PROCEEDINGS OF

International conference on Contemporary Theory and Practice in Construction XV

Banja Luka, June 16–17, 2022

ЗБОРНИК РАДОВА

Међународне конференције Савремена теорија и пракса у градитељству XV

Бања Лука, 16–17.06.2022.

STEPGRAD
СТЕПГРАД
2022

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INTERNATIONAL CONFERENCE ON CONTEMPORARY
THEORY AND PRACTICE IN CONSTRUCTION XV

МЕЂУНАРОДНА КОНФЕРЕНЦИЈА
САВРЕМЕНА ТЕОРИЈА И ПРАКСА У ГРАДИТЕЉСТВУ XV

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STEPGRAD XV

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FOREWORD

It is our great pleasure to write this Foreword to the Proceedings of the International Conference on Contemporary Theory and Practice in Construction, XV - STEPGRAD. The Conference was held on June 16 and 17 at the Lanaco Technology Center in Banja Luka. As in previous years, the Conference STEPGRAD XV continues a tradition of bringing together researchers, academics, and professionals from all over the world, experts in Civil Engineering, Architecture, Geodesy, and related fields, so this year it brought participants from fifteen different countries. The Conference enables the interaction of research students, young academics and engineers with the more experienced academic and professional community to present and discuss current accomplishments. Their contributions make these Proceedings outstanding. The published papers provide the most recent scientific and professional knowledge in the fields of Computational mechanics, Structural engineering, Building materials, Road planning, Energy efficiency, Urban planning, Architecture, History of architecture, Surveying, Education of engineers, etc.

Almost eighty manuscripts were submitted, while 70 of them were accepted and categorized. Each contributed paper was refereed by the two reviewers, members of the Scientific Committee. The papers were refereed based on their interest, relevance, innovation, and application to the broad field of Construction. Invited lecturers this year were associate professor Gordana Kaplan, PhD, from the Technical University of Eskisehir in Turkey, associate professor Daniel Lordik, PhD, from the Technical University of Dresden, associate professor Ana Nikezić, PhD, from the University of Belgrade and Filip Niketić, PhD, from the project company Nicolas Fehlmann Ingénieurs Conseils SA in Switzerland.

These Proceedings will furnish the scientists and professionals with an excellent reference book. We are certain it will give an impetus for further studies in all subject areas.

We thank all the authors and reviewers for their valuable contributions. Special thanks go to our sponsors and the members of the Organizational Committee and Working team.

Snježana Maksimović
Sandra Kosić-Jeremić
Editors

ПРЕДГОВОР

Изузетно нам је задовољство написати овај Предговор за Зборник радова са међународне конференције Савремена теорија и пракса у градитељству XV – СТЕПГРАД. Конференција је одржана 16. и 17. јуна у Технолошком центру компаније Ланако у Бањој Луци. Као и претходних година, конференција СТЕПГРАД XV наставља традицију повезивања истраживача, наставника и стручњака из цијелог свијета, експерата грађевинарства, архитектуре, геодезије и сродних области, па је ове године окупила учеснике из петнаест различитих земаља. Конференција је омогућила интеракцију студената, младих инжењера и научника са искуснијим члановима академске и стручне заједнице у циљу дискусије о савременим тенденцијама у градитељству. Њихов допринос је учинио овај Зборник изузетним. Објављени радови пружају увид у актуелно научно и стручно знање из рачунске механике, инжењерских конструкција, грађевинских материјала, саобраћајница, енергетске ефикасности, урбанизма, архитектуре, историје архитектуре, геодезије, образовања инжењера, итд.

Од скоро осамдесет достављених рукописа, 70 је прихваћено и категорисано. Сваки рад је био прегледан од стране два рецензента, члана Научног одбора. Критеријуми за одабир радова су били њихова актуелност, значај и допринос широкој области градитељства. Позивни предавачи ове године били су проф. др Гордана Каплан са Техничког универзитета Ескишехир у Турској, проф. др Даниел Лордик са Техничког универзитета у Дрездену, проф. др Ана Никезић са Универзитета у Београду и др Филип Никетић из пројектне компаније Nicolas Fehlmann Ingénieurs Conseils SA у Швајцарској.

Овај Зборник радова ће послужити као корисна референца стручњацима и истраживачима те смо сигурни да ће пружити подстицај за даља истраживања у предметним областима.

Захваљујемо свим ауторима и рецензентима на њиховом изузетном доприносу. Посебну захвалност упућујемо нашим спонзорима те свим члановима Организационог одбора и Радног тима.

