Towards deep energy retrofitting: an overview and possibilities for Slovenia and Bosnia-Herzegovina

Results of the »E-REFIT: Strategies for improving energy efficiency through renovation of residential buildings« bilateral project

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Abstract—**Cooperation between scientific institutions from developing and developed countries is of great importance in reaching general goals for a cleaner and healthier environment. As a pioneer in modern technologies, Slovenia is ahead of Bosnia-Herzegovina in terms of the construction sector development and it gradually follows trends in reducing GHG emissions. On the other hand Bosnia and Herzegovina lacks in knowledge and technology in terms of building with renewable materials and following LCA principles. This paper presents several topics analyzed during bilateral project named »Strategies for improving energy efficiency through renovation of residential buildings«. It makes an overview of the strategic projects and legal framework and current energy balance with explanation of dynamic changes in energy consumption. It shows influential parameters on retrofitting, analyzes projects of good practice developed in the European Union and discusses novel retrofitting solutions implementation possibilities to existing building stock of participating countries.**

Key words—energy strategies, energy savings, GHG emissions, building typology, integrated retrofitting systems, building life cycle

I. INTRODUCTION

Large amount of outdated and energy-inefficient building stock in Bosnia and Herzegovina leads to the need for research on new and complete solutions for the renovation of buildings. At the end of 2020, the European Union adopted the »New Renovation Wave Strategy of the European Union«, which includes the use of renewable materials in the renovation of buildings. Bosnia and Herzegovina lags behind global efforts to reduce greenhouse gas emissions heavily caused by the construction sector too. The use of non-ecological materials (primarily thermal-insulation materials and locker smith based on the plastics), dominant construction with high-carbon concrete, long distance transport of materials, energy used from coal thermal power plant and poor legislation that does not promote construction with renewable materials are all factors that lead to increasing pollution. On the other hand, there are no effective strategies for the existing building stock, which is the largest consumer of energy for heating, and which is also faced with the problems of worn off facades, roofs, installations and other elements.

Energy intensity in Bosnia-Herzegovina is estimated to be at 0.40 toe [1] (tone of oil equivalent / 1000 USD of GDP). There is an estimate that 58.44% [2] of the final energy consumption goes to the buildings, while the rest is divided between services (14.90%), industry (19.75%) and transport (6.92%). Total CO_2 emissions for Bosnia-Herzegovina in 2019 was 21.070 kt which is a significant difference compared to Slovenia's 13.600 kt [3]. Since 58.32% [1] of total energy supply in Bosnia-Herzegovina comes from coal thermal power plants, there is an even larger necessity to reduce the level of energy consumption especially in its largest consumer – construction sector (mainly housing).

EU statistics show that buildings account for 38% of all energy consumers in EU [3] and are responsible for a total of 36% GHG emissions [4]. Comparing previously stated values, there is a visible difference of roughly 20% higher energy intensity in Bosnia-Herzegovina compared to European standard, which is also not too bright.

All of these parameters showed that there is a huge necessity to promote energy retrofitting solutions through scientific projects with the aim to gather knowledge and strategies that can influence future government strategies and overall population mindset. With this in mind, Innorenew CoE institute in Izola, Slovenia and Faculty of Architecture, Civil Engineering and Geodesy in Banja Luka, Bosnia-Herzegovina developed a joint project named »Strategies for improving energy efficiency through renovation of residential buildings«.

Over a three-year long period, followed by the pandemic outbreak, researchers (authors of this paper) discussed legislative framework, previous projects of good practice and current trends in sustainable retrofitting approaches. This paper will present some key aspects of strategic planning, legal framework, timber-based retrofitting systems, and implementation of renewable materials in future projects of energy retrofitting.

II. IMPORTANCE OF LEGISLATIVE FRAMEWORK

Legislation represents the backbone of all strategies and further interventions. Both countries adopted building renovation strategies in 2018 and 2019. Bosnia and Herzegovina's strategy is based on defining U-values for specific elements of buildings, which is a step forward towards energy efficiency and CO_2 emission. However, it does not promote the use of renewable and natural materials in energy renovation, which means that the energy required for the production, transportation and installation of materials is not taken into account, as well as the fact that previously removed elements must be deposited, which also leads to energy consumption. In the paper »Energy retrofitting opportunities using renewable materials – comparative analysis of current framework in Bosnia-Herzegovina and Slovenia«, the authors compare the legal framework of energy efficiency in the two countries [5]. A special contribution of the work is in the overview of the flow of energy, from production to its consumption, where it can be seen that, according to data from 2018, Bosnia and Herzegovina is focused on the use of coal (42.30%). In the case of Slovenia, it produces most of its energy from clean sources (primarily nuclear energy), which has achieved a low level of CO_2 production. Compared to the year 2019 and by noticing that domestic energy production was smaller in Slovenia, the overall share of imported energy is larger in 2021 than it was in 2019. According to Slovenia's Energy Statistics [6] the amount of imported energy used to supply the energy sector of Slovenia in 2019 was 137.996 TJ (48.7%) [6] while in 2021 it was 148.292 TJ (53.98%) [7]. By comparing these values, it is visible that this country reduced domestic production in favor of the imported one, however, it also showed lower overall final consumption through all sectors.

