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Improving competences of engineers and workers in the AEC industry for delivering NZEBs

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Abstract: The energy performance of buildings directive requires from the European Union Member States to ensure that by 31 December 2020 all new buildings are nearly zero-energy buildings (NZEBs) and after 31 December 2018, new buildings occupied/owned by the public authorities should also have the NZEB performance. The large-scale deployment of NZEBs represents a challenge for all the stakeholders involved in the construction sector, where the lack of adequate competences is identified as one of the main obstacles. This article aims to provide a solution to overcome the deficient competences related to NZEB to increase them by using roadmaps derived from Horizon projects – Fit-to-NZEB and Net-UBIEP. Fit-to-NZEB aims to increase the knowledge of architecture, engineering and construction engineers and workers in deep energy retrofit through the education in European qualifications framework levels 3–7, while Net-UBIEP seeks to develop the schemes for using building information modelling (BIM) throughout the whole building life cycle to increase energy performance. The results from both projects show that it is inevitable to act soon to make the energy efficiency targets possible to fulfil. The integrated design process and strengthen control on the construction site should be carried out perfectly as they are the most critical parts in delivering NZEBs and all this managed by BIM to minimise information loss and to improve the design of details. To achieve this, professional competences of all the stakeholders in delivering NZEBs must be improved which could be done by implementing the knowledge from these projects.

Keywords: education in construction, nearly zero-energy buildings, Net-UBIEP, Fit-to-NZEB, BIMzeED, building information modelling

1 Introduction

To achieve the 2020, 2030 and 2050 goals set by the European Union through the energy performance of buildings directives (EPBD) (European Parliament and the Council of the European Union, 2010) and energy efficiency directive (EED) (European Parliament and Council of Europe, 2012), a large scale of deep energy retrofit (DER) should be carried out. EPBD mandates that by 31 December 2020, all new buildings and all the buildings under major renovation must have the nearly zero-energy buildings (NZEBs) performance. The same applies to the buildings occupied and owned by the public authorities after 31 December 2018 because buildings owned and occupied by the public authorities should be a good-practice example as they are representing the state and therefore should adopt energy efficiency demands first to encourage building owners and investors in the building sector to follow their example. The EED also sets strict energy-efficiency targets on European building stock with demand for every EU member to develop a programme for deep energy renovation of the building stock up to 2050. As a result of the deadlines mentioned earlier, it can be concluded that the large number of NZEBs will be built from now up to 2050. Thus, the question is whether the engineers and workers in the architecture, engineering and construction (AEC) industry are sufficiently prepared to fulfil such a demand. This article describes the current situation in the AEC industry concerning DER in Croatia and tries to provide a possible solution for increasing the competences of the AEC stakeholders through the European scientific projects.

DER could be a stabiliser for the building sector and consequently the overall EU economy (Saheb et al., 2015) with necessary technological improvement and innovations in the AEC industry to achieve the NZEB performance. The interdisciplinary approach in all the building life cycle, as shown in Figure 1 (from the early

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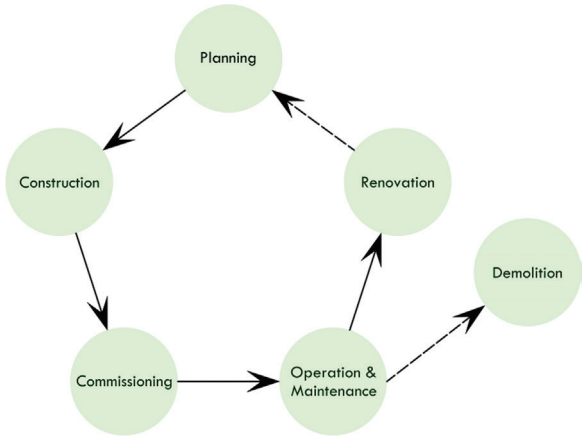

Fig. 1: Building life cycle.

planning phases through the construction, commissioning, operation and maintenance to the demolition and recycling), must be implemented for the same reason as well as a digital transformation of the AEC processes. As one of the enablers of interdisciplinary collaboration, building information modelling (BIM) is therefore inevitable. BIM, integrated with energy performance requirements, can facilitate the improvement of building energy performance more effectively and efficiently. By achieving the NZEB performance, the society will benefit not only in the reduction of the energy demands but also in lowering the emission of the greenhouse gasses, and all of that should be followed by increased indoor comfort for occupants.

