ENERGY SAVINGS POTENTIAL IN MODULAR ENVELOPE RENOVATIONS OF PREFABRICATED RESIDENTIAL BUILDINGS IN BOSNIA-HERZEGOVINA AND SERBIA

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ABSTRACT

In the light of the development of new construction systems and envelopes based on renewable and natural materials, that is recently obligatory for the EU member countries through New renovation Wave strategy, 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 paper presents energy savings, through case study of deep renovation of buildings, using timber modular systems for enveloping the characteristic example of residential building. Paper focuses on the period between 1971 and 1980, due to the considerable number of modular buildings designed during the peak of the construction progress and promotion of prefabricated buildings. Total potential energy savings for such building types is considered according to national typologies of residential buildings in Bosnia and Herzegovina and Serbia. Through a comparative analysis of these countries, the paper presents following parameters of buildings built in period 1971-1980: total number of buildings, total number of apartments, average energy need for heating - Qh,nd, and total energy need for heating before and after the renovation of the envelope applying standard measures from national typologies and applying timber modular envelope systems, which have the potential for deep renovation of buildings.

KEYWORDS _ *renovation strategies, deep energy refurbishment, residential buildings, timber systems, modular envelopes*

INTRODUCTION

In order to achieve the planned total reduction 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 (Renovation Wave Strategy, 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 for 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, thought case study of energy renovation of existing prefabricate residential building. The Strategy for the Renovation of Buildings in Bosnia and Herzegovina (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, however they do not emphasize the refurbishment of building envelopes by renewable and organic products and materials, but only the use of renewable energy sources (MGSIRS, 2022 and Sudimac et. al., 2022).-The starting point for the formation of the Strategy in B&H are the cost-optimal analyses for residential and non-residential buildings done during 2016-2017. In Serbia the formation was based on residential and non-residential buildings done during 2019-2020, developing five potential renovation scenarios, according to level of energy saving potential. Strategy states that the greatest energy savings, about 60%, will be when we apply all valid new U-values on envelope (Rulebook on minimum requirements for energy characteristics of buildings, Of. Gaz. RS n. o. 30/15). Scenario 4 in Serbia is considered as deep renovation, because Scenario 5 is intended for n-ZEB, 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 required for heating, by 60%.

MODULAR ENVELOPE RENOVATION FOR RESIDENTIAL BUILDINGS

Over the years, renewable materials could not find path towards serious use in analysed countries. Reason for these lays in three main factors which are: higher price of renewable materials; poor industrial capacity and lack of knowledge; lack of public awareness on natural, bio-based materials importance in energy renovation (Gajić et. al., 2021). Building stock in both countries became old and in the condition which is already becoming questionable whether 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 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 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 et. al., 2022) Traditional systems with contact façades are most accepted because they are the cheapest and most often used, however, over time, the question of 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, mainly due to the lack of interest, but also legislation that defines the of the carbon footprint of materials used in construction, or missing understanding and rules on life cycle analysis.

Developed EU countries succeeded in implementing these solutions in AEC practice. Topic of modular prefabrication gained serious through several projects developed in 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 its segments with the help of prefabricated spatial structures. Further research developed in recent years promoted different approaches on methodological solutions with emphasis on several key points presented in Table 1. Considering the pedigree of the projects and participant countries it is possible to note similar approaches with different outcomes.

Table 1: Overview of the key outputs from projects developed in 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	-	-	+	-	+
Existing 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-equiped with HVAC systems	-	+	+	+	+
Software	Automated panel distribution	-	+	-	-	-
	Off-site fabrication	+	-	+	+	+
	Robotic manufacturing and new algorithms	-	+	-	-	-

ENERGY SAVINGS POTENTIAL IN MODULAR ENVELOPE RENOVATIONS OF PREFABRICATED RESIDENTIAL BUILDINGS IN BOSNIA-HERZEGOVINA 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). Both project Typologies of Residential Buildings in Bosnia and Herzegovina (Typology of Residential Buildings in B&H, 2016) and Serbia (National Typology of Residential Buildings in Serbia, 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

4 categories and 6 periods, and for Serbia 31 buildings divided into 4 categories and 8 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.