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ENERGY RENOVATION OF RESIDENTIAL BUILDING ENVELOPE USING ORGANIC MATERIALS FOR THE LEVEL OF COST-OPTIMAL IMPROVEMENT/ UPGRADE IN BOSNIA-HERZEGOVINA AND SERBIA

Abstract

Towards building renovation strategies, the research is led by a very deep renovation of residential buildings, which would reduce the energy need for heating below 40 kWh/m^2 or create energy savings 60%. The renovation of the building envelope, guided by organic materials (such as wood), which is in the one of key principles in the New Renovation Wave Strategy of the European Union from October 2020, is presented in the paper. Energy saving made by renovating building envelopes using wooden modular systems, are shown through characteristic building on which their application is adequate. Case study from Bosnia and Herzegovina indicate possible energy savings of 81% for residential type Multi-family houses – MFH from period 1961-1970.

Keywords: building renovation strategies, modular building envelope, wood, energy savings

ЕНЕРГЕТСКА ОБНОВА ОМОТАЧА СТАМБЕНИХ ЗГРАДА КОРИШЋЕЊЕМ ОРГАНСКИХ МАТЕРИЈАЛА ЗА НИВО ТРОШКОВНО-ОПТИМАЛНОГ УНАПРЕЂЕЊА У БИХ И СРБИЈИ

Сажетак

У сусрет стратегијама обнове зграда, истраживање се води веома дубоком обновом стамбених зграда, којом би се смањила вриједност потребне енергије за гријање испод 40 kWh/m^2 или створити уштеду енергије за 60%. Представљена је обнова омотача стамбених зграда која се води органским материјалима, као што је дрво, што представља један од кључних принципа Нове стратегије обнове зграда европске уније из октобра 2020. године. Енергетска уштеда, обновом омотача зграда, кориштењем дрвених модуларних система, приказана је на карактеристичној типској згради. Студија случаја из Босне и Херцеговине указује на потенцијал енергетске уштеде од 81% за стамбени тип зграде – MFH из 1961-1970.

Кључне ријечи: стратегије обнове зграда, модуларни омотач зграда, дрво, уштеде енергије

1. INTRODUCTION

Buildings account for about 40% of total energy consumption in the EU and they are responsible for 36% of greenhouse gas emissions [1].

In countries with higher energy intensity (units of primary energy consumption per unit of GDP of country), energy consumption in buildings is even higher than 50%. The energy intensity of was estimated at 0.40 for B&H [2] and at 0.34 for Serbia [3] (tone of oil equivalent (toe) / 1000 USD of GDP) according to data from the International Energy Agency from 2019. Bosnia and Herzegovina has almost 60% of total energy consumption in buildings [4].

Each EU member state is obliged to adopt documents related to energy savings (National Energy and Climate Plan, and the Strategy for Renovation of Buildings). All countries have the highest energy consumption in buildings, which is why building renovation strategies are being developed and after every 3 years the documents are revised, so that the energy saving plan can be monitored.

According to Renovation Wave Strategy, which the EU recently announced in October 2020, [5] only 11% of the EU existing building stock undergoes some level of renovation each year. However, very rarely, renovation works address energy performance of buildings. The weighted annual energy renovation rate is low at some 1%. Across the EU, deep renovations that reduce energy consumption by at least 60% [6] are carried out only in 0.2% of the building stock per year and in some regions, energy renovation rates are virtually absent. At this pace, cutting carbon emissions from the building sector to net-zero would require centuries.

The most important part of the new strategy are sets out key principles for building renovation towards 2030 and 2050, which, among other things, promote the use of organic materials.

Bosnia and Herzegovina, as well as Serbia, although not members of the European Union, are signatories to the Treaty establishing the Energy Community, [7] [8] which is why they are obliged to draft a Building Renovation Strategy. The obligation to draft the Strategy derives from the Decision of the Ministerial Council of the Energy Community from October 2015 [9] by which the Energy Community adopted the binding application of Directive 2012/27 / EU on energy efficiency [10] from the 2017.

The Strategy for the Renovation of Buildings in Bosnia and Herzegovina (by entities, the Strategy for the Renovation of Buildings in The Republic of Srpska until 2050) was presented to the general public at the ENEF Symposium in November 2019 [10], but has not yet been officially adopted. Encouraging investment in the renovation of the national building fund of the Republic of Serbia presented in November 2021 [11]. The Strategies of B&H and Serbia are guided by cost-optimal analyzes prescribed by Regulations No 244/2012 [12]. but do not emphasize the refurbishment of building envelopes by renewable and organic products and materials, but only the use of renewable energy sources.

The research deals with the presentation of modular renovations of buildings in the European Union, which can mostly use organic construction materials, and the presentation of possible applications on existing buildings in Bosnia and Herzegovina and Serbia. In addition, this method of renovation not only follows the key principles for building renovation in the Renovation Wave Strategy, but also allows for improvement to the level of very deep building renovation and nZEB standards. Following the National Typologies of Residential Buildings of Bosnia and Herzegovina and Serbia and the level of improvement of the envelope according to cost-optimal analyzes, the potential for energy savings in the renovation of buildings that are primary for renovation due to the construction period, and over which modular renovation can be performed.

