB of the period from 1961 to 1980 in relation to all periods of collective housing buildings is 74.2%, while in relation to all types and periods of buildings, it is 18.38%. In Serbia, the number of dwellings in the types of MFH and AB periods from 1961 to 1980 in relation to all periods of collective housing buildings is 46.8%, while in relation to all types and periods of buildings, it is 12.63%. Although both types of buildings are suitable for modular envelope renovation, this research presents the possibility of energy renovation for the MFH type from the period 1961–1970 and the AB type from the period 1971–1980. For calculation requirements, it was assumed that the entire building surface used for residential purposes was heated. In regional countries, it was estimated that only 50% of households heated over 50% of the conditioned area (Csoknyai et al. 2016), whereas indicators for the EU countries are somewhat better (Atanasiu et al. 2014). Multi-family housing buildings are important for this research, and the energy required for heating is estimated. Expert calculations estimate the energy needed for heating individual buildings of all types, as shown in Table 18.3. It presents a comparison of B&H and Serbia by types MFH and AB for the construction period of 1961–1970 and 1971–1980.

Table 18.2 Number of residential buildings, apartments and gross surface in comparative countries

	Bosnia and Herzegovina			Serbia		
	No. of buildings	No. of apartment	Gross area of buildings (m^2)	No. of buildings	No. of apartment	Gross area of buildings (m^2)
SFH and TH	841,543	1,076,240	124,683,708	2,186,246	2,327,707	176,048,838
MFH and AB	20,422	542,945	38,244,921	60,074	860,707	113,638,882
Total	861,965	1,619,185	162,928,629	2,246,320	3,188,414	289,687,720
MFH and AB (1961–1980)	9535	297,644	21,923,226	24,372	402,891	49,160,278
MFH and AB (1961–1970)	5176	119,474	7,985,112	9640	138,955	15,930,173
MFH and AB (1971–1980)	4359	178,170	13,938,114	14,732	263,936	33,230,105
MFH (1961–1970)	3012	50,541	3,184,346	7285	91,109	8,690,967
AB (1971–1980)	2156	125,298	10,350,518	4752	131,135	19,899,758

Table 18.3 Comparison value of energy needed for heating on representative residential buildings in Bosnia and Herzegovina and Serbia (kWh/m^2 a)

Country	Bosnia and Herzegovina—$Q_{h,nd}$		Serbia—$Q_{h,nd}$	
Building type	Multi-family house/MFH	Apartment block/ AB	Multi-family house/MFH	Apartment block/ AB
1961–1970	188.44	153.06	172.00	159.00
1971–1980	146.80	130.90	191.00	158.00

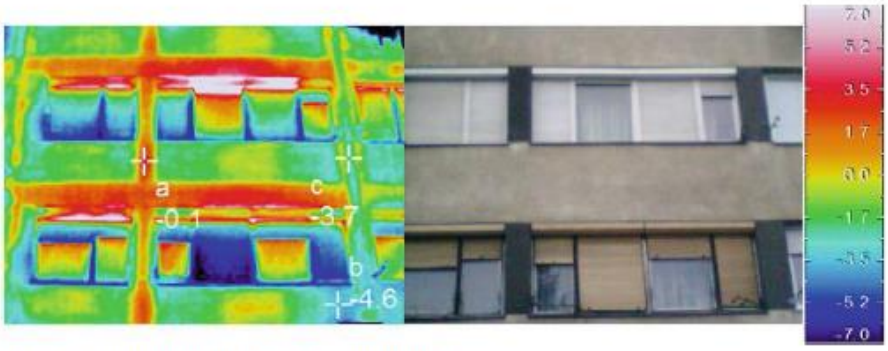
An assessment of such indicators of the energy need for heating shows that although the same name and period of construction, especially since the two countries were under the same legal regulations and requirements for the building envelope until the 1980s, can only indicate higher shape factors of the selected representative examples of MFH and AB buildings for the period 1971–1980 in Serbia. Comparison value of energy needed for heating, for the period 1961–1970, Serbia has a 9% lower value for MFH and a 4% higher value for AB, and for the period 1971–1980, Serbia has a 23% higher value for MFH and a 17% higher value for AB.