Existing residential building stock for energy renovation modular envelope

The potential of construction period between 1971 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. 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), Figure 1., and that their number of floors is 4 or more with at least 20 apartments within such structures.

Figure 1: Part from Typology of residential buildings from period 1971-1980 for Serbia (up) and for B&H (down)

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 (Pye et. al., 2015). From the Typology we can see how many buildings there are free-standing (MFH) and slats (AB) and what is their ratio compared to other types of buildings. The potential building stock over which the building envelope could be upgrade has been examined through a comparative analysis of data on the building stock of both countries. Bosnia and Herzegovina and Serbia have a predominantly higher number of buildings / houses intended for individual housing (B&H 97.63%, SRB 97.32%), compared to the number of residential buildings for multi-family housing. Serbia has 61.6% more buildings compared to B&H, from which SFH 56%, TH 72.5%, MFH 73%, and AB 46.6%. Periods 1961-1970 and 1971-1980 for the residential buildings (MFH and AB) has mutually in B&H 9,355 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, what is shown in the Table 2.

Table 2. Number of residential buildings, apartments and gross surface in comparative countries

	Bosna and Herzegovina			Serbia		
	number of buildings	number of apartments	**gross surface of buildings [m²]**	number of buildings	number of apartments	**gross surface of buildings [m²]**
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
MFH and AB (1961-1980)	9,535	297,644	21,923,226	24,372	402,891	49,160,278
MFH and AB (1971-1980)	**4,359**	**178,170**	13,938,114	14,732	263,936	33,230,105
AB (1971-1980)	2,156	125,298	10,350,518	6,628	69,853	23,053,802
Total	861,965	1,619,185	162,928,629	2,246,320	3,188,414	289,687,720

Comparative analysis indicates that although Serbia has a larger number of buildings of all types. For the 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 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 energy required for heating is estimated. Expert calculations estimates of energy need for heating individual buildings of all types and Table 3. It presents comparison of B&H and Serbia by types MFH and AB for the construction period of 1971-1980.

Table 3. Comparison value of energy need for heating on representative residential buildings in Bosnia and Herzegovina and Serbia (kWh/m²a)

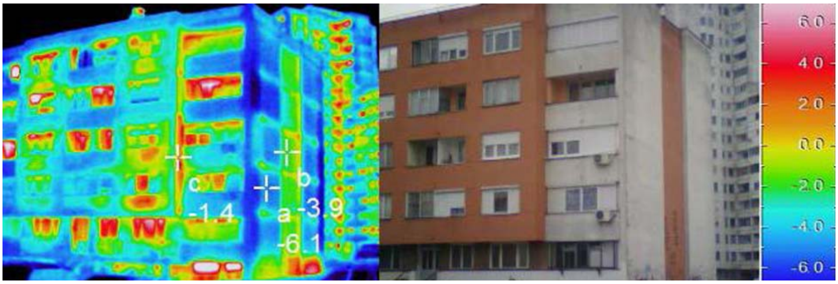
	Bosnia and Herzegovina		Serbia	
Building type 1971-1980 (period)	Multi-family house / MFH	Apartment block / AB	Multi-family house / MFH	Apartment block / AB
$Q_{h,nd}$	146.80	130.90	191.00	158.00

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 period 1971-1980 in Serbia. Comparison value of energy need for heating, Serbia has 23% higher value for MFH and 17% higher value for AB.

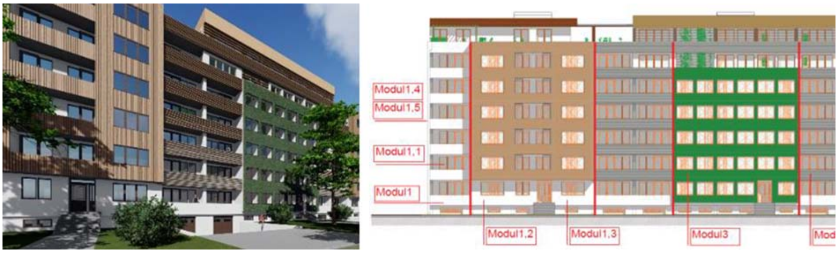
Case study of energy savings potential with modular envelope renovations of residential building

Case study shows sample of buildings in Banja Luka (Bosnia and Herzegovina). Representative samples of the existing residential building is determined by a detailed energy audit - determining the specific energy consumption for heating using EN ISO 13790:2008 - Energy performance of buildings – Calculation of energy use for space heating and cooling. The Sample of characteristic period (1971-1980) led to the conclusion that real Sample from 1974 has a lower specific energy need for heating – $Q_{H,nd}$ than representative building of AB from same period of construction from Typology, Table 4.