It can be concluded that the additional education in the field of NZEBs and BIM needs to provide the necessary technical knowledge to the public administration, engineers, architects, technical supervisors, and site managers, not excluding the other experts. At the moment of writing this article, such education at the Universities in Croatia is being provided sporadically with a few courses concerning NZEBs and BIM, and those courses are also lacking an interdisciplinary approach. On the other hand, lifelong learning (LLL) courses are sporadic and lack a systematic approach, concerned mainly with software training (Milovanović, Banjad Pečur, et al., 2019).

This article consists of seven sections. Section 2 thematically introduces general knowledge on BIM and NZEB to a reader. Section 3 discusses the methodology that is presented with an explanation of methods used within the projects and in this research. Section 4 discusses the analysis of competences specific to NZEB delivery (competences of workers). Section 5 discusses the competences of workers and engineers. Section 6 discusses the competences of AEC stakeholder groups defined within the project Net-UBIEP. Alongside analysis of competences, a discussion is held in the sections that introduce the certain project with presenting the impact of project results on increasing competences for NZEB construction (Section 5) and BIM competences for improving the energy efficiency of buildings (Section 6). The last section presents a conclusion that introduces the BIM knowledge to NZEB deployment with connecting the knowledge from two Horizon projects to increase the quality of delivered NZEBs.

2 NZEB and BIM interdependence

The EPBD sets out the definition for a building with nearly zero energy consumption on the European level: *"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"* (European Parliament and the Council of the European Union, 2010). Every EU Member State has created a definition of the NZEB, based on the abovementioned definition concerning the country's economic and climatic conditions. The Croatian government also recognised the need to stimulate the AEC sector by introducing large scale renovation programmes (European Construction Sector Observatory, 2018). The government launched several financial support instruments and energy renovation programmes targetting family homes and multi-family housing because the residential sector accounts for around one-third of the total energy consumption and, therefore, has the highest energy saving potential (European Bank for Reconstruction and Development, 2017). Public and commercial buildings are also included in the supporting programmes, as they should serve as an example to the other building owners. An ambitious project of the building stock renovation in Croatia is defined by the National Building Renovation Strategy (the Republic of Croatia, Ministry of Construction and Physical Planning, 2017) which includes a plan (the Republic of Croatia, Ministry of Construction and Physical Planning, 2014) for increasing the number of NZEBs up to 2020 as well. Up to the moment of writing this article, a very few NZEBs were designed and built-in Croatia. Because of the inevitable increase in the number of NZEBs, a systematic implementation process, like the scheme which is shown in Figure 2 and described in (Attia, 2018), has been developed.

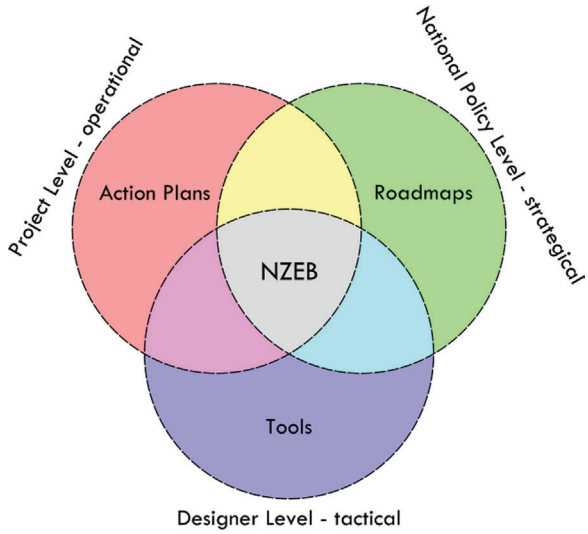

Fig. 2: Three measures to accelerate the implementation of NZEB.

