admission date 16 12 2021
approval date 16 03 2022

original research article
UDC 378.147::72(497.11)
728:697.97

ENERGY REHABILITATION OF EXISTING BUILDINGS: DESIGN STUDIO

A B S T R A C T

This paper presents the methodology and results of design studio whose main topic is sustainability, specifically relating to existing building energy refurbishment, at the postgraduate level - specialist academic studies – *Energy efficient and green architecture* at the University of Belgrade-Faculty of Architecture. Weaknesses and opportunities in teaching sustainability in a design studio are discussed. It points to concrete challenges that the theme of building energy conservation and refurbishment present, and to ways in which they might be integrated in education. This paper considers how the design studio pedagogy could encourage deep and active learning for sustainable design in an attempt to expand the role of the architect to be more responsive to the environmental needs of contemporary society.

Methodology of this studio uses the approach of project-oriented learning by simulating a real-life multidisciplinary project development environment. Three phases of design development are described as: research phase, refurbishment phase and redesign phase. It starts with the research phase, which is developed in parallel with the refurbishment phase. This is because the refurbishment process in this studio is not just limited to the technical aspects of energy efficiency improvement, verified through calculations and simulations. Several design scenarios are developed, examining the minimal, optimal and maximal range of energy efficiency improvements in technical systems and building thermal envelope. Analysis of these scenarios, but also analysis of a much wider spectre of aspects influencing the refurbishment design, results in a final redesign proposal which is a comprehensive, deep refurbishment proposal, tackling not only energy (under)performance, but also possibilities for upgrade of functional, technical and aesthetical aspects of existing building.

Dušan Ignjatović
Faculty of Architecture, University of Belgrade
ignjatovic.dusan@arh.bg.ac.rs

Bojana Zeković
Faculty of Architecture, University of Belgrade
bojana@arh.bg.ac.rs

Nikola Miletić
Faculty of Architecture, University of Belgrade
nikola.miletic@arh.bg.ac.rs

KEY WORDS

DESIGN STUDIO,
DEEP REFURBISHMENT,
REDESIGN,
ENERGY EFFICIENCY,
ENERGY PERFORMANCE

INTRODUCTION

Contemporary challenges of environmental degradation, economic instability and social integration have brought the concept of sustainability into the main focus of contemporary society and scientific community. Bearing in mind that out of the total global CO2 emissions about 40% is generated in buildings, out of which 28% is related to the exploitation phase of the building (heating, ventilation, cooling, electricity supply) while the remaining part is related to the process of materials and components manufacture and transportation,[1] it is imperative to integrate sustainability principles into architectural education on all levels. It is also necessary to highlight the importance of building refurbishment as a primary action in need on the road to built environment sustainability. This is highlighted in the newest legislation acts in the EU,[2] but also through a growing interest of the professional community on design practices which put refurbishment into their focus.[3]

While there is a need for conveying broad and general knowledge base on the environmental aspects of the field through theoretical courses and seminars, the design studio-based education process, as the dominant platform of architecture education,[4] should enable meaningful learning for sustainable design and needs to develop students' skills in integrating acquired theoretical knowledge in the design process.[5] Existing teaching methods, which focus on lectures and assignments to equip students primarily with theoretical knowledge, are not enough for integrating sustainability in the architecture education[6] since studies show that students tend to forget theoretical knowledge in one year if it is not applied somewhere.[7] This said, the design studio presents the perfect platform to incorporate the teaching of sustainability in regards to built environment. Still, as literature overview shows, despite a broad consensus on the need to integrate more sustainability in the curriculum, there is no clear consensus regarding teaching methods or curriculum design for integration of sustainability in architectural education.[8]

This paper presents the methodology and results of design studio whose main topic is sustainability, specifically energy refurbishment, and discusses weaknesses and opportunities in teaching sustainability in a design studio. It points to concrete challenges that the theme of building energy conservation and refurbishment present, and to ways in which they might be integrated in education. This paper considers how the design studio pedagogy may encourage deep and active learning for sustainable design in an attempt to expand the role of the architect to be more responsive to the environmental needs of contemporary society.

1. DESIGN STUDIO AND SUSTAINABILITY EDUCATION

Design studio-based teaching is the dominant method of university education for young architecture and urbanism students throughout the world.[9] It is the primary space where students acquire and use previously acquired knowledge and explore their creative skills. As such, it has to constantly adapt to the new forms of knowledge that is preceding it, and remain a platform where students can use the gained knowledge. However, there are numerous theories how the creative design process is informed through previously gained knowledge, and how this knowledge is embedded in design solutions.

As indicated previously, the research presented here is based on design studio process that seeks to integrate knowledge gained from theoretical subjects and design studio activities. In the majority of schools of architecture, a traditional, mechanistic paradigm is used, meaning the educational process of architecture is reduced to a large number of disconnected components.[10] Yet, from a constructivist viewpoint, knowledge domains are not separated in the reality, and need to be perceived together, as a whole. Tempelman and Pilot propose the synthesis of the three design principles (context, content and chain of activities) as a new approach for linking theory and practice in design education.[11] Similarly, different authors explain how critical thinking, linked to procedural knowledge, is developed in the design studio through a three-level process of developing creative thinking.[12] As stated before, there is no definitive way of teaching sustainability in a design studio. There are many different views regarding the best way to tackle this body of knowledge. Linking critically reflective practice with sustainable design education is widely advocated in recent works as it highlights the need for students to critically evaluate sustainable development ideas.[13] In the field of architecture, this is especially needed due to many possible design approaches. Some authors argue that in order to produce a truly sustainable solution (a design that works properly for a particular society), the architect must adopt the role of mediator between different social actors and design solutions.[14]

The papers advocate the need for integration of research into teaching and exposing the students to primary source materials that enable them to get as close as possible to the realities being studied.[15] Project-oriented learning in particular is recognised as an appropriate approach for constructivist concepts. It is a student-centred approach which involves real life problems and helps students in acquiring and integrating new kinds of knowledge in the project.[16] Researchers generally agree that deep learning is a best way of teaching sustainability in the design studio setting due to its interdisciplinary and holistic nature.[17] Deep learning presents a critical approach to learning in which the student is questioning every action or design decision he/she makes along the way. In this process, through experience of the iterative process of design, students produce new knowledge and gain a deeper understanding of the subject matter. This process is similar to Schön's *reflection-in-action* learning process,[18] which describes how professionals conduct the process of design through a constant reflection during the act of creation. However, it is criticised for defining learning process as not so dynamic, limited to the relation between peers and students, while today it is more in need of a learning community, allowing for *inquiry and investigation* as activities central to studio pedagogy. Authors agree that in this *active and experiential learning*, while very similar to deep learning, instructional strategies encourage higher-order thinking and group work instead of individual research.[19] Experiential learning refers to learning in which the learner is directly in touch with the realities being studied and in active learning students are involved in thinking that simultaneously involves analysis, synthesis, and evaluation of a wide spectrum of issues and phenomena.[20] The value of these approaches becomes evident when looking at the literature and research findings that were developed over the past several decades, which indicate that students favour discussion methods over lecture and one-way mode of knowledge. This only highlights the importance of a design studio as a platform for research and discussion, flexible enough to encompass all new methods and techniques that are developed with the rising complexity of topics being studied, sustainability being the most prominent one.