18.3.2 Case Study of Energy Savings Potential with Modular Envelope Renovations of Residential Building

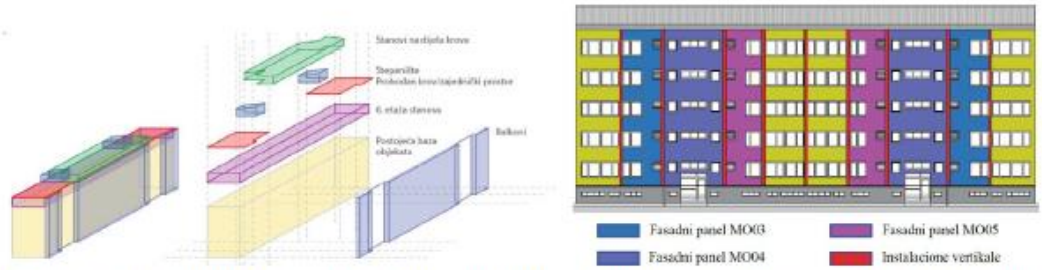
The case study shows a sample of buildings in Banja Luka (Bosnia and Herzegovina). Representative samples of the existing residential building are determined by a detailed energy audit—determining the specific energy consumption for heating using a standard which is still in force in B&H, EN ISO 13790:2008—Energy performance of buildings—Calculation of energy use for space heating and cooling. Sample 1 of the characteristic period (1961–1970) led to the conclusion that the real Sample from 1964 has a lower specific energy need for heating—QH, and than the representative building of AB from the same period of construction from Typology, Table 18.4.

Representative Sample 1, which was built in the period after the Second World War rather than in 1964, is a masonry construction of five-story brickwork, only with horizontal reinforced concrete ring beams. After the earthquake in Banja Luka in 1969, we were given vertical reinforced concrete columns and additional reinforced concrete walls for refurbishment. This building does not possess thermal insulation in the walls, floor, and roof, and it has a couple of wooden windows—windows glazed with two single glasses. Sample 1 is a compact building, rectangular in shape with no sunshade element like an overhang, balcony or loggias, with the form factor of the building (A/V ratio) of 0.40. A detailed energy audit was conducted for the building. The calculated value of the energy needed to heat the existing selected sample corresponds to the average value stated for typical buildings in the Typologies of B&H and Serbia. Table 18.4. By applying cost-optimal measures on the sample

Table 18.4 Comparative review of the energy needs for heating of representative sample 1 of the existing residential building before and after renovation of the building envelope



Thermal-vision image before renovation



Design for the renovation of the building envelope—3D view and segment of the façade (Huseinbašić et al.)

Period		1964	
Dimension		10 × 42 m	
Heated space area		2025 m^2	
No. of floors		P + 4	
Heated space volume		5670 m^3	
Heat capacity	Wh/m^2 a	72	
Metabolic heat from person	W/m^2	3.8	
Orientation		NW—SE	
		Before	After
U-value walls	W/m^2 K	2.03	0.30
U-value windows	W/m^2 K	3.12	1.60
U-value roof	W/m^2 K	1.64	0.20
U-value floor	W/m^2 K	1.02	0.30
G-value	–	0.49	
A/V ratio	–	0.40	
Percentage of window area	%	23.70	
Infiltration	1/h	0.60	0.50

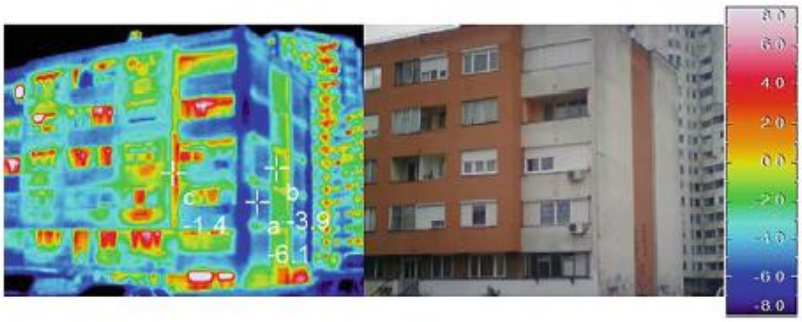
(continued)

Table 18.4 (continued)

