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COMPETENCES OF ENGINEERS AND WORKERS IN THE ARCHITECTURE, ENGINEERING & CONSTRUCTION INDUSTRY FOR DELIVERING NEARLY ZERO-ENERGY BUILDINGS

Stručni rad / Professional paper

Summary

By 31 December 2020, all new buildings in the European Union, and therefore in Croatia, should be Nearly Zero-Energy Buildings (NZEB). A question which arises is: are the engineers and workers in the Architecture, Engineering & Construction (AEC) industry well prepared for delivering such a solution? Information loss and lack of collaboration bring potential problems in the construction phase, so quality of final product (NZEB) drops drastically. Building Information Modeling (BIM) is a good solution for the problems described, since it reduces information loss in the building life cycle (design, construction, operation & maintenance, demolition) and increases collaboration between stakeholders, as they need to work with the same information model. The building should also be a good representative of the design itself, so it should be built as correctly as possible. The article shows in what way the Horizon 2020 Fit-to-NZEB and Net-UBIEP projects can be used to solve lack of competences for building NZEB and problems of BIM implementation in the AEC industry in Croatia. The Net-UBIEP project aims to develop schemes for BIM usage in increasing building energy performance (validation through surveys), while project Fit-to-NZEB aims to develop competences for deep energy retrofit through education at EQF levels 3-7.

Keywords: *competences, Nearly Zero-Energy Buildings, Fit-to-NZEB, BIM, Net-UBIEP*

[Publisher's note: The body of the work, below, has not been revised or proofread by the Croatian Society for Quality (HDK)]

1. INTRODUCTION

Improving the energy efficiency of European building stock is a key step in achieving 2020, 2030 and 2050 EU energy and CO_2 emission targets. European Directives, in particular, the EED [1], EPBD [2] as well as amended EPBD and EED [3] and related national regulations, set very strict energy-efficiency targets on European building stock, with the aim to generalize nZEB by 2021. Panev et al. [4] see energy renovation as a stabiliser for the building sector and consequently the overall EU economy while technological aspects whose improvement is necessary and innovations needed to push forward the market uptake of Nearly Zero-Energy Buildings (nZEB) will foster economic growth. The construction industry presents a major opportunity to not only reduce energy demand but also to improve process efficiency and reduce carbon emissions. Original culture and practices of the construction sector are widely perceived as a "low-tech" area with a significant proportion of "blue collar" workers but the construction industry is experiencing its digital revolution, with an intensification of digital

support in all stages of building design and construction. The process of designing, re-purposing, constructing and operating a building or facility involves not only the traditional disciplines but also many new professions in areas such as energy and environment. In this context, it is evident that Building Information Modelling (BIM) integrated with energy performance requirements (nZEB) will facilitate the improvement of energy performance in a more effective and efficient manner. Computer generated BIM models are increasingly needed to simulate the planning, design, construction and operational phases of an nZEB project in order to reduce so-called energy performance gap and to improve the quality of nZEBs.

The lack of qualified workers is more than evident due to the migration of workers to western European countries as well as booming publicly and privately funded energy renovation projects and the lack of students enrolled into professional high schools (Vocational Education and Training – VETs) related to energy efficiency. The VET programmes (European Qualification Framework - EQF level 2 and 3) are recording a decreasing number of students year after year. Additionally, it is more and more common, that after finishing professional school (VET) the work requires from the graduate something slightly different, and sometimes even something entirely divergent from what was emphasized during studies.