1.1. Studio Methodology

While the student's design process exhibits difference in detail sequences, timing and approach, the general design studio process generally consists of three distinct phases including research, design proposal and project development. Research is used here to describe the activity of gathering or producing knowledge relevant to the project. The research phase consists of predesign research, but the research itself continues in parallel with the design proposal as well as project development phase. One of the main characteristics of the studio that is present here is its multitude of outputs (design proposals) which are developed throughout the entire design process.

This paper presents the methodology and results of a design studio at the postgraduate level of studies, namely specialist academic studies – *Energy efficient and green architecture* at the University of Belgrade – Faculty of

Architecture. Design studio named *Energy rehabilitation and certification of existing buildings* – case study is an elective studio that students can choose at the end of the one-year studies. Other subjects are mostly theoretical, with student outputs of either classic exams or seminar papers dealing with different topics that are taught in the study programme. This studio is therefore the only opportunity within these studies for application of the design studio methodology and project-oriented learning.

Students who enrol in this specialist course are mainly young professionals[21] who want to gain specific knowledge in the field of sustainable buildings design and performance evaluation, related legislation, certification procedures and theoretical background. Therefore, not all of them have a background in architecture or design education. This can be challenging from the perspective of task formulation and expected outputs from each student. On the other hand, the opportunity for group assignments, where mainly young engineers of similar interests (sustainable building) but different educational background work together on a complex assignment (energy efficient refurbishment project), provides an excellent opportunity not only to apply gained theoretical knowledge in other subject matters, but also to simulate a real-life multidisciplinary project development environment.

Incorporating built environment into the curriculum helps students focus on specific aspects of the built environment; particularly those that pertain to human - environment interactions. By studying the actual real-life environment students can understand the practical realities and different variables that affect real-life situations, which helps them apply and synthesise knowledge gained in other theoretical, lecture-based courses. Haase states that by introducing more realistic problem parameters, students are better equipped to critically understand and overcome challenges they might confront in design studio or their future careers.[22] The main aspects of student's research in this studio are analysis of the selected building for the case study, which covers its urban layout and architectural aspects of the project together with context - including the built and natural environment, as well as constructive, technological and material features in order to determine constraints and potentials in the refurbishment process. This phase is of utmost importance for the later design stage since inadequate refurbishment in technical as well architectural sense can degrade the quality of existing building stock, while supreme design quality and energy performance achieved through energy rehabilitation can upgrade the material value, cultural identity, comfort and sustainability in numerous ways.

Integrating real-life environment into the classroom for discussion, reflection and critical inquiry, as stated by Salama, enables students to shift from being passive listeners to being active learners and cogent thinkers.[23] Well prepared in the research stage, students enter the second phase of design proposal, where the conditions of the site serve as analytical, conceptual and strategic points of departure for the student's design visions and proposals. The goal of design studio is translating the knowledge gained from research on the project to the design solutions and learning by doing. Such an approach, linking relevant knowledge with design projects, as shown by Saghafi, assists students to create responsive design.[24]

Methodology of this studio emphasises the research stage, which continues also in the phase of defining refurbishment solutions. All the activities which occur in these stages serve as an input for the redesign phase. The output of the refurbishment stage consists of some solutions for the building's energy (under) performance: three refurbishment scenarios that are defined according mostly to the technological and material features in order to determine constraints and potentials in the refurbishment process.[25] These scenarios are defined as following:

- 1st level improvement scenario: building fabric upgrade to the level satisfying current legislation.[26] Not all of the building fabric (thermal envelope) is being refurbished. This can be considered the minimum of refurbishment activities that put the building in compliance with current regulation for existing buildings upgrade. Technical systems for heating and hot water preparation are not considered in this refurbishment.
- 2nd level improvement scenario: upgrading the entire building fabric, so the all elements of thermal envelope satisfy current energy efficiency targets (U-values). Technical systems for heating and hot water preparation are also not considered in this refurbishment.
- 3rd level improvement scenario: this scenario deals with upgrading technical systems for heating and hot water preparation, and regarding building fabric, superior fenestration components are incorporated.

Although described improvement scenarios can be considered as design proposals in terms that the existing building under further project development would be refurbished, these scenarios lack the design component and therefore cannot be considered a valid output of a design studio. This phase of development improvement is defined as a refurbishment phase since the work on defining these scenarios informs future design decisions in terms of constraints

of the fabric and technical systems upgrade regarding energy performance. It is clear that further improvements can be achieved only through a holistic refurbishment proposal - a comprehensive approach that deals not only with upgrade of existing structure in its technical and material properties, but also tackles functional, structural and aesthetic aspects of the existing building.
This redesign proposal is the result of the final, redesign phase, and it is considered the main output of this design studio. The improvement scenarios which are defined in the refurbishment phase are compared to the final design in terms of energy performance (reduction in energy needs, energy consumption and CO2 emissions), and economic viability (investments and payback periods).

A diagram summing up the design studio methodology is presented below (Figure 1). Throughout the entire design studio student can either work in groups or independently. It is usual for students to work in groups in the research and predesign phase, and for students to develop their own design proposals in the design phase. Students with no background in architecture education usually work in groups in all stages of the design studio.