Even though roadmaps and action plans have been developed in Croatia, the implementation of NZEB is still lagging behind other EU countries (European Commission, 2019), and one of the potential reasons is the existing competences of all stakeholders in NZEB and also DER. In Croatia, NZEB and DER construction projects are managed mainly by small and medium-sized companies, with a limited ability to catch up with the massive flow of the information and knowledge available today. On the other hand, building energy consumption optimisation process requires an integrated design and interdisciplinary approach. This way will only lead to a high-quality indoor environment, and it will satisfy the occupants' needs (Cromwijk et al., 2017) and the NZEB requirements. An advanced NZEB and DER design require practical and efficient information sharing among all the members from the different disciplines in an integrated design group (IDG) to make the decisions about selecting the right set of energy retrofit design options (Yang, Ergan and Knox, 2015). This advancement could be achieved by introducing integrated product design (IPD) into the NZEB design process (Cromwijk et al., 2017). It became clear that better information management during a life cycle of an NZEB is necessary for avoiding mistakes and storing reliable information which can be achieved by BIM.

BIM model is a representation of the functional and physical characteristics of a building in a digital environment with information stored and attached to building elements stored as objects. That organised and shared information database about the facility is a regular basis for the decision-making process not only in the design and the construction phases but also throughout the whole building life cycle.

All the stakeholders in the AEC industry and wider should be educated explicitly in an integrated design approach using BIM to improve the quality of both designed and built NZEBs. BIM is an excellent tool for designing NZEBs because more time is spent on the early planning and the design phase, therefore, a more advanced solution could be provided with the cost-optimality. The other main reason for using BIM as a tool for NZEB design, and managing building information, is that not only more variant solutions can be examined but also a preliminary energy simulation could check all of those solutions, so the quality of NZEB design increases drastically (Gumbarević et al., 2019).

3 Methodology

Improving competences in the AEC industry should include improving competences of all the stakeholders, workers, professionals and engineers regarding NZEB and BIM.

This article presents the current situation in Croatian AEC industry from three important aspects:

1. Competences of workers
2. Competences for NZEB and DER project stakeholders
3. BIM competences for improving energy efficiency.

Concerning the competences of workers, overall desk research on the current situation in the Croatian construction sector is presented. The research was based on information from the national acts, European project CROSKILLS and literature.

The competences related to delivering NZEB and DER projects were analysed by the project Fit-to-NZEB, and the main conclusions for this article were derived from the Fit-to-NZEB findings. The starting point of the Fit-to-NZEB approach was the research on the existing training programmes in partner countries, which were then cross-checked and with the list of competences identified and created by the experts in NZEB and DER depending on the European qualifications framework (EQF) levels of training participants. The learning outcomes were then created for different target groups and different EQF levels of training participants. This was the basis delivering of the innovative training programme to increase the competences in NZEB and DER of workers and engineers. The innovative approach arises from the training methodology which is

focused on practical and hands-on training of workers and engineers. Faculty of Civil Engineering, University of Zagreb was in charge for implementing the programme in higher education (following the roadmap for DER competences improvement presented later in the article), the programme was conducted on the faculty and validated by target population – 31 students specialised in civil engineering. Validation was conducted with five-point Likert scale questionnaires. The mentioned roadmap serves to increase the DER competences not only in Croatia but also in all partner countries if it is fully implemented and can be extended to vocational education and training (VET) training of workers (EQF levels 2–4).