In total, some 30,000 workers are needed in construction industry to satisfy current contracts [5], while the analysis was made in 2013 [6] which assessed that in total some 37,600 workers in the field of energy efficiency and renewable energy sources (RES) would have been needed at the time to be able to achieve the 20-20-20 targets, and under the assumption that 3% of heated usable floor area of buildings would be renovated every year. The direct impact of the national building fund renovation program until 2020 on employment in the construction sector could amount to up to 26,000 new jobs. Due to the lack of construction workers, the Croatian government has defined a permissible quota of foreign workers which could come and work in Croatia at 10,070 men [5]. Employers are still not satisfied since they cannot find a enough qualified foreign workers and get them to work in Croatia due to relatively low salaries compared to salaries in West European countries. One of the most significant problems of the construction market in Croatia (all participants in construction projects) is the lack of knowledge and competences on nZEB. It has to be enhanced that three-year (VET) educational programmes for professions related to nZEB and Deep Energy Retrofit (DER) are obsolete since they were not changed since 1996 and 1997 and the teaching material used, contains very little topics related to energy efficiency. Several gymnasiums in Croatia are providing programmes titled Gymnasium for sustainable development as good preparation for pupils who intend to go to Universities to study similar programmes there. This programme offers three different modules, Eco-sustainability, Energy sustainability and Sustainable construction. Within these three modules, students are among other subjects attending courses on Renewable energy sources, Energy refurbishment of buildings, Passive and low-energy buildings. Never the less it has to be enhanced that this is a new four-year programme developed in the last 5 years, where students which finished it are not able to perform construction works and are intended to attend University. Croatian educational system is currently not producing experts and workers which could enter the construction market and have sufficient competences with respect to nZEB and BIM. From July 2017, the Ministry of Construction and Physical Planning enforced the “Ordinance on education and certification system of construction workers working on the installation of building components which affect the energy efficiency of buildings” [7] which is envisioned to increase the number of skilled workers working on energy refurbishment and construction of new nZEBs. Similar ordinances exist for the installers of RES Systems where there are also several training centres established which give education on the installation of RES systems [5] – [11].

It can be concluded that additional education at the Universities, as well as lifelong education (EQF level 6 & 7) in the field of nZEBs and DER of existing buildings up to the nZEB level, is needed to provide the necessary technical knowledge to public administration, designers, technical supervisors, and site managers, not excluding other experts. At the moment, such education at the Universities is provided sporadically with only one or two subjects in the specific field and is lacking interdisciplinary approach, while Life Long Learning (LLL) courses are sporadic and lack systematic approach and coordination between different market players.

2. NEARLY ZERO-ENERGY BUILDINGS

European Energy Performance of Buildings Directive (EPBD, 2010/31/EC) (EPBD II) [2] sets out the definition for a building with nearly zero energy consumption at the European level. nZEB is defined by the EPBD II as *"a building that has a very high energy performance" where "the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby* [2]. On the basis of this definition, the EU Member States have created a definition for nZEB at the national level, which takes into account the given country's economic and climatic conditions. The residential sector alone accounts for around one-third of the country's total energy consumption and, therefore, has the largest energy saving potential [12].
In a line with Directive 2012/27/EU [1] of the European Parliament and of the Council on energy efficiency, the Croatian government developed its 2nd National Energy Efficiency Action Plan (NEEAP) [13], in which the government highlighted the need for policy action to make buildings more energy efficient in order to meet the national energy efficiency targets. The government also recognised the need to stimulate the construction sector by introducing large scale renovation programmes to speed up the recovery of the construction industry [14]. In the 3rd NEEAP (2014-2016) [15], the government announced its intention to launch a range of public programmes to improve energy efficiency in buildings. The government launched several financial support instruments and energy renovation programmes which have targeted family homes, multi-family housing, public buildings and commercial buildings. These renovation programmes provide government funding through the Environmental Protection and Energy Efficiency Fund (EPEEF) to building owners to encourage and assist them to carry out energy-saving renovation work on their buildings. The activities that are eligible for funding are:

- Renovation of the building envelope, which refers to improvements in building insulation;
- Complete building renovations, which covers both the building envelope and the building energy system

National Building Renovation Strategy (Art 4 EED) [16] is a part of an ambitious project of building renovation, which includes also a Plan for increasing of the number of nZEBs until 2020 [17]. In Croatia, nZEB construction projects preparation (both new and renovation) is mainly provided by small and medium-sized companies, which have a limited ability to follow the massive flow of information and knowledge now available. Specialization in designing and building new nZEBs and DER of existing buildings to nZEB level and professional opportunities emerging from specialisation is virtually non-existent. The construction professionals are continuing with "business as usual" approach also when

building nZEBs. At the moment of completing this paper, very few nZEBs were designed, let alone constructed as stakeholders lack experience and often learn from their own mistakes. Thus, the importance of appropriate competences and the lack of appropriate competencies regularly becomes evident in the late stage of the project development, when the costs of rectifying mistakes become high.

The significance of residential and services buildings in terms of share in total energy consumption can clearly be seen in national final energy consumption data. In 2016, the share of the consumption in buildings was over 35% in 16 countries (11 of them have a share over 40%) (Figure 1) which makes buildings the largest end-use energy consumption sector in most European countries [18].