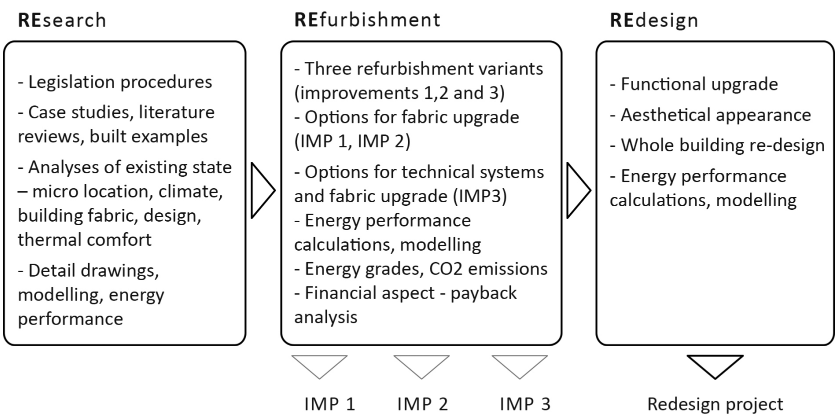


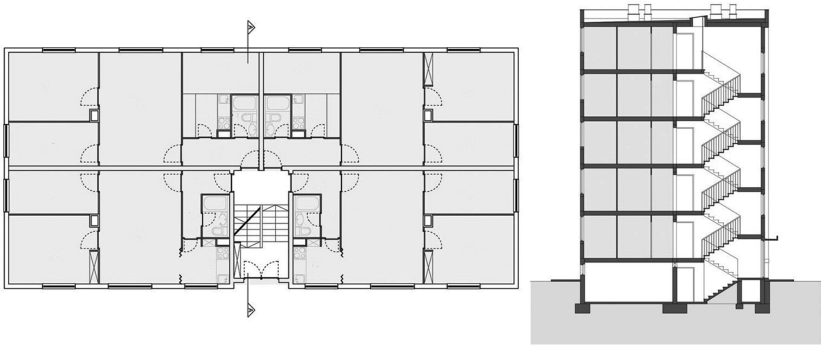
Fig. 1. Design studio methodology

1.2. Design Studio Case Study

1.2.1. Research Phase: The Existing State

The assignment of the design studio presented in this paper is refurbishment of a typical multifamily residential building, which is part of a housing block located in Bežanijska kosa in Belgrade's New Belgrade municipality. This housing block consists of 16 typical five-storey buildings (Figure 2). These buildings were built in the 60s, and are characterised by simple flat roofed volumes, with no specific architectural features or design elements. Each building has 20 residential units, 10 smaller ones (51 m2) and 10 larger ones (58 m2), two of each on each floor (Figure 3). Buildings do not have elevators or terraces. The heating system is individual, with heating stoves and electrical boilers in every apartment. The construction system is massive, with longitudinal massive walls built of 'durisol' blocks.[27]

Research phase is characterised by gathering information about building's material, technical and performance characteristics, analysing the location, climate data, prevailing wind directions, Sun exposure. These analyses were done as a group work of entire class (four students). The aim of these analyses is to inform design decisions. This research phase is universal in design studio



UP: Fig. 2. Part of the analysed housing block, layout of typical multifamily residential buildings

DOWN: Fig. 3. Typical floor layout and cross section of analysed building methodologies, but the scope of different analyses varies depending on the topic of the studio. The emphasis may be on characteristics of the location (microclimate, vegetation, native species, etc.), cultural issues, population, demographic, property value, public transport infrastructure, or available public facilities. Also, a wider area may be analysed, entire neighbourhood or municipality if the topic of the design studio is more complex, and the programme of the future project also needs to be defined. This particular design studio focused on analysing natural elements of the location, which influence the typical building in terms of its comfort issues (thermal, daylight, acoustic, indoor air quality), and also functional, material and technical characteristics of the building itself. Analysis of natural elements showed that the building layout is favourable in terms of the sun and wind exposure (Figure 4), allowing redesign solutions which enable passive solar heating. Longitudinal building facades are not exposed to dominant winds, which enables new design elements that provide better connection between apartments and outdoor space (large glazed windows, balconies, terraces, loggias, etc.).

Also, this design studio specifically deals with energy performance characteristics of the building in question.[28] As an input for energy calculations/simulations a detailed 3D model is required, done based on the archive documentation (technical drawings of the building and description of constructive elements and finishing) or in-situ measurements.

Detailed digital drawings are done, and based on them modelling of a single thermal zone model with definition of all elements of thermal envelope is carried out. Calculations are done in the KnaufTerm software.[29] For the present state of the analysed building the calculations showed that none of the elements of thermal envelope satisfy current legislation (U values much higher than the minimum allowed), as well as the achieved energy grade (F energy class, energy need for heating of 170.33 kwh/m^{2}y). Dominant transmission heat losses occur through facade walls, (44%), followed by losses through flat roof and windows, (22% each). These data serve as input for definition of refurbishment scenarios, limited to interventions on thermal envelope and technical systems in the predesign phase.

1.2.2. Refurbishment Phase: Improvement Scenarios

As described within the studio methodology, the refurbishment phase, which follows the initial research phase, is aimed at defining three refurbishment scenarios that are designed mostly according to the technological and material features to determine constraints and potentials in the refurbishment process.