		Before	After
Internal temperature	°C	20.0	20.0
Setback temperature	°C	16.7	16.7
Internal heat gains			
Ventilation	kWh/m^2 a	0.0	0.0
Lighting	kWh/m^2 a	2.6	2.6
Various equipment	kWh/m^2 a	13.5	13.5
Energy need for heating	kWh/m^2 a	164.4	31.2

envelope, it is possible to lower the value of the energy needed for heating below 40 kWh/m^2 (31.2 kWh/m^2). Sample 2 of the characteristic period (1971–1980) led to the conclusion that real Sample 2 from 1974 has a lower specific energy need for heating—QH, and than the representative building of AB from the same period of construction from Typology, Table 18.5. Representative Sample 2, an existing residential five-story building, which was built in the period 1971–1980 rather than 1974, is a skeleton structural system Zezelj—"IMS" of precast prestressed columns and floors. Facade walls are prefabricated sandwich panels with 3 cm of insulation pressed cane and wooden couple windows—windows glazed with two single glasses. Sample 2 is rectangular in shape, but the building has an overhang and lots of loggias, with the form factor of the building (A/V ratio) of 0.46. A detailed energy audit was conducted for the building. The calculation was guided by the design parameters of the building envelope characteristic for the specified period, with data characteristic of the real environment of the building (climate data and built environment) and the use of the building (building users and devices). The calculated value of the energy needed for heating the existing selected sample corresponds to the average value stated for typical buildings in the Typologies of B&H and Serbia. Table 18.5. By applying cost-optimal measures on the sample envelope, it is possible to lower the value of the $Q_{H,nd}$ = 40 kWh/m^2 (39.3 kWh/m^2). Sample 1 shows five modules were defined as total façade envelope, and in the second case, for Sample 2, three modules and five submodules were defined as total façade envelope (façade panels made with wooden substructure filled with thermal insulation with wooden frame windows) with energy characteristics defined by cost-optimal analysis in B&H. The renovation of the building envelope was done from the conceptual design to the details, with energy analysis bill of quantities and recalculation of works, in order to determine energy savings and economic viability of the investment. The solution is guided by prices from 2021. It was concluded that in addition to the renovation of the envelope, it is necessary to upgrade the building with new dwellings and the addition of new technical systems for energy production to enable their initial investment in such renovation.

Table 18.5 Comparative review of the energy needs for heating of representative sample 2 of the existing residential building before and after renovation of the building envelope



Thermal-vision image before renovation



Design for the renovation of the building envelope—3D view and segment of the facade (Murguz et al.)

Period		1974	
Dimension		13.65 × 106 m	
Heated space area		6315 m^2	
No. of floors		P + 4	
heated space volume		17,682 m^3	
Heat capacity	Wh/m^2 a	46	
Metabolic heat from person	W/m^2	4.9	
Orientation		E—W	
		Before	After
U-value walls	W/m^2 K	1.35	0.30
U-value windows	W/m^2 K	3.08	1.60
U-value roof	W/m^2 K	0.70	0.20
U-value floor	W/m^2 K	1.04	0.30
G-value	–	0.34	
A/V ratio	–	0.46	
Percentage of window area	%	19.90	
Infiltration	1/h	0.50	0.50

(continued)

Table 18.5 (continued)

		Before	After
Internal temperature	°C	20.0	20.0
Setback temperature	°C	16.6	16.6
Internal heat gains			
Ventilation	kWh/m^2 a	0.0	0.0
Lighting	kWh/m^2 a	2.5	2.5
Various equipment	kWh/m^2 a	12.0	12.0
Energy need for heating	kWh/m^2 a	157.7	39.3

18.4 Comparative Analysis of Energy Savings

Following the same standard EN ISO 13790 standard, energy requirements of buildings are calculated and expressed in Typologies of buildings in Bosnia-Herzegovina and Serbia. In typologies of building are stated energy savings after applying the measures on the building envelope, which are governed by the valid country regulations and called the standard improvement of building energy performance.

Standard improvement measures in typology of residential building defined in accordance with usual measures applied during building reconstruction in the territory of B&H (improvement of thermal characteristics of walls and ceilings by technically common procedures—added thermal insulation 10 cm thickness with $\lambda = 0.041$ W/mK) as well as a possible replacement of existing windows with new ones (defined minimal U-value 1.60 W/m^2 K). In Serbia, the measures applied from valid regulation for existing buildings (external walls 0.4 W/m^2 K, roof 0.2 W/m^2 K, windows 1.5 W/m^2 K and floor 0.4 W/m^2 K). Tables 18.4 and 18.5 analyse the current condition of buildings and their values of QH and representative types; examples of the case study from B&H are closer to the values of QH and types of Serbia.

Applying these measures to restore the envelope in typologies would create a 60% lower QH in buildings in B&H, while in Serbia, it is possible to have a 48% lower QH in buildings. The reason for this can be found in the fact that in B&H type AB, the existing condition has a lower value of QH. In case studies, Sample 1 and Sample 2 were treated with cost-optimal measures in the B&H area, which is listed in Tables 18.4 and 18.5, and which leads to savings of 81% for MFH type and 75% for AB type. For these characteristic types of buildings, which could be renovated in a modular system, we can analyse the possibilities of energy savings in MWh/a by country, applying standard measures from Typology and cost-optimal measures applied in the case study.