2. BUILDING RENOVATION STRATEGIES

Each EU member state is obliged to adopt documents related to energy monitoring and savings, and as all countries have the highest energy consumption in buildings, it is necessary to develop building renovation strategies. Building renovation strategies have been constantly revised in the EU for 3 years, and the EU recently published recommendations for a new strategy, in October 2020. EU members respect the regular creation of documents for a long-term building renovation strategy until 2050 and to date published strategies for 2015, 2018 and 2021.

The European Union Renovation Wave Strategy, published by the European Commission [5], 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.

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 most important part of the strategy are sets out key principles for building renovation towards 2030 and 2050: Energy efficiency first'; Affordability; Decarbonisation and integration of renewables; Life-cycle thinking and circularity; High health and environmental standards; Tackling the twin challenges of the green and digital transitions together and Respect for aesthetics and architectural quality.

Principle of „Life-cycle thinking and circularity" it is clarified with minimising the footprint of buildings requires resource efficiency and circularity combined with turning parts of the construction sector into a carbon sink, for example through the promotion of green infrastructure and the use of organic building materials that can store carbon, such as sustainably-sourced wood.

Building renovation strategies are directly related to the Comprehensive National Energy and Climate Plan on the Comprehensive National Energy and Climate Plan, also known by the acronyms NECP and NEKP. The Government has not yet established the legal basis needed for the National Energy and Climate Plan. An early version of the NECP was submitted to the Secretariat in November 2020. The draft NECP is planned to be submitted to the Secretariat for formal comments by the end of 2021, after entity-level energy and climate plans will have been finalized. [13] Serbia is the last member of the Energy Community to start writing an integrated national energy and climate plan. The finalization of the draft NECP is planned by the end of 2021, followed by adoption by the Government in early 2022. [14]

B&H and Serbia, have Action plans that are insurance models in planning until 2030, and are the basis for NCEP. [15] [16] [17]

Strategies renovation of buildings provides an overview by sector along with a list of barriers, funding opportunities, cost-effective proposals, and available materials and energy potentials from renewable sources and heating systems. The concept of construction and renovation is based on an approach that does not have net greenhouse gas emissions and does not show seismic and fire risks.

The strategy states the development, among other things, of the key parameter on which the energy need for heating depends, the U-coefficients of building envelopes in Serbia and B&H. The values are shown at the time when Serbia was in the former Yugoslavia, together with Bosnia and Herzegovina, then the year of change 2010, which is still valid. The strategy is guided by cost-optimal analyzes of the renovation of models of typical buildings.

Cost-optimal analysis was based on that period of construction and the type of building, and a combination of applied improvement measures. After a cost-optimal analysis, the Strategy also states what the new U-values should be.

The strategy in Bosnia and Herzegovina, which was presented in November 2019, but which has not yet been adopted due to the situation with the Covid virus, and probably also due to the freedom to adopt documents, because they still do not belong to the European Union, but they have some obligations, because they are members of the Energy Community.

Bosnia and Herzegovina created a strategy that was preceded by the development of a Typology of Buildings, followed by a cost-optimal analysis, which considered various variants of the height of the U-values for the building envelope and their performance on the market of country.

The Republic of Srpska (entity of Bosnia and Herzegovina) Building Renovation Strategy assumes three scenarios, representing different levels of ambition for future renovation, based on two drivers: renewal rate, defined as the ratio of the usable floor area of annually renovated buildings to the total usable area of the entire building stock, and depth of renovation, which indicates the energy savings achieved through the choice of renovation measures. [18]

Cost-optimal analysis included different packages of 33 measures to the two most common types of housing: single-family house and multifamily house. Measures that improve the envelope, specifying thickness and thermal conductivity of the material/insulation or U-value of the product-window, are discussed without specifying the use of renewable materials. The measures of improvement of the heating system and domestic hot water (DHW) system mention the centralization of the system and the use of renewable energy sources.

Bosnia and Herzegovina performed an analysis on real buildings and the parameters for the building envelope were taken according to the regulations depending on the period of construction, while Serbia performed an analysis on models which represent partially corrected typical buildings, with all their material and technical features.

In B&H, individual houses built before 1980, are the most vulnerable from the aspect of renovation, because they have the highest level of energy need for heating. In the Strategy concluded that the heated area is larger in houses after 1980, and projection was made on such buildings. And for residential multy-familiy buildings, the period before and after 1980 is also analyzed. Public buiildings were treated as individual houses. The starting point for the formation of the Startegy in B&H are the cost-optimal analyzes for residential and non-residential buildings done during 2016-2017. The local cost is optimum, when, despite some differences in the reference buildings in all cases U-values are: for external walls 0.3 W/m^{2}K, for roof 0.2 W/m^{2}K and for windows 1.6 W/m^{2}K. The strategy states that the greatest energy savings, about 60%, will be when we apply all these measures. By applying all measures, the price of the investment is twice as high, while energy consumption has been reduced by five times. The greatest emission reduction effects can be expected by changing fuels and / or improving the efficiency of heating systems. For multi-family buildings, a pellet heating boiler is preferred. In many places, measures are mentioned to replace old windows with PVC windows, which is unacceptable to write in the strategy, because it automatically favored this type of frame, which is not an organic material.