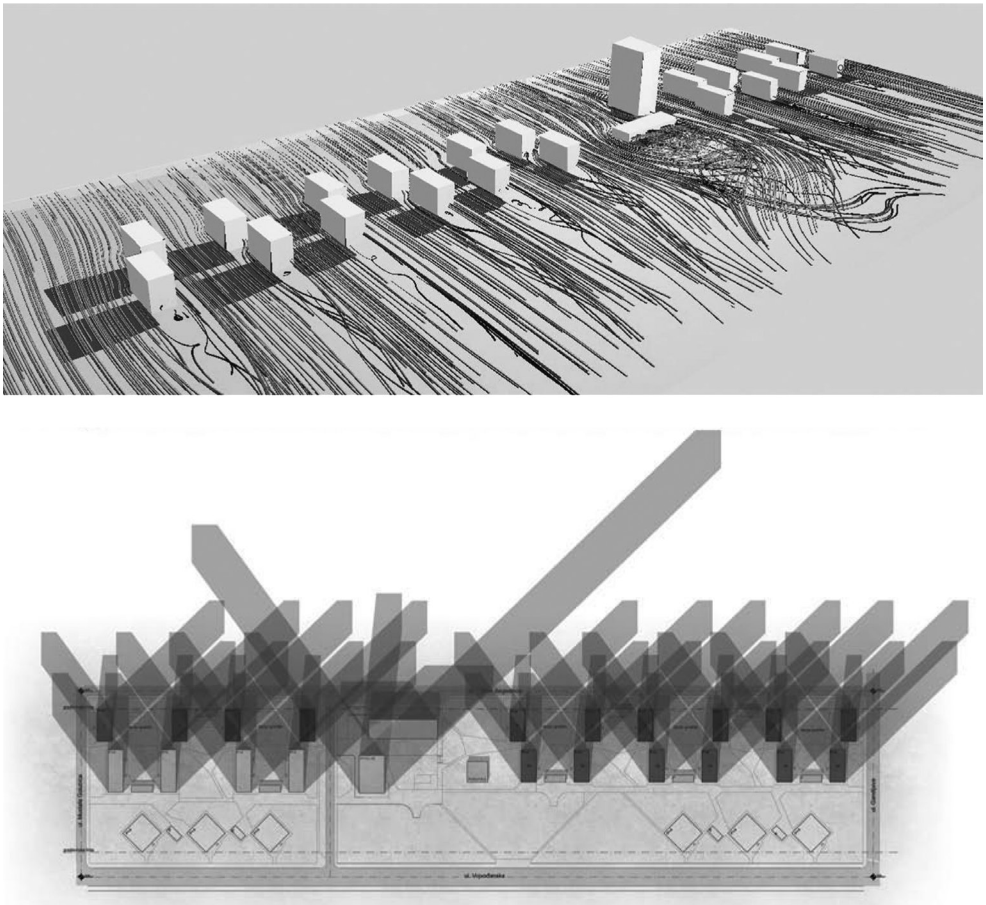


Fig. 4. Dominant wind direction and shading analysis

The interventions that are envisioned as part of these improvement scenarios are limited to the upgrades of elements of thermal envelope and technical systems. Technical systems for heating and hot water preparation are considered in the 3rd stage of improvement. In the first two scenarios only elements of thermal envelope are improved: in the first, only the ones that make the overall energy performance for one energy class better than the current one (current regulation for buildings that are being refurbished). In the second, all elements are improved to the level which is according to current regulation in terms of maximal allowed U-value. In the third improvement scenario, windows are the only thermal envelope component which is further improved, while other measures focus on improvements of heating system and sanitary hot water preparation system to further lower primary energy and CO_2 emissions.

In the case of the analysed building, since the largest share of transmission heat losses occurs in façade walls, flat roofs and windows, these elements were first options for improvement. In further analysis, and on-site visits, it is concluded that façade walls and flat roof are in extremely bad conditions, and that only refurbishment scenario which could significantly improve the standard of living must include improvements of both elements. Further calculation showed that by their improvement energy rating is improved by two levels, cutting energy need for heating by 50% (84.56 kwh/m^{2}y).

In the second refurbishment scenario improvements of all elements of thermal envelope bring the building's energy rating on the level of compulsory energy rating for new buildings (C level). Also, energy need for heating is lowered by 70% compared to the existing state (49.47 kwh/m^{2}y).

The third refurbishment scenario mainly deals with outdated and energy inefficient systems for the heating and hot water preparation aimed at further reducing primary energy and CO_2 emissions. Regarding the thermal envelope, only windows are further improved in this scenario, from U-value of 1.3 W/m^{2}K as envisioned in the second refurbishment scenario to U-value of 1.0 W/m^{2}K. The heating and hot water preparation systems are proposed as a single central system, operating through a low-temperature gas boiler. This cuts down initial primary energy by 90%, while CO_2 emissions are lowered up to only 4% of the initial value. Comparative energy performance data for three levels of improvements are shown in Figure 5.

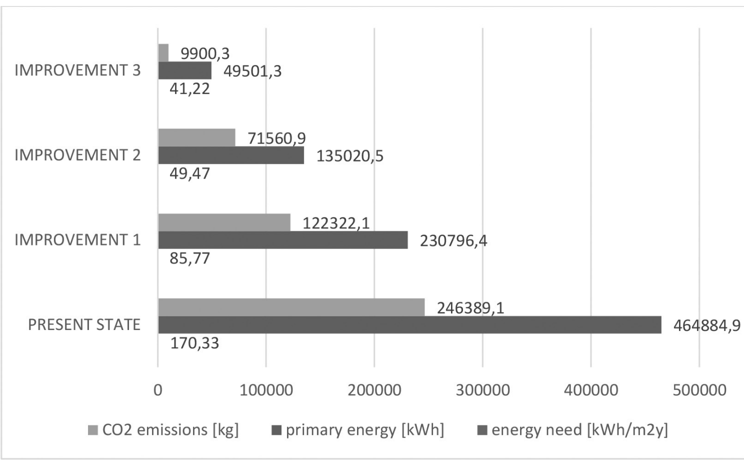


Fig.5. Comparison of three variant solutions developed in the refurbishment phase in terms of energy performance

As much as these are impressive results in terms of energy saving, these refurbishment scenarios offer no solutions to the recognised problems in functional and architectural qualities of the analysed building. These interventions would surely contribute to the improved comfort issues, but would not resolve some of the spotted problems such as lack of connection to nature (no terraces, small windows), no elevator, functional organisation of the apartments and their size (small kitchens and inadequate spatial distribution of rooms). Therefore, a comprehensive deep refurbishment proposal needs to be designed for these issues to be tackled.

1.2.3. Redesign Phase: Comprehensive Refurbishment Proposals

In this stage, both individual and group student work is possible. In this studio there was a combination of individual and group work, so three redesign projects were developed (Figure 6). All redesign projects considered the enlargement of usable area and improvement of functional issues by activating flat roof in forms of additional level, adding terrace volumes and its construction, and adding an elevator shaft. All proposals paid special attention to detailing, connections of new constructive elements to the existing ones, and solutions of thermal bridges. The enlargement of usable area of the building by activating available areas for intervention, such as attic space or flat roof, as well as addition of volumes adjacent to the building, is the method which proved to be effective in improving the building's energy performance and material value.[30] All three refurbishment

Fig.6. Redesign projects: 1) By students Bojana Čanković and Nataša Jovanović 2) student Marija Stanić 3) Aleksandra Nikolić

design projects tackled this issue through various design solutions. One of the main functional issues of the existing state is certainly the lack of an elevator. According to domestic legislations, buildings up to four floors do not need to have an elevator. However, with planned activation of the flat roof level and the addition of a withdrawn floor, the elevator becomes a necessity. A diagram shown in Figure 7 depicts the process of design development of the first design proposal (by B. Čanković and N. Jovanović), which incorporates additional volumes of elevator shaft, additional floors and additional volumes of terraces (glazed or open ones). Roof is inclined towards favourable orientation for positioning of PV panels and enables duplex apartments on the added floor. Construction of the additional volumes (new facade walls elements, roof slabs, terrace slabs) is a lightweight wooden construction.