TABLE I. Comparison of energy consumption in Slovenia and Bosnia and Herzegovina [2][8][9][10]

	Slovenia		Bosnia-Herzegovina	
	2016	2020	2016	2020
Total energy consumption (TJ)	208,062	188,499	151,442	172,818
Household energy consumption (TJ)	49,650	45,636	47,703	75,369
Space heating (TJ)	31,185 Final energy consumption for space heating (TJ)	31,132 Final energy consumption for space heating (TJ)	70,537.968 Calculated $Q_{H,nd}$ - energy need for heating	Not available

Table 1 shows data related to the total final consumption in the housing sector of the analyzed countries, as well as the total required energy for heating. In the case of Bosnia and Herzegovina, a significant imbalance can be observed between the actual energy used and the required energy for heating. The reason for this is the large number of abandoned households, households that are in occasional use, as well as the fact that the parameter of required energy for heating $Q_{H,nd}$ takes into account total volume of buildings, while in reality the buildings are mostly partially heated. Although the parameter is approximate, it expresses a realistic picture of the construction sector of Bosnia and Herzegovina, which is based on individual housing and unplanned settlements, where it is very difficult to specify such values. In the same table, one can see a big jump in energy consumption in the housing sector in the period from 2016 to 2020 in the case of Bosnia and Herzegovina, while in Slovenia this value has decreased, which proves inadequate measures to improve the energy efficiency of existing buildings, while increasing the number of new buildings. In the case of Slovenia, it is interesting to see on Figure 1 that the biggest consumers of energy are transport and industry, while housing is in third place. Since 2017, Bosnia and Herzegovina has recorded a sharp increase in energy consumption in the housing sector, bringing this category to first place. This situation arises as a consequence of the intensive construction of new buildings, slow process of existing buildings' energy renovation and use of energy inefficient heating methods. On the other hand, Slovenia shows overall reduction of energy consumption in all sectors.

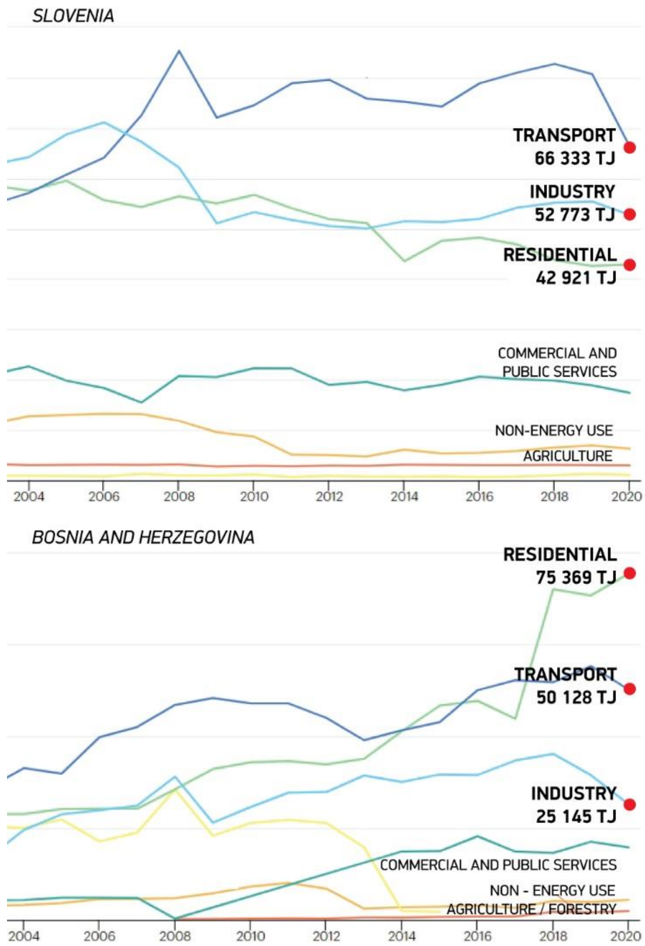

Figure 1 - Final energy consumption by sectors in Slovenia (up) and Bosnia-Herzegovina (down) [8][9]