Concerning BIM competences for improving the building energy performance, all Net-UBIEP project partners worked together to map digital competences concerning BIM and energy efficiency to each key stakeholder in the AEC industry. From these results, the three-dimensional matrix of competences was designed and served as input for delivering the training materials (the body of knowledge) for each stakeholder group. Following the roadmap for increasing the BIM competences in energy efficiency, pilot seminars and classroom courses were organised to validate training programmes. Validation of classroom courses on BIM and energy efficiency was performed by 93 training participants from various sectors of the AEC industry using pre- and post-training questionnaires. Questionnaires were prepared to validate defined competence lists for all the different target groups as well as trainee satisfaction with course and instructor (trainer) effectiveness. Training participants, professionals and workers belonging to the different target groups were asked to judge their competences before the training as well as after the training. The purpose of the "Pre training questionnaire" was to assess the initial level of knowledge, experience and current practices regarding BIM. "Post training questionnaire" was used to determine the progress of the training participants during the courses and the efficiency of the courses in simple ways. Questions about the completeness or redundancy of the foreseen schemes and training courses were also included in the "Post training questionnaires." Validation questionnaires had various types of questions: multiple choice, close-ended, yes-no and 5-point Likert scale expanded by "no opinion" answer for those who cannot assess the answer.

The results from the validation and three-dimensional matrix of competences served as input for e-learning development and future standardisation of the course. The ambition for standardisation of Net-UBIEP training on BIM and energy efficiency led to joint collaboration with buildingSMART International (bSI) in developing bSI training programme in the area of energy performance as will be discussed in detail later in the article. Except for these reasons, the validation results provide good input data for assessing the BIM implementation (and connection to energy efficiency) in Croatia as 92 answers were collected from subjects from different sectors of the AEC industry.

4 Competences of workers

The lack of qualified workers is a huge problem in Croatia due to the migration of workers to the Western European countries as well as because of increased demand for workers for energy retrofitting projects caused by importing the foreign unqualified or underqualified workforce. Moreover, for the education of workers in energy efficiency and construction, professional high schools are recording a decreasing number of students year after year. A total of 30,000 workers are needed in the construction industry in Croatia to satisfy the current contracts (Bogdan, 2018). Analysis from 2013 (BUILD UP Skills Croatia - CROSKILLS, 2013) assessed that about 37,000 workers are needed in the AEC industry in a field of energy efficiency and Renewable Energy Sources (RES) to achieve the energy-saving

Fig. 3: Examples of low-quality construction work and its consequences.

targets, under the assumption that 3% of a building's heated usable floor area would be renovated every year up to 2050. As salaries in the AEC industry in the Western European countries are higher than those in Croatia, there is a problem to attract enough qualified foreign workers. Due to the lack of construction workers, the Croatian government in 2018 has defined a permissible quota of 10,070 workers who can work in Croatia (Bogdan, 2018). The most recent research (Cerić and Ivić, 2019) shows that this quota is rapidly increasing year after year (compared to 500 permissible quotas in 2016) and for 2019 the permissible quota increased to 17,800. Even if there is a sufficient number of workers (foreign and domestic), they must be educated for constructing NZEBs but the VET programmes in Croatia related to NZEBs and DER are obsolete and mainly unchanged since 1996. Teaching materials used in VET programmes for the AEC sector contain very little topics related to energy efficiency and DER. Thus, the educational system in Croatia is not producing workers and experts who could enter the construction market with sufficient knowledge and competences concerning BIM and NZEBs. As a consequence, a high number of low-quality projects are delivered (Figure 3) because even if the design is satisfying NZEB standards, buildings are not constructed according to required designed performances.

From July 2017, the Ministry of Construction and Physical Planning enforced the "Regulation on education and certification system of construction workers working on the installation of building components which affects the energy efficiency of buildings" (the Republic of Croatia, Ministry of Construction and Physical Planning, 2017), to increase the number of qualified workers for energy refurbishment of old buildings and construction of new NZEBs with 11 training centres established. There are regulations for installers of RES systems too, and several training centres providing education are also established. There are also additional efforts to improve the compendium of knowledge through Horizon 2020, Erasmus+, etc. projects which are being implemented in different institutions in Croatia, among them Fit-to-NZEB, Net-UBIEP and BIMzeED projects.