Elements of glazed or open terraces bring additional quality to all apartments since their structure was modest in the existing state, with no elements of outdoor connection (terraces, balconies, large glazed elements). A typical floor layout of

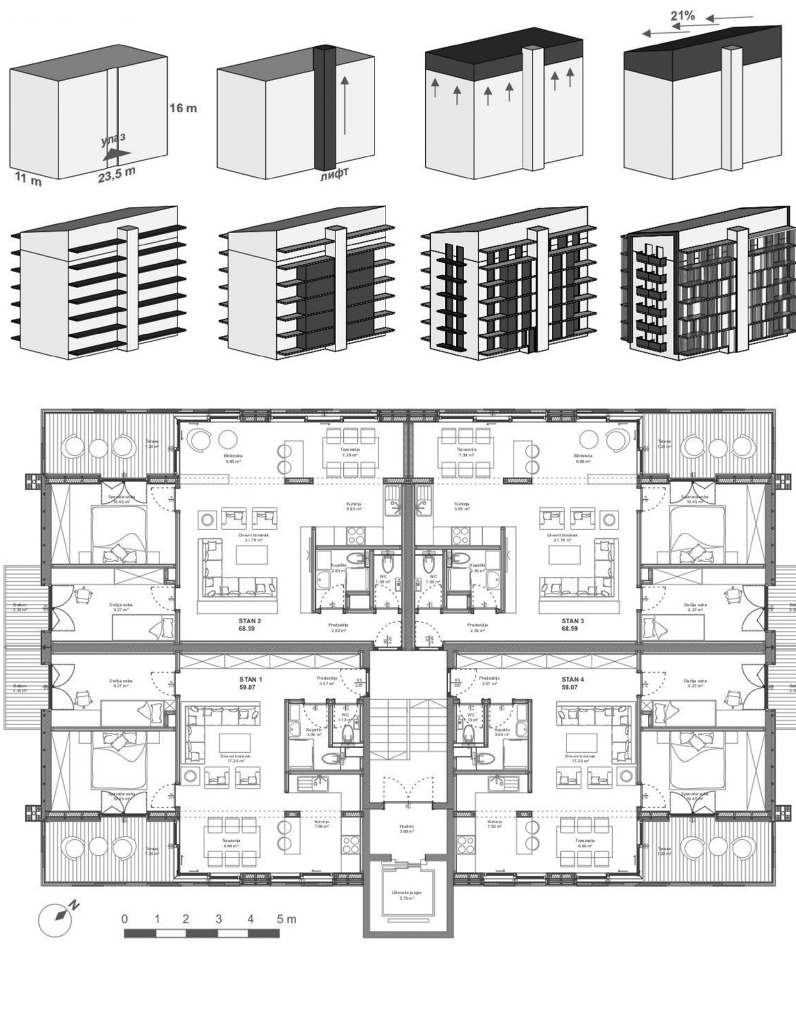


Fig. 7. Refurbishment design development diagrams and functional organisation of a typical floor (design by students B. Čanković and N. Jovanović)

this redesign proposal is shown in Figure 7. Each apartment gets additional space in the dining and living areas as well as two terraces, so each room has a connection to the outdoor space.

Similar functional organisation is presented in other design proposals, with variations in the size of added volumes. In the second proposal, (M. Stanić) additional elements of the typical floor layout are limited to the open terraces (Figure 8), built as light steel construction anchored to the concrete loadbearing elements of existing building. This is also the solution for the construction of the withdrawn floor, with flat roof ending suitable for positioning of PV panels under the most optimal angle. The last floor consists of two large apartments with three-sided orientation, opening to large roof terraces on north-east and south-west side.

The most radical functional reorganisation of existing apartments, followed by the design of the facade is in the third redesign proposal by student A. Nikolić. The modular design of the facade, defined by the position of constructive elements, is followed by different materialisation of facade fields, solved functionally either as loggias, vegetative screens or glazed portions (Figure 9). The typical floor plan thus does not exist – each floor and each apartment have a unique structure in terms of number of loggias, terraces, window positions,