Tables 18.6 and 18.7 shows that the amount of energy can be further saved by applying cost-optimal measures compared to standard measures listed in the Typologies—in B&H for type MFH an additional 63,632 MWh/a, which represents an additional about 23.3%, while in Serbia for type MFH it can be saved another 424,148 MWh/a which is an additional 43.4% on savings from standard measures.

Table 18.6 Comparative representation of $Q_{H,and}$ in kWh/m^2 of representative examples of MFH buildings, before and after applying standard measures in typologies of B&H and Serbia and from case study

Type	MFH	MFH
	Before measure	After
1961–1970 B&H	188.44	67.86
1961–1970 Serbia	172.00	55.00
1964 (case study)	164.40	31.20

Table 18.7 Energy need for heating of MFH in B&H and Serbia before and after standard measures and case study measures (MWh/a)

MFH	MFH	MFH	MFH	MFH
Before measure	After measure from typology	Saving energy	After measure from case study	Saving energy
327,081	117,787	209,294	54,155	272,926
1,532,704	981,213	551,941	556,615	976,089

Tables 18.8 and 18.9 shows that the amount of energy can be further saved by applying cost-optimal measures compared to standard measures listed in the Typologies - in B&H for type AB an additional 129,381 MWh/a, which represents an additional 13.6%, while in Serbia for type AB it can be saved another 961,343 MWh/a energy, which is an additional 35% on savings from standard measures.

Table 18.8 Comparative representation of $Q_{H,nd}$ in kWh/m^2 of representative examples of AB buildings, before and after applying standard measures in typologies of B&H and Serbia and from case study

TYPE	AB	AB
	Before measure	After measure
1971–1980 B&H	130.90	51.80
1971–1980 Serbia	158.00	81.00
1974 (case study)	157.70	39.30

Table 18.9 Energy need for heating of AB in B&H and Serbia before and after standard measures and case study measures (MWh/a)

AB	AB	AB	AB	AB
Before measure	After measure from typology	Saving energy	After measure from case study	Saving energy
1,354,882	536,156	818,726	406,775	948,107
3,642,500	1,867,357	1,775,143	906,014	2,736,486

18.5 Conclusion

Currently, the new EU strategy for sustainable renovation of buildings favours deep renovation, with energy savings of about 60%. The analysis shows that cost-optimal measures, with slightly more demanding U-values for the non-transparent part of the envelope (external walls 0.30 W/m^2 K, roof 0.20 W/m^2 K and floor 0.30 W/m^2 K) than standard measures in Serbia and Bosnia and Herzegovina, and even less demanding U-value for windows (1.60 W/m^2 K), for MFH buildings can save 272,926 MWh/a in B&H and 976,089 MWh/a in Serbia and for AB buildings can save 948,107 MWh/a in B&H and 2,736,486 MWh/a in Serbia. This case study showed that it is possible to lower the value of energy needed for heating below 40 kWh/m^2 or, according to the requirements of the Strategy, to create savings of 60% (from case studies, 81% for MFH and 75% for AB). In addition, as the New Renovation Wave Strategy in one of the key principles of building renovation towards 2030 and 2050 expands the use of organic building materials, case studies have shown the application of cost-optimal measures through modular systems in organic materials, systems that could accommodate new technical systems, which should be considered in future research in the case of renovation of buildings according to nZEB standards.

References

International Energy Agency, Overview for Bosnia and Herzegovina. (On-line). Available: https://www.iea.org/countries/bosnia-and-herzegovina

International Energy Agency, Overview for Serbia. (On-line). Available: https://www.iea.org/countries/serbia

European Commission (2020) Renovation wave strategy. Available online: https://ec.europa.eu/energy/sites/ener/files/eu_renovation_wave_strategy.pdf

European Union Parliament and Council; Regulatory Commission; Regulation No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements

Government of the Republic of Serbia, Ministry of Civil Engineering, traffic and infrastructure (MGSIRS) (2022). https://www.mgsi.gov.rs/sites/default/files/Predlog%20Dugorocne%20strategije%20PUONFZRS.pdf

Sudimac B, Gajić D, Peulić S (2022) Energy renovation of residential building envelope using organic materials for the level of cost-optimal improvement/upgrade in Bosnia-Herzegovina and Serbia. In: STEPGRAD2022 conference, Banja Luka, Bosnia and Herzegovina