In Serbia summarizing the periods of construction, two characteristic buildings built before 1960, ie after 1960, were singled out and selected as reference, with the aim of representing the entire construction fund of old buildings and buildings built after the beginning of the application of these regulations, ie. since 2013 (new buildings). The starting point for the formation of the Startegy in Serbia are the cost-optimal analyzes for residential and non-residential buildings done during 2019-2020.

Improvement measures have been defined for all buildings and packages of measures have been formed. Five possible renovation scenarios have been prepared, of which the first, the basic scenario implies unsubsidized renovation and construction according to the current regulations, and the last, most advanced one envisages the renovation of buildings at the level of almost zero energy buildings. Scenario 4 was proposed as the basis for the Strategic Goal of the Republic of Serbia. Scenario 4 is a scenario with an increased coverage and level of improvement of the adopted packages of measures and with an increased reduction of CO2 emissions of 31% compared to the initial situation in 2020 and a reduction of primary energy consumption in 2050 of 38% compared to 2020 consumption. years.

In the strategy of Serbia does not state the cost-optimal level through the U-values of the building envelope. In the current Ordinance on the energy efficiency of buildings, the limit values of the U-coefficients are specifically stated for the renovation of existing buildings and for new buildings. In Serbia, for existing building U-values are: for external walls 0.4 W/m^{2}K, for roof 0.2 W/m^{2}K and for windows 1.5 W/m^{2}K and for floor 0.4 W/m^{2}K and for new building U-values are: for external walls 0.3 W/m^{2}K, for roof 0.15 W/m^{2}K, for windows 1.5 W/m^{2}K and for floor 0.3 W/m^{2}K. [19]

Scenario 4 in Serbia is considered a deep renovation, because Scenario 5 is intended for nZEB, and as BiH 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%.

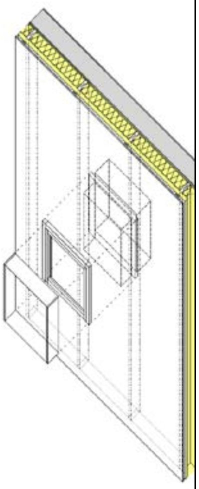
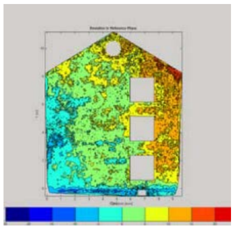
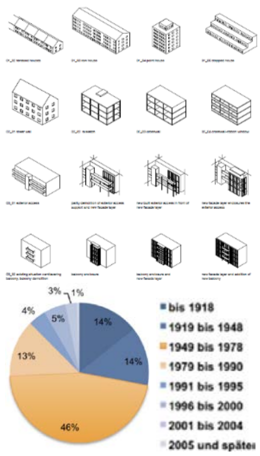
3. DEEP ENERGY RENOVATION OF THE RESIDENTIAL BUILDINGS USING MODULAR PREFABRICATED SYSTEMS

Presented projects show varity of methodologies in research on the prefabricated modules retrofitting. It is interesting to see different approaches in setting typologies, how to classify them in the categories, ways to survey buildings, do building construction and envelope analysis, and see how to set exact aspects that retroffiting should accomplish. Some of the projects mostly answered affirmatively, however some remained unclear on methodology of surveying or building typology classification.

TES Energy Façade (Prefabricated timber based building system for improving the energy efficiency of the building envelope), Table 1, presented a very comprehensive and systematic approach in upgrading buildings energy performance. [20]

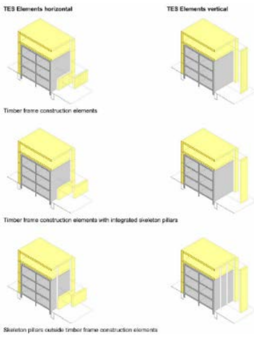
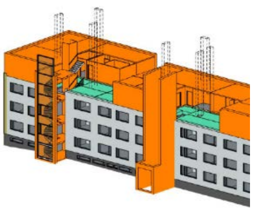
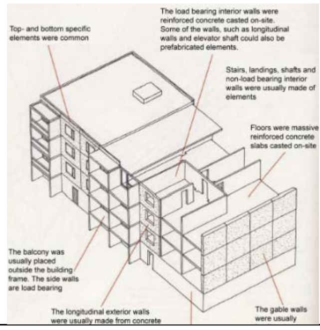
This project is probably one of the most thorough studies on this topic. It shows state of art approach in thinking modular retrofitting. Detailed and systematic division of the building stock according to several criteria (especialy in Germany) enables excelent background for further research and development on modules. A holistic approach in gathering wide range of influencing aspects on design is great methodology in getting most optimal design wich will answer on demanding aesthetical, fire-safety, ecology and energy standards. This project questions not only energy performance of the building, but also, building soft skills such as layout adjustment for future demands, thus prolonging life cycle of the buildings.