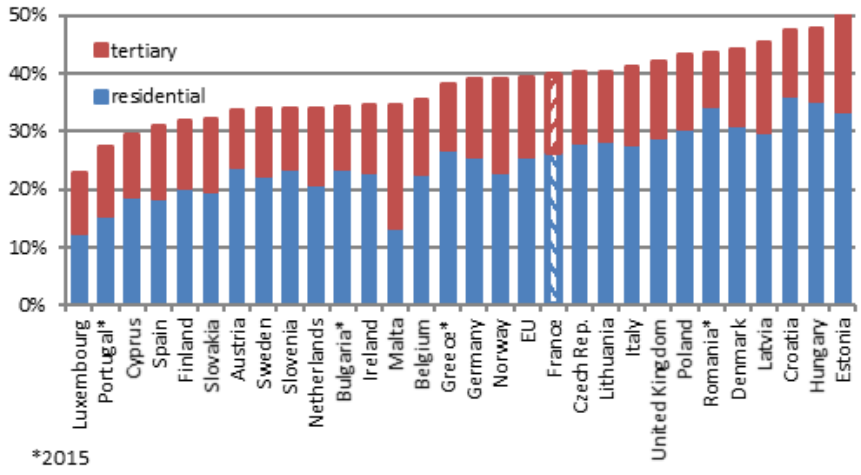


Figure 1 Residential and tertiary buildings consumption by country (% of the total final consumption – 2016) [18].

It is well known that, buildings have a central role to play in the energy transition of the EU since they are responsible for about 40% of primary energy consumption in the EU and about 36% of energy-related CO_2 emissions while at the same time around 75% of the building stock is energy inefficient [19]. DER of existing buildings is necessary to phase-out inefficient buildings from the EU building stock. DER implies the implementation of cost-effective measures that will significantly reduce delivered and final energy consumption compared with pre-renovation consumption, leading to very high energy performance.

The increase of the number of qualified construction specialists at all levels is directly related to the accessibility and quality of the training and educational programmes and the inclusion of training on intelligent energy efficiency and RES solutions in building renovation. The optimisation of building's energy use requires an integrated design approach and cross-disciplinary teamwork, which then leads to the high quality of indoor environments and satisfying the occupants' needs [20]. According to Yang et al. [21], an advanced nZEB design requires effective and efficient sharing of information among members from different disciplines in an Integrated Design Group (IDG) in order to make wise decisions about selecting the right set of energy retrofit design options. This could be achieved by introducing Integrated Product Design (IPD) into the nZEB design process [20]. Additionally, it has become clear that better management of the information during the whole life cycle of the nZEB is necessary in order to avoid mistakes and have trustful information at any time which can be achieved by BIM approach.

3. BUILDING INFORMATION MODELLING FOR NZEB PROJECTS

Building Information Modelling (BIM) is a representation of the functional and physical characteristics of a facility in a digital environment. BIM is organized and shared database of information about a facility which is a reliable basis for decision-making processes during its life-cycle (from earliest conception and design phases to demolition). In Croatia, BIM technology is used sporadically and is largely restricted to use in design offices with frequent lack of interdisciplinary collaboration within the BIM design process and with little knowledge and competences on the BIM design process [22]. Even though Croatia has well developed and organized AEC–focused professional associations and chambers, BIM was and still is primarily emphasized and developed in scientific and educational circles [23]. There is still no sign of BIM in Croatian construction legislation. However, there are active initiatives making the first steps towards standardizing BIM with the Croatian Standards Institute TC 551. In Croatia, currently, there is no national standard that defines requirements for existing BIM professional profiles. BIM professional profiles with their tasks and competencies in BIM projects are covered, i.e. scarcely defined in "General guidelines for BIM approach in civil engineering" published by Croatian Chamber of Civil Engineers in June 2017 [24]. As its name says, those guidelines are quite general and do not elaborate BIM professional profiles in detail. Figure 2 shows the hierarchical organizational structure of BIM roles/responsibilities.