Slovenian legislation is based on the European framework, and theirs' system of adopting strategies is simpler, compared to Bosnia and Herzegovina where, in addition to national strategies, there are also strategies at the entity level. Slovenia adopted a UZJN document which requires all public institutions to include a certain percentage of wood in the new, or in the renovation of existing buildings - more precisely, 30% wood or 20% wood in combination with 10% of other ecologically certified material [11]. Both countries have similar legislation, but in the case of Bosnia and Herzegovina, there is a lack of reference to renewable materials. Besides legislation, most important for concrete approaches are the rulebooks and defined limiting factors such as U-values for walls, windows. Here, the conclusion is that both countries are guided with European standards and have similar values shown in Table II.

TABLE II. DEFINED U-VALUES FOR SPECIFIC BUILDING ELEMENTS IN BOSNIA-HERZEGOVINA AND SLOVENIA [12][13]

Element	Slovenia [W/m^{2}K]	Bosnia-Herzegovina (north zone) [W/m^{2}K]
Envelope wall	0.28	0.30
Windows	1.30	1.60
Roof - flat	0.20	0.20
Floor between apartments	0.90	n/a
Wall towards non-heated space		No value (should be 0.60)

The conclusion is that the necessity to reduce energy need for heating has been reduced in both countries over the years. In Bosnia-Herzegovina it dropped for around 3.5-3.2 times, and similar drop is for the case of Slovenia too. However, in the Slovenian case, the biggest savings are achieved in single family housing – roughly 6 times less energy need for heating compared to the investigated timeline. [14]

The analysis of the existing construction fund of both countries is presented in the European project "Tabula". In this typology, the conclusion was reached that in Bosnia and Herzegovina, individual housing facilities are more common, more precisely they amount for 39.83% more in comparison to Slovenia; on the other hand, shared housing buildings are more common in Slovenia, i.e. 19.33% more than in Bosnia and Herzegovina.

The presented reference buildings, the number of buildings and estimates of the required energy for heating according to the reference periods of construction served as a basis for a comparative presentation of the possibilities of energy renovation of buildings in the two countries. These possibilities are presented in the paper "Prefabricated timber panels application possibilities for the energy refurbishment of residential buildings envelope in Bosnia-Herzegovina and Slovenia". Relying on reference examples of European practice, the authors show that by applying a system like TES - Timber energy system developed in Norway, Finland and Germany, it is possible to achieve significant savings. The paper came to the conclusion that by applying standard solutions - improving the energy efficiency of facade walls, roofs and windows, it is possible to save about 1,243,328 MWh/a in the case of Bosnia and Herzegovina and about 3% less in the case of Slovenia.

Applicability of this methodology to the comparison of other countries with the same problems of energy poverty stands out. Individual studies solve problems within a single country; however, cross-border projects are of essential value to stimulate global efforts to reduce greenhouse gases because the economy at these levels is the most intensive. In this regard, the previous two papers were the basis for the development of research comparing the systems in Serbia and Bosnia and Herzegovina, where a variant of the cost-optimal improvement of facilities and associated energy savings was shown, according to each of them, that the ranges of energy savings are between 1,540,113 MWh/a and 2,778,105 MWh/a depending on the applied scenario.

III. DEEP (ENERGY) RETROFITTING USING INTEGRATED TIMBER SYSTEMS

In the developed European context, there are clear strategies but also implementation projects that apply new solutions that accelerate and promote the complete renovation of buildings - not only the envelope, but also improve the function, stability, installations and durability of buildings. The justification of energy renovation projects is also based on health benefits, as a good part of the building stock of the analyzed countries, especially Bosnia and Herzegovina, does not meet the recommendations for the quality of interior comfort. Indoor Environmental Quality (IEQ) of buildings include aspects that affect occupant health and well-being, such as indoor air quality, thermal comfort, visual comfort and acoustic comfort [15]. All these parameters are affected by the building envelope performance as a boundary between the indoor space and outer conditions [16]. Taking this into account, and in the light of occupants' well-being, energy retrofitting should not only be conducted based on thermal performance, but also, a variety of influential reasons including subjective comfort feeling of the building.