Table 1.Key aspects of the TES Energy Façade project [20]

Project name	Countries	Example of the modular panel	Existing structure survey	Building typology
TES EnergyFaçade Prefabricated timber based building system for improving the energy efficiency of the building envelope	Finland, Germany, Norway		Photogrammetry, tachymetry and/or 3D laser scanning of the existing structure. Pictures below shows deviation on the wall surface derived by sophisticated mapping systems. 	

Smart-TES EXTENSIONS is the continuation of the previous project (TES Energy) and is a step forward to building extensions rather than clasic retrofit (usualy narrowed to the envelope level), Table 2. Project results booklet showed several types of these extensions - horizontal, anex, vertical anex, terrase/ balconies anex etc. Since the name is about the extensions, often several stories high, this project explained load transfer - via TES facade and extensions, via esxtensions, via extensions and existing building, via existing building loadbearing structure [20]. Also, functional differentiation is considered since horizontal anexes tipicaly affect existing flats and rooms (layout, ventilation, insolatieon etc.), compared with vertical anex that can perform independently. Prefabricated space modules required special attention for the transport requirenments different among involved countries [20].

Table 2.Key aspects of the Smart-TES EXTENSIONS [21]

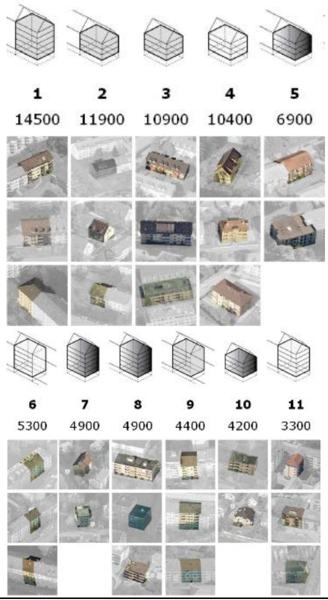
Project name	Countrie s	Example of the modular panel	Existing structure survey	Building typology
Smart-TES EXTENSIONS	Finland, Germany , Norway	 	Existing buildings are measured using special 3D laser scanning technologies to ensure perfect fit of the prefabricated modules to the existing building fabric.	Building typology is now based on research of building components, load-bearing elements and load transfer. This was necessary for development of the modules as annexes that will add significant amount of new load to the structure. 

This study is a good example of the long reasearch projects which are being developed furthermore trough time amd with systematic approach of case-study learining. Buildings upgrades are good principle due to neccessity to reduce needs for demolitions of old buildings, thus make less construction waste in the dumpfields. Old buildings often do not have elevators, have poorly insulated roof or are missing balconies, which are examples also shown in the booklets. This project shows modular examples of how these problems can be overcomed making good scientific and practical background even for other countries with same building stock problems.

ECBCS (Prefabricated systems for Low Energy Renovation of Residential Buildings) is a project 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 3. [22] 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 optimized accordingly what can result in better overall building performance and economical benefit of the investment. Project resulted with 6 successful demonstration sites (*until 2012 report) in Austria, Netherlands and Switzerland. Energy consumption goals were fully achieved; furthermore, with solar installations these demands were reduced almost to zero [22].

Table 3.Key aspects of the ECBCS project [22]

Project name	Countries	Example of the modular panel	Existing structure survey	Building typology
ECBCS Prefabricated systems for Low Energy Renovation of Residential Buildings	Austria, Czechia, France, Netherland, Portugal, Sweden Switzerland		Existing buildings are measured using special 3D laser scanning technologies to ensure perfect fit of the prefabricated modules to the existing building fabric.	

Each of projects gave some interesting conclusions and this work will try to present similar methodology possible to be implemented on the case studies in Bosnia-Herzegovina and Serbia.

4. ENERGY RENOVATION POSSIBILITIES OF THE BUILDING ENVELOPE OF EXISTING RESIDENTIAL BUILDING STOCK IN B&H AND SERBIA WITH MODULAR PANELS

Comparative analysis of data on the residential building fund of B&H and Serbia, was carried out through a methodological framework for research of typology of residential buildings based on the European international research project "TABULA" in accordance with directives 2002/91 / EC and 2006/32 / EC and co-financed by the European Commission program IEE. The TABULA project, initiated by researchers at the Darmstadt IWU Housing and Ecology Institute, establishes a unique framework for the classification of typology of residential buildings in Europe, with a defined methodology for calculating the energy performance of buildings. Both project Typologies of Residential Buildings in Bosnia and Herzegovina [23] and Serbia [24] an 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 [25] it was reduced to 22 buildings for BiH divided into 4 categories and 6 periods, and for Serbia 31 buildings divided into 4 categories and 8 periods. All buildings older than 40 years should have a deep renovation, not only because thermal protection legislation has improved in the last 40 years and is constantly improving, but also in terms of efficiency, the estimated duration of building envelopes are 30 years, while technical systems are 15 years. [26]