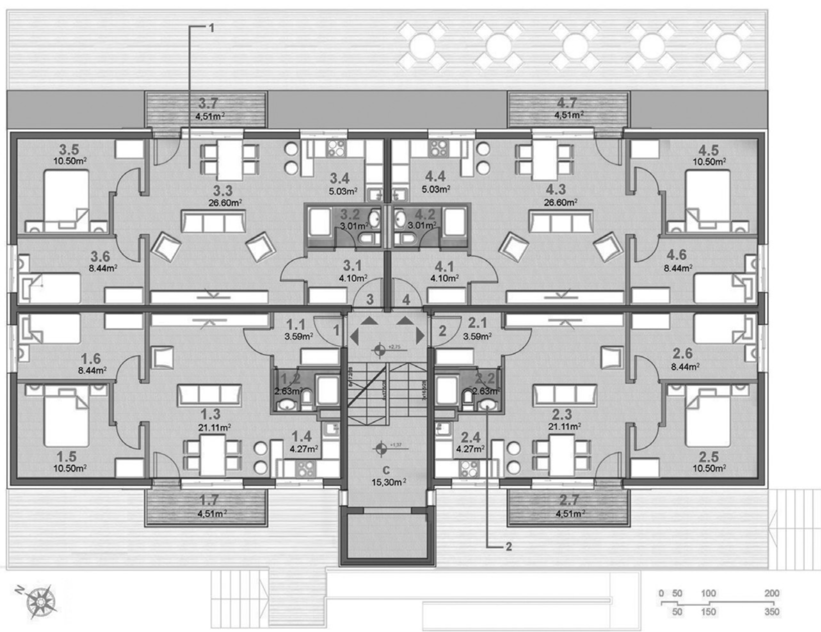
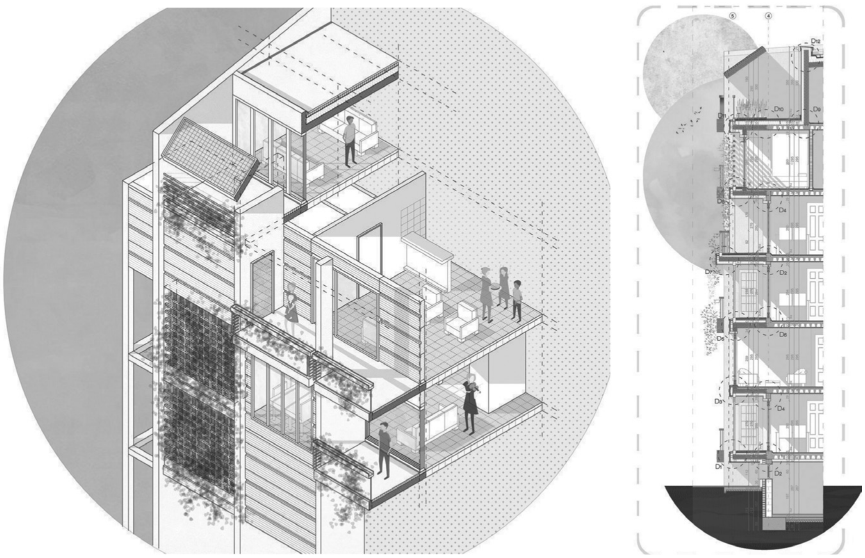
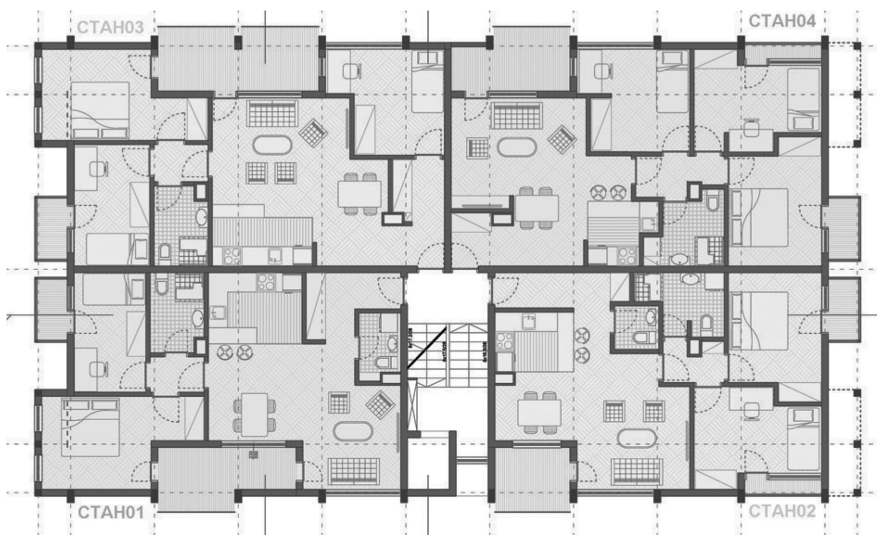


Fig. 8. Functional organisation of a typical floor and design by student M. Stanić





UP: Fig. 9. Axonometric section and section detail, design by student A. Nikolić

DOWN: Fig. 10. Functional organisation and design of the 2nd floor by student A. Nikolić sizing of rooms and their facade solutions. The core of all apartments is solved as an open plan consisting of living, dining and kitchen areas, with varying position of the adjoining loggia (Figure 10). The last floor, added withdrawn floor is solved as two larger apartments with adjoining roof terraces on both longitudinal sides. The entire construction of new structural elements (terrace slabs, façade walls, roof slabs) is envisioned using CLT panels.

This enlargement of functional living space in all proposed redesign projects significantly influences the rise of the entire property value. Not only do these existing apartments become significantly improved, but also new apartments are built on the added floors, which could, from the financial point of view, create impetus for investing in this type of refurbishment, either from the community of the tenants or from the third-party investors (private companies).

Regarding energy performance, all redesign solutions have significantly improved aspects of thermal comfort and energy efficiency through design interventions. All elements of thermal envelope have been improved to the level of complying with current regulations or even surpassing it. Connections of new structural elements have been detailed in order to reduce thermal bridges. The first and second redesign proposals achieve energy savings of about 80% placing the buildings into the B energy rating (energy need for heating about 35 kwh/m^{2}y). The third redesign proposal achieves a C energy rating, with energy savings of about 70%, primarily due to a less compact design compared with the other redesign proposals.

2. DISCUSSION

All presented refurbishment scenarios and redesign project proposals achieve significant energy savings and energy performance upgrades compared to the existing state. Compared to the refurbishment proposals, redesign proposals achieve energy performance level which is between improvement proposals 2 and 3. This means that all presented solutions achieve energy performance in range with standards for new construction through the process of deep energy refurbishment. However, in comparison to these improvement scenarios, the redesign approach provides solutions with additional quality in terms of functionality of the building and each apartment. Also, the process of redesign is an opportunity not only to conduct energy performance upgrades, but also allows for a thorough refurbishment of all building elements, installations and finishings. This is the real opportunity for the ‘second life’ of existing buildings which have surpassed their proposed lifespan. Also, in terms of energy efficiency, the redesign process takes into account the enlargement of usable space, which not only improves the geometrical characteristics related to energy performance, but also provides an added value which offers opportunity for various investments, rental and usage schemes. Tackling these relations should also be part of the design studio since the social and economical aspect of redesign proposals cannot be neglected in the process of sustainable refurbishment. The unquestionable higher investment cost of redesign solutions can be tackled through higher market value not only of the existing apartments, but also through the newly formed apartment units. The higher property value achieved through the redesign of existing buildings would also affect the entire housing complex and its surroundings, raising its overall living quality and aesthetic appeal.

CONCLUSION

This paper presents methodology and results of a design studio with the topic of energy rehabilitation of an existing building. Results of this design studio are different refurbishment proposals, varying in the scope and design principles. Refurbishment scenarios which follow simple improvement algorithms, focusing on the upgrade of thermal envelope and technical systems, are defined in order to inform future design decisions in terms of constraints of the fabric and technical systems upgrade in relation to energy performance. The redesign phase is a comprehensive approach that deals not only with upgrade of existing structure in its technical and material properties, but also tackles functional, structural and aesthetic aspects of the existing building.

Three refurbishment proposals and three redesign proposals are presented. All proposals achieve significant energy savings compared with the existing state. The redesign proposals achieve similar level of energy savings as refurbishment options 2 and 3, which can be considered the level of deep refurbishment, but with many wider benefits following the redesign proposals. These benefits include higher property values, added value in the newly formed apartment units, functional and aesthetic appeal of the entire neighbourhood and a better life quality.

NOTES

N.B. **Acknowledgments**: The paper is a part of the research funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia, under the grant number 451-03-68/2020-14/200090. The research is done under research labs of University of Belgrade-Faculty of Architecture: Building stock laboratory and SaRA (Sustainable and Resilient Architecture).