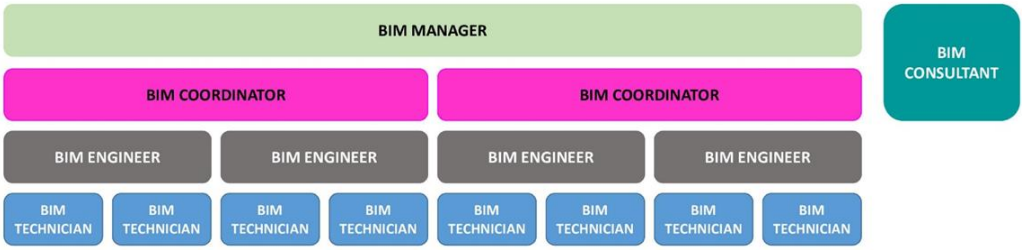


Figure 2 Hierarchical organizational structure of BIM roles/responsibilities [24].

Croatian Chamber of Civil Engineers has proposed the assignment of corresponding roles in BIM projects in relation to the standard roles in construction projects (Figure 2) [24]. It must be noted that regulations, processes and stakeholders involved in building life-cycle in Croatia form a complex matrix which requires more comprehensive analysis and definition of BIM profiles, as well as their corresponding roles which differ substantially from those presented in Figure 2.

The design process regarding nZEB needs to be a collaborative effort between all stakeholders. There is a substantial need for professionals, such as architects and engineers as well as other stakeholders, to be specifically educated in an integrated design approach and trained to work in cross-disciplinary teams using BIM approach. Similar to digital breakthroughs in other industries, BIM is beginning to transform the construction business by reorganizing the value chain. BIM promotes collaboration at each stage of a project instead of reinforcing the industry's traditional silos [25]. BIM should be a good tool for designing the nZEB because more time is spent in the design phase and therefore a better solution could be provided, i.e. cost optimal solution of the NZEB. Not only more variant solutions could be examined but also all they could be checked by preliminary energy simulation so the quality of NZEB design increases [26].

4. NET-UBIEP

The Horizon 2020 funded project Net-UBIEP aims at increasing the energy performance of buildings by wide spreading and strengthening the use of Building Information Modelling (BIM), during the life cycle of the building. It is thought that the use of BIM will allow the simulation of the energy performance of the building using different materials and components, both to be used in the building design and/or in building design refurbishment [27]. The main objective of the project is to integrate Building Information Modelling with energy performance requirements in order to promote the improvement of energy performance in a more effective and efficient manner. The project proposes BIM Qualification Models integrated with energy (nZEB) competences, to widespread a better comprehension of energy issues along with all the value chain of building industry so that both existing and the new building will have better energy performances. Public Administrations, Professionals (Engineers/Architects), Technicians (Installers/Maintainers) and Tenants will be therefore involved in the Net-UBIEP activities [28]. The definition of the BIM Qualification Models passes through the identification of specific energy BIM competencies for each of the above target needed to implement BIM models during the whole building life cycle.
During the project, the "integrated" BIM Qualification Models have been validated by stakeholders thanks to the delivering of different training activities (Seminars/Classrooms Courses/E-Learning Courses) addressed to at least six BIM Professional Profiles: BIM Manager, BIM Evaluator, BIM Coordinator, BIM Expert, BIM facility manager, BIM user. Once the schemes are validated through a survey, they will be proposed for standardization to find a broader acceptance at European and international level through regulatory organizations (CEN/ISO). Existing BIM professional profiles in partner countries have been identified by inventorying, comparing and discussing already available profiles. Within this process, the EQF methodology has been used to clearly identify knowledge, skills and competencies and to create common profiles. List of Competencies to energy Performance needed for each BIM professional profile was defined where competencies on energy performance are mapped to the defined target groups, public administration, professionals, technicians and owners. Also, there is a mapping to the different BIM professions: BIM manager, BIM coordinator, BIM expert, BIM expert user, BIM evaluator, BIM facility manager and the unaware BIM user. Multimedia Handbook for all four target groups were developed and are being validated through different training activities.