Every building is unique, like snowflakes. But looking from a distance snowflakes are alike. Same goes for buildings. With some assumptions and for some specific observations a group of buildings are the same. And a single representative of those buildings is typical building. As is the case with the refurbishment of prefabricated timber panels, a unique envelope would have to be designed and constructed for each building individually. [23]

Adequate buildings for the application of prefabricated timber panels are selected according to three criteria: - layout, which allows modular division of the facade sheath; - the period of construction, which requires as a whole the complete thermal improvement of the envelope, and - the quantity of such buildings within the species. Collective residential buildings (MFH and AB), in contrast to individual residential buildings (SFH and TH), also have larger envelope areas that need to be renovated and, depending of the type of building (buildings with more of the same slats and floors), can be heat-upgraded with the same pre-fabricated elements of organic materials, which are also the subject of this analysis.

4.1 EXISTING RESIDENTIAL BUILDING STOCK FOR ENERGY RENOVATION MODULAR ENVELOPE

Specifically, the potential of the construction period 1960-1980 was investigated. The construction of prefabricated reinforced concrete systems in the EU began in 1960 [27], while in BiH and Serbia the imitation of prefabrication began, and after 1970 the construction of complete prefabrication of residential buildings began. 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), Figure1., and that their number of floors is 4 or more and that there are at least 20 apartments within such structures.

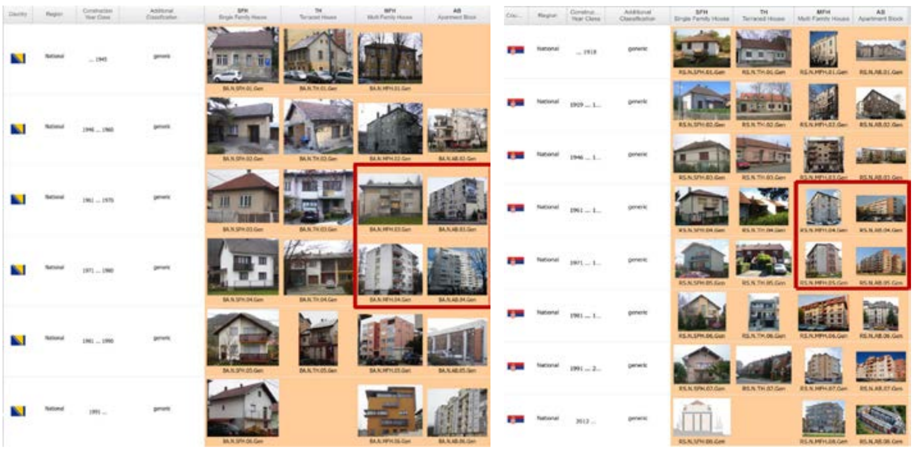


Figure 1. *Typology of residential buildings of Bosnia and Herzegovina (left) and Serbia (right) [28] [29]*

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 [30]. 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 collective 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 collective housing (MFH and AB) has mutually in B&H 9,355 buildings (compared to number of all buildings 1%, in relation to the number of the same types 45.8%), while in Serbia this number, 2.5 times higher than the number of buildings in BiH, is 24,372 buildings (in relation to the number of all types of buildings 1%, and in relation to the number of the same types 40.5%). But when looking at the number of dweeling units within these buildings, the ratio decreases, because the number of dwellings in individual buildings is 66.47% in B&H and 73% in Serbia respectively, what is shown in the Table 4.

In B&H, the total number of individual dwelling buildings is about 841,543 while the number of collective dwelling buildings is around 20,422. When observing the number of dwelling units, 10,764,240 belongs to individual dwelling, while 542,945 belong to collective dwelling. In Serbia, the total number of individual dwelling buildings is about 2,186,246, while the number of collective dwelling buildings is about 60,074. When looking at the number of dwelling units, 2,327,707 belong to individual dwelling, while to collective dwelling 860,707, Table 4.

Comparative analysis indicates that although Serbia has a larger number of buildings of all types, the ratio to the number of apartments is lower, ie 61.6% more individual buildings have Serbia, while the ratio to the number of apartments is 50.8% for Serbia.

Table 4.Number of residential buildings and apartments in comparative countries

	Bosna and Herzegovina		Serbia	
	number of buildings	number of apartments	number of buildings	number of apartments
SFH and TH	841,543	1,076,240	2,186,246	2,327,707
MFH and AB	20,422	542,945	60,074	860,707
MFH and AB (1961-1980)	9,355	297,644	24,372	402,891
MFH (1961-1980)	5,215	103,143	17,265	223,910
Total	861,965	1,619,185	2,246,320	3,188,414

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 study will present the possibility of energy renovation for the MFH type. By comparing the number of buildings and apartments of the MFH type, in the mentioned period, although Serbia has 3.3 times more buildings than B&H, but the ratio of apartments is reduced to 2.2 times. The average shows that one MFH type building has about 20 dwelling units in B&H, while in Serbia the average is about 13 dwelling units per MFH type building.