There are several parameters [17] to bear in mind when assessing possibilities and determining which solution to use and these are:

• Finding deviations on the facade – this can be specifically important to the fully prefabricated systems that need to adhere flawlessly to the existing structure;

• Irregularities in load-bearing construction;

• The need for functional upgrades – layout possibilities (determination by building soft skills and disposition of construction elements, installation shafts, partitions);

• Occurrence of thermal bridges and moisture - quality check marks (water leakage, mold growth, infiltration, potential emission of hazard elements done with thermal imaging and air infiltration tests);

• The condition of the external locksmith;

• Composition of façade layers;

• Disposition of openings;

• HVAC elements and other;

• plumbing system - potential elements of conflict that lead to the destruction of the internal structure of the wall and actually represent one of the most common problems of the appearance of moisture, mold and material deformation. [16]

By its typology, position on the wall and way of mounting four systems can be used in building refurbishment, some of which are more applicable to the analyzed countries. During this project four examples were analyzed. These examples [14] are shown below on the Figure 2:

1) External composite insulation system (ETICS). The most common insulation measure with manually brought up insulation panels covered with a plaster coating.

2) Ventilated façade system. The insulation is brought up between substructures, fixed with a mounting system, covered by various claddings.

3) Partly prefabricated façade system. Assembly of prefabricated substructure is filled with blown-in insulation.

4) Prefabricated module system. Fully prefabricated modules are assembled in the fabrication hall, transported and mounted on prepared sub-structure onto the façade.

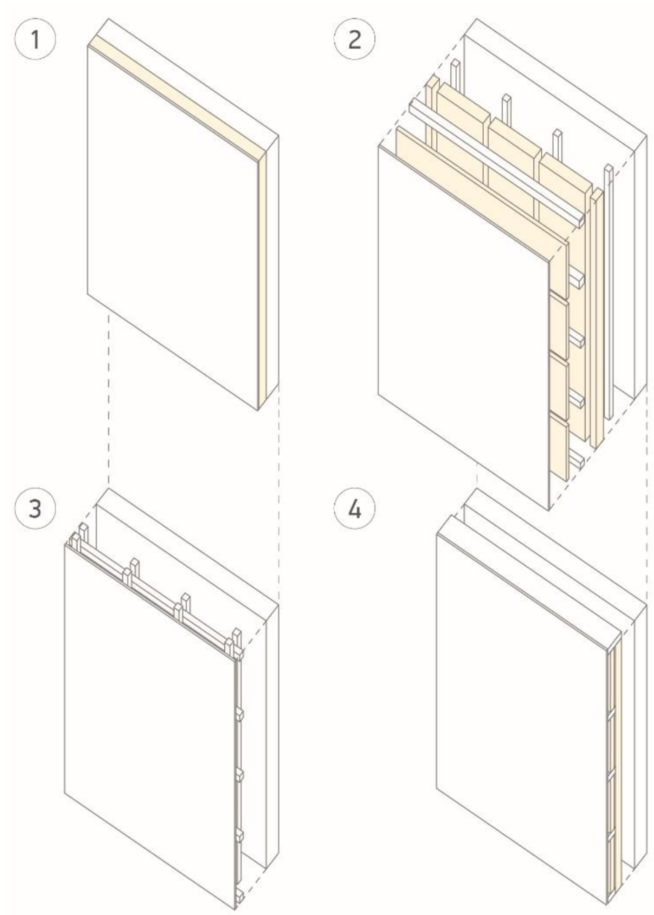

Figure 2 - Examples of the facade systems - exploded diagram. Source: Author's figure.

Widest spread measure is ETICS because it is cheapest and easiest to construct in countries with low prices of manual labor and when there are no other environmental conditions rather than defined U-values. This way, all buildings which are subject to renovation use PVC based insulation and window frames. What also highly influences retrofit necessity is the durability of the building itself, which is determined by the selection of materials, which must be designed for the required service life as well as be compatible with one another in the ensemble [17]. Architects and building physicists have a crucial role designing buildings with compatible envelopes and details to ensure healthy living conditions within. When this is achieved, there are less probable connection failures, outer envelope dismantles due the aging process etc.

As guidance for the research several good examples developed in the period from 2009 to 2022 can be used. Among the first developed projects was TES (Timber energy system) that showed a comprehensive and systematic approach in upgrading buildings energy performance [18]. Its promising results brought the project an upgraded Smart-TES EXTENSIONS continuation, that evolved from panel system to modular volumes as annexes in necessity to compensate for missing elevator shafts, balconies etc. [19] The use of prefabricated insulation integrates the building as a whole, ensuring a high-quality execution in a faster time. Prefabricated retrofit systems are standardized in construction layers and joints [14]. Some more advanced projects as BERTIM - Building energy renovation through timber prefabricated modules developed software tools and algorithms for automatic position and shape arrangement to ensure as tight fit as possible on the opaque envelope [20].