5. FIT-TO-NZEB

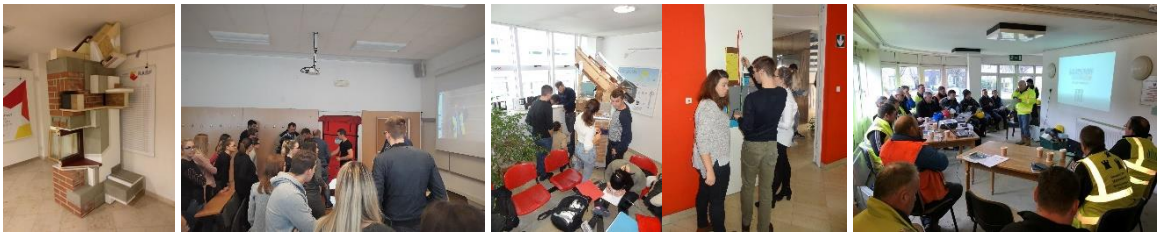
Fit-to-nZEB (Horizon 2020) [29] project aims to increase competence and skills of the building professionals in the field of DER in the target countries (Czech Republic, Romania, Bulgaria, Italy, Croatia, Ireland and Greece) through the unique educational programmes developed by the consortium, which will contribute to both the quality and the scale of the deep energy building renovations.
The project consortium developed an innovative EQF level 3-7 training schemes for retrofitting buildings up to nZEB-levels, implemented under the project framework. The training programs have been organized in different countries across Europe with a common structure, learning outcomes and competencies. Courses were delivered by Universities, professional high schools and colleges, vocational training centres (VTCs) as well as through on-the-job training and validation programmes [30].

Prior to the development of the compendium of competences, within the Fit-to-nZEB project, an analysis of existing training programmes for DER in the partner countries was performed with the identification of gaps and deficiencies. In all target countries, a tangible lack of integration of the topic in the professional secondary, high and higher education and vocational training programmes were identified. The observation shows that the allocation of the identified programmes within the EQF system is quite broad and unstructured, and it is very difficult to harmonize and compare the results of the analysis at the national level - as related to both the professional education and the vocational training system. In the secondary and high education (EQF 3-5) system, principles of DER are not included in official training programmes. In higher education (EQF 6-7), there are some fragments of the topic represented by certain subjects that are studied separately from each other. That is why the lack of qualification is filled in most cases by vocational education. Vocational training was divided into two large parts according to the target group, for construction workers (EQF 4-5) and supervising professionals (EQF 6-7), this training is however not harmonised and do not provide official DER qualification in their national qualification frameworks [31].
The analysis of the Fit-to-nZEB project showed the necessity to develop each EQF level programme for DER implementation in each target country [31]. Additionally, a compendium (systematically organized collection of requirements) of competences for DER was derived from all relevant professions. The Fit-to-nZEB project delivered all necessary requisites for the introduction of educational content on DER of buildings in the curricula at all levels of the educational and training system in South-eastern Europe [31]. End users of the developed compendium of competences are developers of new training programmes on DER and nZEB renovations, as well as decision makers, involved in the educational system, and the trainers. It is thought that the elaborated learning outcomes can be applied to the development of wide range of training programmes of vocational or specialised education for construction specialists and that they represent the fullest collection of new competencies related to DER in the involved countries [31].
New training programmes target at all professional groups involved in the retrofit process. Based on the compendium, training programmes for the following EQF levels were developed [31]:

- **EQF level 6-7**: A design-focused training programmes on DER for higher education, 60 hours of training (*30 theoretical hours and 30 practical hours*), with all necessary requisites.

- **EQF level 3-5**: A training programme to be included in the professional high schools in training plans and programmes for the tradesperson professions in “Construction”, consisting of *24 theoretical hours and 36 hours of practical training*. Training content for professions in “Electrical engineering and energy sector” professional direction was also developed, consisting of *24 hours of theoretical and 18 hours of practical training*.

- **EQF level 3-4**: Two training programmes for acquiring qualification on part of the profession (specialization, or similar qualification according to each national qualification framework), to be used by the VTCs, *16 hours of theoretical and 24 hours of practical training*. A comprehensive scheme for validating competencies acquired at the workplace, consisting of entry-level tests, with theoretical and practical training (*8-12 hours*) and evaluation scheme.



a) b) c) d)

Figure 3 a) example of the training models, b) execution of the university training – blower door, c) university training – minimizing thermal bridges, d) on the job training in Ireland [31].

In order to create a hands-on and practical training demonstration, training models were designed and developed (Figure 3 a), c)). Visualization by means of models during training programmes is an essential method for better assimilation of the programme content. These training models are being used by the training centres, specifically serving the goal of providing a close-to-real training environment regarding the retrofitting process.