Table 4: Comparative review of the energy need for heating of representative sample of existing residential building before and after renovation of building envelope



Thermal-vision image before renovation



Desing for the renovation of the building envelope – 3D view and segment of the facade, source: student project developed on Master of Energy Efficiency in Buildings at University of Banja Luka

PERIOD		1974	
DIMENSION		13.65x106m	
HEATED SPACE AREA		6315m²	
No OF FLOORS		P+4	
HEATED SPACE VOLUME		17682m³	
heat capacity	Wh/m²a	46	
metabolic heat from person	W/m²	4.9	
ORIENTATION		E - W	
		BEFORE	AFTER
U-value WALLS	W/m²K	1.35	0.30
U-value WINDOWS	W/m²K	3.08	1.60
U-value ROOF	W/m²K	0.70	0.20
U-value FLOOR	W/m²K	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
		BEFORE	AFTER
internal temperature	°C	20.0	20.0
setback temperature	°C	16.6	16.6
internal heat gains			
Ventilation	kWh/m²a	0.0	0.0

Lighting	kWh/m²a	2.5	2.5
various equipment	kWh/m²a	12.0	12.0
ENERGY NEED FOR HEATING	kWh/m²a	157.7	39.3

Sample is rectangular in shape, but the building has a overhangs and lots of loggias, with form factor of the building (A/V ratio) of 0.46. A detailed energy audit was conducted for 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 4. 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. The project of renovation of the envelope of the sample buildings in the modular system, which described in paragraph before, was developed at the combined master study "Energy efficiency in buildings" at the University of Banja Luka. In this case five modules were defined 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 and 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.

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 buliding 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.

In Bosnia-Herzegovina, the measures applied are more demanding for the wall and window than prescribed in the Federation of Bosnia-Herzegovina regulation, while in entity Republic of Srpska they reach the U-value for windows and do not reach the predicted U-value for walls. 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 λ=0.041W/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). Table 4. is analyzing the current condition of buildings and their values of $Q_{H,nd}$ of representative types, examples of the case study from B&H are closer to the values of $Q_{H,nd}$ types of Serbia.

Table 5: (left) Comparative representation of $Q_{H,nd}$ in kWh/m² of representative examples of AB buildings, before and after applying standard measures in Tipologies of B&H and Serbia and from case study; **Table 6:** (right) Energy need for heating of AB in B&H and Serbia before and after standard measures and case study measures (MWh/a)

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

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

Applying these measures to restore the envelope in Typologies, would create 60% lower $Q_{H,nd}$ in buildings in B&H, while in Serbia is possible 48% lower $Q_{H,nd}$ of buildings. The reason for this can be found in the fact that in B&H types AB existing condition has a lower value of $Q_{H,nd}$. In case study, Sample were treated with cost-optimal measures in the B&H area, which is listed in Table 4, and which leads to savings of 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. Table 6. 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 about 24%, while in Serbia for type MFH about 51.5%.

CONCLUSIONS

Currently, new EU strategy favours deep renovation, with energy savings 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/m²K, roof 0.20 W/m²K and floor 0.30 W/m²K) than standard measures in Serbia and Bosnia and Herzegovina, and even less demanding U-value for windows (1.60 W/m²K), for AB can save 948,107 MWh/a in B&H and 2,736,486 MWh/a in Serbia. This case study, which reaches the above measures, showed that it is possible to lower the value of energy need for heating below 40 kWh/m², or according to the requirements of the Strategy to create savings 60% (from case study 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 these cost-optimal measures through a modular system 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.

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