Republic of Srpska Goverment, Energy Efficiency Law, https://ekofondrs.org/sadrzaj/dokumenti/ee/zakon_o_energetskoj_efikasnosti.pdf

Republic of Srpska Goverment, Regulation on minimum requirements for energy performance of buildings, https://ekofondrs.org/sadrzaj/dokumenti/ee/Pravilnik_o_minimalnim_zahtjevima_za_energetske_karakteristike_zgrada.pdf

Gajić D, Peulić S, Mavrič T, Sandak A, Tavzes Č, Malešević M, Slijepčević M (2021) Energy retrofitting opportunities using renewable materials—comparative analysis of the current frameworks in Bosnia-Herzegovina and Slovenia. Sustainability 13(2):603

Peulić S, Gajić D, Sandak A, Tavzes Č, Mavrič T, Rašović J, Slijepčević M, Antunović B, Malešević M, Okilj U (2023) Towards deep energy retrofitting: an overview and possibilities for Slovenia and Bosnia-Herzegovina. In: ENEF 2023 conference, Banja Luka, Bosnia and Herzegovina

Peulić S, Gajić D (2022) Influential parameters on the adaptability of taller timber buildings. COST ACTION CA 20139, holistic design of taller timber buildings (HELEN), STATE OF THE ART REPORT. COST Association, Brussels, Belgium

Heikkinen P, Kaufmann H, Winter S, Larsen KE (2009) Energy Façade—prefabricated timber-based building system for improving the energy efficiency of the building envelope, research project from 2008–2009. Wood wisdom-Net, Helsinki

Zimmermann Mark (2012) ECBCS Annex 50 prefabricated systems for low energy renovation of residential buildings: project summary report

BERTIM (2019) Innovative wood prefabrication for energy efficient renovations. Project Results Booklet

Volf M, Hejtmánek P, Lupíšek A, Kalamees T, Christensen F, Olesen S, van Oorschot JAWH, Mørck OC, Borodinecs A, Šenfeldr P (2018) Development and advanced prefabrication of innovative, multifunctional building envelope elements for modular retrofitting and connections. A set of basic modular facade and roof elements, including renewable energy production and integration of HP insulation

EPISCOPE.EU. BA Bosnia and Herzegovina—country page, National Building Typologies. Accessed 3 May 2023. https://episcope.eu/building-typology/country/ba/

EPISCOPE.EU. RS Serbia—country page country page, National Building Typologies. Accessed 3 May 2023. https://episcope.eu/building-typology/country/cy/

Arnautović-Aksić D, Mladen B, Nijaz D, Darija G, Petar G, Džana K, Milovan K, Erdin S, Darko T, Nermina Z (2016) Typology of residential buildings of Bosnia and Herzegovina. Faculty of Architecture, University of Sarajevo, Sarajevo

Popović J, Milica ID, Ana R, Aleksandra R, Ljiljana Đ, Nataša ĐI, Miloš N (2013) National typology of residential buildings in Serbia. Faculty of Architecture University of Belgrade, Beograd

Loga T, Stein B, Diefenbach N (2016) TABULA building typologies in 20 European countries—making energy-related features of residential building stocks comparable. Energy Build 4–12

Giebeler G, Fisch R, Krause H, Musso F, Petzinka K-H, Rudolphi A (2009) Refurbishment manual. Birkhäuser, Basel, Boston, Berlin

Pye S, Dobbins A. Energy poverty and vulnerable consumers in the energy sector across the EU: analysis of policies and measures. https://energy.ec.europa.eu/system/files/2015-07/INSIGHT_E_Energy%2520Poverty_Appendices_0.pdf

Csoknyai T, Hrabovszky-Horváth S, Georgiev Z, Jovanovic Popovic M, Zeković B, Villatoro O, Szendrő G (2016) Building stock characteristics and energy performance of residential buildings in eastern-European countries. Energy Build 39–52

Atanasiu B, Kontonasiou E, Mariottini F (2014) Alleviating fuel poverty in the EU. Investing in home renovation, a sustainable and inclusive solution. In: Buildings performance institute Europe (BPIE)

Huseinbašić E, Jojić A, Petrović S, Jović D, Radaković M. Design for the renovation of building envelope_Distribution of characteristic TES modules on the facade envelope (course "Team project" on Master study "Energy Efficiency of Buildings" at University of Banjaluka)

Murguz A, Malešević N, Šućur A. Design for the renovation of building envelope_Distribution of characteristic TES modules on the facade envelope (course "Team project" on Master study "Energy Efficiency of Buildings" at University of Banjaluka)