1 UNEP 2018 Global Status Report: Towards a zero-emission, efficient and resilient buildings and construction sector.

2 The European Commission *Renovation Wave Strategy* from 2020, as key element of the *European Green Deal* and *The New European Bauhaus*, aims to at least double renovation rates in the next ten years and make sure renovations lead to higher energy and resource efficiency.

3 "Awarding the Pritzker to a team synonymous with refurbs marks an important shift in architectural values", says Phineas Harper commenting on Lacaton & Vassal's Pritzker Architecture Prize (2021) Dezeen, accessed February 22,2022. https://www.dezeen.com/2021/03/17/lacaton-vassals-pritzker-architecture-prize-opinion.

4 Salama, Ashraf M., 2006. "Learning from the environment: Evaluation research and experience based architectural pedagogy." *CEBE Transactions* 3, no. 1: 64-83.

5 Blagojević, Ljiljana. "Mediating Post-Industrial City Issues and Realities in the Study Process: Innovating Architecture Design Studio." International Scientific Conference & XXIV Meeting of Serbian Surveyors: Professional Practice and Education in Geodesy and Related Fields. Proceedings (2011).

6 Mohamed, Kamal Eldin and Elias-Ozkan Soofia Tahira. "Incorporating sustainability principles into architectural design education: Results of an experimental design studio." *Journal of Green Building* 14, no. 3 (2019), 143–158.

7 Saghafi, Mahmoud Reza. "Teaching strategies for linking knowledge acquisition and application in the architectural design studio." *International Journal of Architectural Research: Archnet-IJAR* 15, no. 2 (2021), 401-415.

8 Ibid, 3. See also: Grover, Robert, Stephen Emmitt and Alex Copping. "Critical learning for sustainable architecture: opportunities for design studio pedagogy." *Sustainable Cities and Society* 53, no. 3 (2019).

9 Salama, Ashraf M. "Editorial: Committed Educators are Reshaping Studio Pedagogy." *Open House International. Special Issue on Design Studio Teaching Practices* (The Urban International Press, United Kingdom) 31, no. 3 (2006), 4-9.

10 Salama, Ashraf M. *Transformative Pedagogy in Architecture and Urbanism*. Solingen: Umbau-Verlag (2009).

11 Tempelman, Erik and Pilot Albert. "Strengthening the link between theory and practice in teaching design engineering: An empirical study on a new approach." *International Journal of Technology and Design Education*, (2011).

12 Nik Lukman, Nik Ibrahim and Nangkula Utaberta. "Learning in Architecture Design Studio," *Procedia - Social and Behavioral Sciences*, 60 (2012), 30-35.

13 Grover, Robert, Stephen Emmitt and Alex Copping. “Critical learning for sustainable architecture: opportunities for design studio pedagogy.” *Sustainable Cities and Society* 53, no. 3 (2019).

14 Marinović, Goran Ivo. “Participatory sustainability beyond techno-aestheticism and ecological modernisation.“ *SAJ*, 10 (2018), 183-200.

15 Salama, Ashraf M. “Editorial: Committed Educators are Reshaping Studio Pedagogy.” *Open House International*. 31, no. 3 (2006), 4-9.

16 Saghafi, Mahmoud Reza. “Teaching strategies for linking knowledge acquisition and application in the architectural design studio.” *International Journal of Architectural Research: Archnet-IJAR* 15, no. 2 (2021), 401-415.

17 Grover, Robert, Stephen Emmitt and Alex Copping. “Critical learning for sustainable architecture: opportunities for design studio pedagogy.” *Sustainable Cities and Society* 53, no. 3 (2019).

18 Schön, Donald A. *The reflective practitioner: How professionals think in action* (New York: Basic books, 1984).

19 Salama, Ashraf M. “A theory for integrating knowledge in architectural design education.” *International Journal of Architectural Research: ArchNet-IJAR 2*, no. 1 (2008), 100-128.

20 Kolb, David A. *Experiential learning: Experience as the source of learning and development* (Englewood Cliffs, NJ: Prentice Hall, 1984).

21 Specialist studies are addressed to graduate students with master’s degree (300 ECTS) in architecture, civil engineering and mechanical engineering.

22 Haase, Jeffrey. “Temporary Space - Permanent Knowledge.“ *Open House International* 31, no. 3 (2006): 103-111.

23 Salama, Ashraf M. “A theory for integrating knowledge in architectural design education.” *International Journal of Architectural Research: ArchNet-IJAR 2*, no. 1 (2008), 100-128.

24 Saghafi, Mahmoud Reza. “Teaching strategies for linking knowledge acquisition and application in the architectural design studio.” *International Journal of Architectural Research: Archnet-IJAR 15*, no. 2 (2021), 401-415.

25 The methodology for definition of these refurbishment scenarios has been established through the work on typology of residential and public buildings in Serbia (publications available online at http://eeplatforma.arh.bg.ac.rs/en/publications?tab=0) and used excessively in investigation of refurbishment potential of building stock in various scales (building level, municipal/local level, and national level). See also: Ćuković Ignjatović, Nataša, Ignjatović Dušan and Zeković Bojana. “Improving energy efficiency of kindergartens in Serbia: challenges and potentials.” *Thermal Science Volume* 24, Issue 6 Part A, (2020) 3521-3532.

26 Defined by the Rulebook on energy efficiency in buildings (2011) and Rulebook on conditions, content and method of issuing energy performance certificates (2012) issued by the Ministry of Construction, Transport and Infrastructure of Republic of Serbia.

27 ‘Durisol’ is a type of lightweight concrete block, built from mixture of concrete and wood-processing residues, usually with a concrete infill, acting as lost formwork in wall construction. It was widely used during the last decades of the 20th century in Serbian building practice.

28 Ignjatović, Dušan, Rajčić Aleksandar and Stanković Bojana. “Building Simulations and Modelling: Energy“ in. *Energy resources and building performance, thematic book series Reviews of Sustainability and Resilience of the Built Environment for Education, Research and Design as results of the Erasmus+ project, Creating the Network of Knowledge Labs for Sustainable and Resilient Environments (KLABS)*, eds. Thalia Konstantinou, Nataša Ćukovic Ignjatović and Martina Zbašnik-Senegačnik. (TU Delft Open, 2018), 129-144.