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 [31] whereas indicators for the EU countries are somewhat better [30].

Such is the situation with buildings / houses of individual housing, and after the renovation of such buildings, real savings of delivered energy could not be seen. Collective housing buildings are important for this research and the energy need for heating such buildings is estimated. The experts calculations estimates of energy need for heating individual buildings of all types and Table 5. are presented comparison B&H and Serbia by type MFH for construction periods 1961-1970 and 1971-1980. 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 example of MFH for period 1971-1980 in Serbia.

Table 5.Comparison value of energy need for heating representative residential buildings in Bosnia and Herzegovina and Serbia (kWh/ m2a)

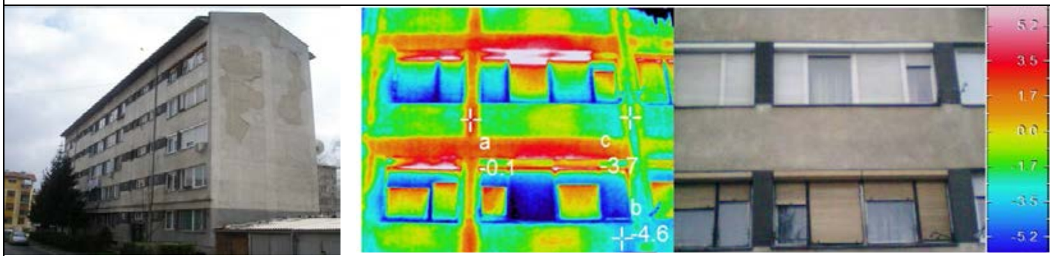
	Bosnia and Herzegovina	Serbia
	MFH	**MFH**
1961-1970	188.44	172.00
1971-1980	146.80	191.00

Looking at the period 1961-1970, MFH have 8.7% higher energy need for heating buildings in B&H. Period 1971-1980, for MFH have 23% higher energy need for heating buildings in Serbia.

4.2 CASE STUDY OF ENERGY RENOVATION OF RESIDENTIAL BUILDING WITH ORGANIC MODULAR ENVELOPE

Case study presented on representative sample of buildings in Banja Luka (Bosnia and Herzegovina). A representative samples of an 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 (1961-1970) led to the conclusion that real Sample from 1964 has a lower specific energy need for heating than representative building of MFH from same period of construction from Typology, Table 6.

Table 6.Comparative review of the energy need for heating of representative sample of existing residential building before and after renovation of building envelope

SAMPLE			
			
Layout of building and thermal-vision image before renovation			
PERIOD		1964	
DIMENSION HEATED SPACE AREA		10x42m 2025m²	
No OF FLOORS		P+4	
HEATED SPACE VOLUME		5670m³	
heat capacity	Wh/m²a	72	
metabolic heat from person	W/m²	3.8	
ORIENTATION		NW - SE	
		BEFORE	AFTER
U-value WALLS	W/m²K	2.03	0.30
U-value WINDOWS	W/m²K	3.12	1.60
U-value ROOF	W/m²K	1.64	0.20
U-value FLOOR	W/m²K	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
		BEFORE	AFTER
internal temperature	°C	20.0	20.0
setback temperature	°C	16.7	16.7
internal heat gains			
ventilation	kWh/m²a	0.0	0.0
lighting	kWh/m²a	2.6	2.6
various equipment	kWh/m²a	13.5	13.5
ENERGY NEED FOR HEATING	kWh/m²a	**164.4**	**31.2**

Sample is a compact building, rectangular in shape with no sunshade element like overhang, balcony or loggias, with form factor of the building (A/V ratio) of 0,40.

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 need for heating the existing selected sample corresponds to the average value stated for typical buildings in the Typologies of B&H and Serbia. Table 6.

By applying cost-optimal measures on the sample envelope, it is possible to lower the value of the energy need for heating below 40 kWh/m^2.

The project of renovation of the envelope of the sample buildings in the modular system, which are described in Chapter 3, 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, Figure 2.