5 Fit-to-NZEB – competences for DER projects

Fit-to-NZEB is a Horizon 2020 project aimed at developing skills and competences of the professionals in the field of DER in the target countries (Czech Republic, Romania, Bulgaria, Italy, Croatia, Ireland and Greece). The goal was achieved through the unique educational programmes developed by the consortium that contributed to both the quality and the scale of the DER. The consortium developed an innovative EQF levels 3–7 training schemes for building retrofit up to the NZEB level. Those training programmes have been organised in countries across Europe with a conventional structure, learning outcomes and defined competences. The programme was delivered by the Universities, professional high schools, vocational training centres (VTC), and through "on-the-job" training and validation programmes (*Objectives & results - Fit-to-NZEB*). The partner countries analysed the existing training and educational programmes for DER to develop the compendium of competences with the identification of gaps and deficiencies. The analysis showed that there is a lack of DER and NZEB topics in the professional, high, and higher education as well as in vocational training programmes. In the EQF 3–5 systems (secondary and high education), principles of DER are not included in the official training programmes at all. In the EQF 6 and 7 (higher education), there are fragments of DER topics represented by certain topics without a systematic approach and the connection between them. The above-mentioned problems are the main reasons why LLL should solve the lack of qualification concerning DER. LLL is divided into two parts – training concerning AEC workers (EQF 4 and 5) and training for HEI professionals (EQF 6 and 7). However, at this moment trainings are not harmonised and do not provide a formal NZEB or DER qualification in the national qualification frameworks of the partner countries. Fit-to-NZEB project delivered all the necessary requisites (Table A1 in Appendix) for the introduction of educational content regarding DER and NZEB at all the educational and training levels in south-eastern Europe (Milovanović, Bagarić, et al., 2019). Developed compendium of competences is intended for the developers of new training and educational programmes on NZEB renovations. Elaborated learning outcomes developed by the project Fit-to-NZEB which can be applied to the development of a wide range of training programmes of vocational or specialised education for AEC specialists are described in detail in (Milovanović, Bagarić, et al., 2019) while below only the main outlines of the developed training programmes are presented.

> *"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 the 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 competences acquired at the workplace, consisting of entry-level tests, with theoretical and practical training (8-12 hours) and evaluation scheme."

The partner institutions created training models that represent parts of a real building to show good examples of build construction details. The models were used for practical and hands-on training and demonstration. Visualisation by developed models (Figure 4) during the training programmes is an essential method for achieving intended learning outcomes and better-quality training.

5.1 Innovative training courses in Croatia

Training programme in Croatia integrated all the available and newly designed tools for a practical demonstration and training, and the examination programmes to guarantee a successful implementation of the newly developed training. The training materials developed under the Fit-to-NZEB project were translated into Croatian language and were used during the training. The course for EQF 6 and 7 was delivered by the University of Zagreb, Faculty of Civil Engineering. Additionally, the University of Zagreb, Faculty of Civil Engineering has implemented the course on DER in the LLL programme which has been reviewed and approved by the Ministry of Construction and physical planning.

Innovative training was performed through the presentations (lectures and exercises) developed within the project, demonstration videos, demonstration models, samples of components and materials, infrared thermography cameras, blower door system and confetti creative

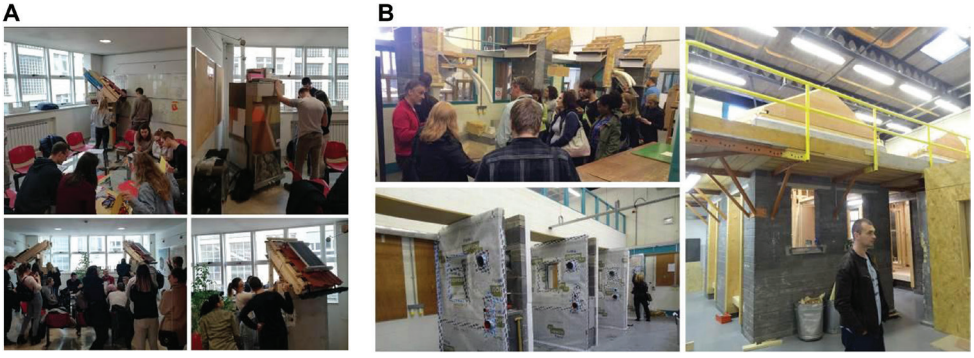

Fig. 4: Interaction with developed models: (a) Croatia and (b) partner countries.