The models also provide the trainees with an insight into small-scale RES systems (PV, solar thermal, mini-wind, biomass, thermal pumps) in a close-to-real environment, bridging the skills between the different crafts and professional occupations involved in the process. Additionally, the MVHR units are installed in rooms within/beside the model itself. The rooms and measuring devices for testing the ventilation equipment and wind tightness of building envelope are available for practising at the premises (Figure 3 b).

6. CONCLUSION

It is clear that there is an incredible lack of training available in the target countries relating to nZEB and DER, most likely reflecting the low interest in this topic to date on the part of employers. However, as the nZEB standard becomes mandatory across Europe, the level of interest in nZEB and DER can be expected to increase significantly.

There is much responsibility being placed on designers and construction workers to deliver a positive experience for building owners who embark on an nZEB and DER project, and without the appliance of science, there is much that can go wrong. The implication of this for the programmes is that they must strike a balance between theory and practice. In short, all players need to know not only the ‘how’ but also the ‘why’ and the ‘what if’. Whilst the incorporation of practical training is important, therefore, it must not be introduced to the detriment of a poor theoretical basis. General trends in education are that there is an increase in authentic teaching methodologies and information technologies in the learning process in both HEI and VET in the field of both nZEB and BIM. For example, it was proved through EU projects and pilot courses that participants stressed the value of shortening of the theoretical part in favour of practical learning. Studying on the examples full-scale demo models and practical models, real equipment and practical walls, where trainees can implement a practical solution, or visits of construction sites with nZEBs under construction, is the most valuable. Furthermore, an important trend is to motivate trainees to take active participation in their learning process, while trainers should take the role of a coach and consultant rather than presenter and controller. With Net-UBIEP and Fit-to-NZEB projects, competences of all stakeholders in the AEC industry will increase and therefore a quality of nZEB which is a common goal of both projects. Another important European project is starting at the moment of writing this paper, it is Erasmus+ project BIMzeED which will

increase competences of AEC stakeholders through education and training for construction students, site managers, craftworkers and other experienced operatives regarding BIM usage for NZEB delivering.

ACKNOWLEDGEMENTS

Authors would like to acknowledge the Horizon 2020 projects Net-UBIEP and Fit-to-NZEB, and Erasmus+ Project BIMzeED. One of the authors (Sanjin Gumbarević) would like to acknowledge the Croatian Science Foundation and European Social Fund for the support under project ESF DOK-01-2018.

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KOMPETENCIJE INŽENJERA I RADNIKA U POLJU GRAĐEVINARSTVA PRI REALIZACIJI ZGRADA GOTOVO NULTE ENERGIJE

Sažetak

Do 31. 12. 2020. godine sve nove zgrade u Europskoj uniji pa tako i u Republici Hrvatskoj moraju biti zgrade gotovo nulte energije (NZEB). Postavlja se pitanje jesu li današnje kompetencije inženjera i radnika u građevinarstvu dovoljne da se to i realizira u praksi. Nedostatak informacija te nedovoljna komunikacija između projektanata kao i prema izvođačima radova dovode do problema u fazi izvođenja novih te energetske obnove postojećih zgrada, čime pada kvaliteta isporuke projekta. Modeliranje građevinskih informacija (BIM) se nameće kao rješenje opisanih problema jer smanjuje nedostatak informacija u cjeloživotnom ciklusu zgrada (projektiranje, građenje, upravljanje, rušenje) i poboljšava suradnju između svih sudionika kroz promoviranje rada na jednom informacijskom modelu. Zgradu je, također, potrebno i pravilno izvesti kako bi bila što vjerniji prikaz projektiranog stanja. Rad prikazuje na koji se način kroz projekte Fit-to-NZEB i Net-UBIEP programa Obzor 2020 rješavaju problemi nedostatka kompetencija u smislu NZEB-a i BIM-a u području zgradarstva. Net-UBIEP ima za cilj izradu kompetencija za korištenje BIM-a u poboljšanju energetske učinkovitosti zgrada (validacija anketama), dok Fit-to-NZEB definira kompetencije u području dubinske energetske obnove kroz obrazovanje pri EKO razinama 3-7.

Ključne riječi: *kompetencije, zgrade gotovo nulte energije, Fit-to-NZEB, BIM, Net-UBIEP*