29 A widely used free software available online (https://www.knaufinsulation.rs/knaufterm-2-pro-srbija) for calculations of energy needed for heating in line with domestic legislation.

30 Ćuković Ignjatović N., Ignjatović D., Stanković B. “Possibilities for energy rehabilitation of typical single family house in Belgrade - case study. “Energy and Buildings, Vol. 115, Special Issue: A selection of International Academic Conference “Places and Technologies 2014”, Belgrade, Serbia (2016), 154-162. See also: Ćuković Ignjatović, Nataša and Ignjatović Dušan. “Some possibilities of extensions in building renovation.”PLEA 2006 - 23rd International Conference on Passive and Low Energy Architecture, Conference Proceedings.

BIBLIOGRAPHY

Bachelard, Gaston. *The Poetics of Space. Beacon Press*, 1994.

Baudrillard, Jean. *Why Hasn't Everything Already Disappeared?* Seagull Books, 2009.

Barbaras, Renaud."Invisibility at the heart of appearance: on perception, art and desire." In: *Paradoxes of Appearing: Essays on Art, Architecture and Philosophy*, ed. by Michael Asgaard Andersen, 169-185.

Bergson, Anri. *Materija i pamćenje*. Fedon, 2013.

Bourriaud, Nicolas. *Formes de vie. L'art moderne et l'invention de soi*. Denoël, 2009.

Bourriaud, Nicolas. *L'exforme. Presses universitaires de France* - PUF, 2017.

Delez, Žil. *Razlika i ponavljanje*. Beograd: Fedon, 2009.

Gavrić, Zoran and Bjelić, Branislava, ed. *Marcel Duchamp: Spisi – Tumačenja*. Samizdat Bogovađa, 1995.

Hauzer, Arnold. *Socijalna istorija umetnosti*. Kultura, 1966.

Hendrix, John. *Theorizing a contradiction between form and function in architecture*. Routledge, 2013.

Ibelings, Hans. *Supermodernism: Architecture in the Age of Globalization*. NAi Publishers, 1998.

Jameson, Fredric. *Postmodernism or the Cultural Logic of Late Capitalism*. London: Verso, 1991.

Kaminer, Tahl. Architecture, *Crisis and Resuscitation: The Reproduction of Post-Fordism in Late-Twentieth-Century Architecture*. Routledge, 201.

Latur, Bruno. *Nikada nismo bili moderni*. Mediterran Publishing, 2010.

Lavin, Sylvia. *Flash in the Pan*. Architectural Association Publications, 2015.

Milenković, Vladimir. *Arhitektonska forma i multi-funkcija*. Beograd: Zadužbina Andrejević, 2004.

Mitrović, Jelena and Milenković, Vladimir. "Arhitektura kupole: mapiranje nebeske dubine." *Theoria* 1, no 63. (2017): 163–175. http://www.doiserbia.nb.rs/img/doi/0351-2274/2017/0351-22741701163M.pdf.

Niče, Fridrih. *Volja za moć*. Dereta, 2012.

Oliva, Akile Bonito. *Ideologija izdajnika*. Svetovi, 1989.

Oliva, Akile Bonito. A.B.O.M.D., Svetovi, 1977.

Panofsky, Erwin. *Rasprave o osnovnim pitanjima nauke o umetnosti*. Bogovađa: Samostalno izdanje, 1999.

Rabinow, Paul. "Beyond Ethnography: Anthropology as Nominalism." *Cultural Anthropology*, no.1 (2009): 355-364.

Renaud Barbaras, ”Invisibility at the heart of appearance: on perception, art and desire,” 169-185. In *Paradoxes of Appearing: Essays on Art, Architecture and Philosophy*. Ed. by Michael Asgaard Andersen. Lars Müller Publishers, 2009.

Stevens, Wallace. ***The Collected Poems of Wallace Stevens***. New York: Vintage Books, 1990.

Till, Jeremy. ***Architecture Depends***. The MIT Press, 2009.

Vignjević, Ana. Metamaterijalnost: ahitektura i pejzažni kod. Doktorska disertacija. Univerzitet u Beogradu - Arhitektonski fakultet. 2016.

Virilio, Paul. ***War and Cinema***. London: Verso, 1994.

Wingham, Ivana. ***Mobility of the Line: Art Architecture Design***. Birkhauser Verlag AG, 2013.

Ricoeur, Paul. “Architecture and narrativity.” Translated by Eileen Brennan, Robbie Carney and Samuel Lelièvre. ***Études*** *Ricoeuriennes / Ricoeur Studies* 7, no. 2 (2016): 31-42.

Ricoeur, Paul. *Memory, History, Forgetting.* Translated by Kathleen Blamey and David Pellauer. Chicago: University of Chicago Press, 2004.

ENERGETSKA REHABILITACIJA POSTOJEĆIH OBJEKATA: PROJEKTANTSKI STUDIO

Dušan Ignjatović, Bojana Zeković, Nikola Miletić

U ovom radu je predstavljena studija slučaja dizajn studija sa temom energetske sanacije postojećih zgrada, na postdiplomskim studijama – Specijalističke akademske studije – Energetski efikasna i zelena arhitektura, na Univerzitetu u Beogradu – Arhitektonskom fakultetu. Metodologija ovog studija koristi pristup projektno orijentisanom učenju, simulirajući realno multidisciplinarno okruženje za razvoj projekata. Opisane su tri faze razvoja dizajna: faza istraživanja, faza renoviranja i faza redizajna. Počinje sa fazom istraživanja, koja se razvija paralelno sa fazom obnove. To je zato što proces renoviranja u ovom studiju nije ograničen samo na tehničke aspekte poboljšanja energetske efikasnosti, verifikovane proračunima i simulacijama. Razvijeno je nekoliko scenarija projektovanja koji ispituju minimalni, optimalni i maksimalni opseg poboljšanja energetske efikasnosti u tehničkim sistemima i toplotnom omotaču zgrade. Analiza ovih scenarija, ali i analiza mnogo šireg spektra aspekata koji utiču na dizajn rekonstrukcije, rezultiraju konačnim predlogom redizajna koji je sveobuhvatan, duboki predlog renoviranja, koji se bavi, ne samo energetskim (pod)performansama, već i mogućnostima za nadogradnju. funkcionalnih, tehničkih i estetskih aspekata postojećeg objekta.

KLJUČNE REČI: DIZAJN STUDIO, DUBINSKO RENOVIRANJE, REDIZAJN, ENERGETSKA EFIKASNOST, ENERGETSKE PERFORMANSE