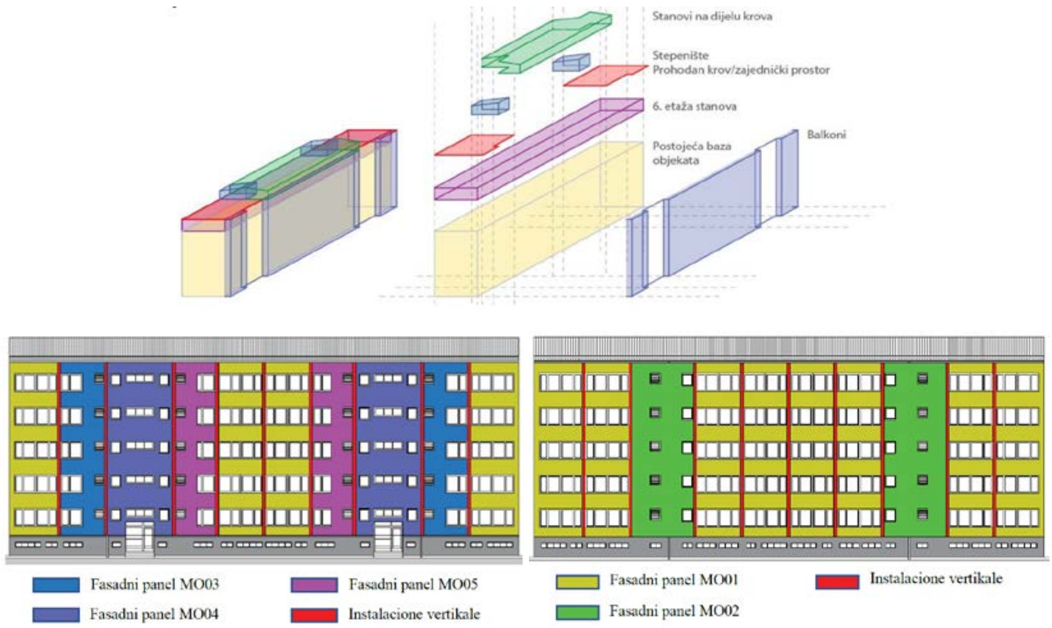


Figure 2. *Sample 1 – Desing for the renovation of the building envelope [32]*

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. For Sample, the solution is guided by prices from 2020. 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.

5. POSSIBILITES OF ENERGY SAVINGS AFTER ENERGY RENOVATION OF BUILDING WITH ORGANIC MODULAR ENVELOPE

Follow 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 the existing windows with new ones, with better characteristics (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 7.

Analyzing for the current condition of buildings and their values of energy need for heating of representative types, examples of the case study from B&H are closer to the values of energy need for heating types of Serbia.

Table 7.Comparative representation of energy need for heating in kWh/m² of representative examples of MFH buildings, before and after applying standard measures in Tipologies of B&H and Serbia and from case study

		MFH	**MFH**
		Before measure	After measure
Bosnia and Herzegovina	1961-1970	188.44	67.86
	1971-1980	146.80	68.23
Serbia	1961-1970	172.00	55.00
	1971-1980	191.00	72.00
Case study	1964	164.40	31.20

Applying these measures to restore the envelope in Typologies, would create 60% energy savings in almost all buildings, except for the type MFH from the period 1971-1980 in B&H (53%). The reason for this can be found in the fact that in B&H types MFH existing condition has a lower value of energy need for heating. In case study, Sample were treated with cost-optimal measures in the B&H area, which is listed in Table 6, and which leads to savings of 81% for MFH type.

For these characteristic type of buildings, which could be overhauled in a modular system, from case study, we can analyze 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 8.

Table 8.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**
Bosnia and Herzegovina	1961-1970	327,081	117,787	**209,294**	54,155	**272,926**
	1971-1980	189,255	68,938	**120,317**	31,523	**157,732**
	total			**329,611**		**430,658**
Serbia	1961-1970	1,532,704	981,213	**551,941**	556,615	**976,089**
	1971-1980	2,442,013	1,453,841	**988,172**	629,997	**1,812,016**
	total			**1,540,113**		**2,778,105**

Comparative analysis shows that the amount of energy that can be further saved by applying cost-optimal measures compared to standard measures listed in the Typologies is in B&H for type MFH about 23.4%, while in Serbia for type MFH about 44.5%.

The analysis shows that cost-optimal measures, which 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 for windows and less demanding U-value (1.60 W/m^{2}K), they can save for MFH in B&H 430,658 MWh/a and in Serbia 2,778,105 MWh/a.

6. CONCLUSION

Currently, in new EU strategy favors the deep renovation, energy savings, about 60% and it includes, to renovate of the all envelope of building. Cost-optimal analysis based on energy and economic analysis of measures for the renovation of buildings in Bosnia and Herzegovina, published in the B&H Strategy, indicated that U-values should be 0.30 W/(m^{2}K) for an external wall, 1.60 W/(m^{2}K) for an opening of the envelope (windows and doors), 0.30 W/(m^{2}K) for a ceiling under an unheated space (roof), and 0.30 W/(m^{2}K) for a ceiling above an unheated space (floor).

Renovation of the envelope of existing building of type MFH, in a case study, which reaches the above measures, showed that it is possible to lower the value of energy need for heating below 40 kWh/m^2, or according to the requirements of the Strategy to create savings 60% (from case study 81% for MFH).

In addition, as the New Renovation Wave Strategy in one of the key principles of building renovation towards 2030 and 2050 extends 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 accept new technical systems, which should be considered in case of renovation of buildings to nZEB standards.

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