The development of new strategies and technologies is a demanding process that involves several actors and brings together several fields. In the mentioned projects, there is a clear need for detailed recording of facades, energy audit, testing of space users, planning of construction possibilities and financial construction, as well as additional training of the workforce that will carry out projects of this type. All examples of renovation from ethics to fully prefabricated systems are acceptable, however, buildings that are completely prefabricated and modular could be suitable for pilot projects of whole building renovation with the help of prefabricated timber systems. This would establish a clear system and approach to the renovation of buildings, which could become much more cost-effective than non-modular systems.

IV. Conclusion

Developing countries such as Bosnia and Herzegovina can significantly benefit from energy renewal projects. Looking at it from the aspect of energy efficiency, there are significant reductions in the energy required for heating. On the other hand, a number of other benefits open up, such as extending the life of buildings, activating the industry and educating experts in this field. All new technologies require additional training of the personnel involved in the process as well as adaptation of the infrastructure and production. Although the time of installation and work on the construction site will be reduced, this fact can lead to a slow implementation of modern prefabricated solutions in construction practice, especially if it is not represented in residential construction. Although more and more researchers deal with the topic of integrated wood systems for building renovation, it can still be said that no serious progress has been made in the wider application of these solutions [18]. The reason for this is obvious problems in the relationship between industry - users - law makers; as well as the still more affordable price of non-renewable materials for construction.

Practical problems in the implementation of these projects, such as a large amount of information, cross-sectoral management, recording of existing facilities, creation of documentation of the existing condition, selection of solutions and creation of projects, until its realization, represent a challenge for the domestic practice of Bosnia-Herzegovina, which is still not mature for such task. However, international cooperation projects should enable the transfer of knowledge in the implementation of these projects because the resources definitely exist. The solution to solve this issue might also be implementation of the Building Information Modelling (BIM). BIM as a digital representation of the building offers unique possibilities to combine diverse information related to the construction, including all phases of its life - from the concept to demolition and recycling. Building renovation or refurbishment projects will be more sustainable if supported by a commonly usable methodology that is adapted to existing and old buildings, since they often present more complexities than the new construction. BIM can add enormous value to renovation and retrofitting projects. Laser scanning can be used to create a comprehensive model that offers data on construction materials, costs, and manufacturer information. By optimal utilization of resources during renovation, the workflow management of the buildings will be more energy-efficient and sustainable that will improve inhabitants' lives.

Despite the current difficult circumstances for the implementation of such projects, it is necessary to include renewable materials in the strategies, that is, to define the minimum percentage of natural materials used in the renovation of buildings. In addition, it is necessary to look at the complete life cycle of materials and buildings - include the energy required for production, transport and installation of a material in the final carbon footprint of the building, and start applying LCA methods when creating documentation. Although artificial materials are cheaper and installation somewhat simpler, European directives allow the use of these materials less and less due to their bad impact on the environment, therefore, over time, there will be a need for countries that aspire to join the European Union to adapt to these requirements and significantly reduce the use artificial materials.

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SAŽETAK

Saradnja naučnih institucija iz zemalja u razvoju i razvijenih zemalja je od velikog značaja u postizanju opštih ciljeva za zdraviju životnu sredinu. Kao pionir modernih tehnologija, Slovenija je ispred Bosne i Hercegovine po razvoju građevinskog sektora i postepeno prati trendove u smanjenju emisija gasova staklene bašte. Sa druge strane, Bosni i Hercegovini nedostaju znanje i tehnologija sa aspekta gradnje obnovljivim materijalima i ispunjavanja LCA (Life Cycle Assessment) principa. U ovom radu predstavljene su teme istraživane tokom trajanja bilateralnog projekta nazvanog „Strategije za unapređenje energetske efikasnosti kroz obnovu stambenih zgrada“. Rad prikazuje pregled strateških projekata i zakonskog okvira te aktuelnog energetskog bilansa sa objašnjenjem dinamičkih promena u potrošnji energije. On pokazuje uticajne parametre pri dubokoj energetskoj obnovi zgrada, analizira projekte dobre prakse razvijene u Evropskoj uniji i razmatra mogućnosti implementacije novih rešenja za rekonstrukciju postojećeg građevinskog fonda zemalja učesnica.

MOGUĆNOSTI PRIMJENE DUBOKE ENERGETSKE OBNOVE U BOSNI I HERCEGOVINI I SLOVENIJI

Rezultati bilateralnog projekta »E-REFIT: Strategije za unapređenje energetske efikasnosti kroz renoviranje stambenih zgrada«

Slobodan Peulić, Darija Gajić, Ana Sandak, Črtomir Tavzes, Tim Mavrič, Jelena Rašović, Mladen Slijepčević, Biljana Antunović, Milica Malešević, Una Okilj