Fig. 5: Learning about detailing (the impact of thermal bridges reduction, airtightness problems, etc.) by solving problems with confetti creative systems.

system for learning about detailing (Figure 5). In addition, three site visits were organised (to the construction site of newbuild NZEB, deep energy renovation of the cultural heritage building and a renovated family house that is self-sustained using RES sources).

A group of students specialised in civil engineering had undertaken the education course in Croatia within the framework of the project. During the training course, the students had to make a design of the NZEB building, specifically deep energy renovation, where they got drawings of existing buildings and had to suggest a solution for energy renovation, calculate the energy balance and design the details. Working on their design projects, students were encouraged to discuss their solutions and work closely together with the lecturers. In addition, students had to do research and write a short paper on the topic they are interested in and make a pitch presentation to their peers on the topic. At the end of the training programme, the students had undertaken the exam while their practical work was discussed in detail with the trainers and then graded.

The above-mentioned is part of the roadmap for increasing the competences for NZEB and DER developed within the Fit-to-NZEB project (Figure 6). In Croatia, the whole compendium of knowledge, teaching models and infrastructure for the trainings were implemented in one higher education institution (—HEI) (Faculty of Civil Engineering, University of Zagreb) and approved to be used for the LLL. To achieve full implementation, the developed courses were made available to other training institutions to educate both, new engineers and workers for building new NZEBs and DER up to NZEB standard.

The direct results of the project are infrastructure for innovative trainings that are described in this section and the number of new professionals educated within the project. The project consortium educated a total of 353 trainees in EQF 2 and 3 consist mainly of construction workers. When concerning the EQF 3–5 levels, the project consortium educated 120 trainees coming from professional schools and technical colleges. Finally, in EQF 6 and 7, when educating HEI professionals, the project consortium educated 99 trainees educated in civil engineering and/or architecture (31 of them come from Croatia). The institutions that were part of Fit-to-NZEB project continued to educate new trainees based on developed infrastructure, and in case of Croatia, the second generation of HEI professionals took the training course developed within the project. Figure 6 shows the implementation of abovementioned results, more specifically the results in a view of training infrastructure were implemented in VET, life-long learning and in higher educational institutions in all the countries where project consortium institutions came from so that each conducted training increases the number of professionals concerning NZEB construction.

5.2 Evaluation and validation of the courses

A feedback questionnaire survey was conducted among the training course participants (31 students) after the entire training programme was conducted. The majority of UniZG (Faculty of Civil Engineering, University of Zagreb) trained students gave their feedback about the training course on 21 January 2019 using an interactive VoxVotesystem to perform this survey.

Figure 7 shows that students attending Fit-to-nZEB training course held by UniZG strongly agree (67%) and agree (33%) that the lectures were very praxis orientated and relevant. It was also found that 89% of students strongly agree or agree (59 and 30%, respectively) that the structure of learning materials was very good. In addition, 92% of students think (48% strongly agree and 44% agree) the layout of learning materials was very good, and all students agree that the content of learning materials was in accordance with the contents of the course (Figure 7).

Figure 8 shows that students who attended the Fit-to-nZEB training course held by UniZG strongly agree (50%) and agree (38%) that their knowledge or competences about the topic were significantly increased after the course. Furthermore, 65% of students strongly agree and 31% agree that they could learn much from the practical work and practical exercises while only 4% of students remained neutral. These results are in line with the "validation" question that was asked to check whether respondents are speeding up and therefore cheating when filling out the survey. Figure 8 shows that students strongly disagree (46%) or disagree (38%) with the statement that they prefer a more theoretical approach of the learning material without the practical work.

Figure 9 gives feedback on students' views on discussion possibilities during the course regarding the course topic and methods on which they strongly agree and agree (31% and 58% respectively) that the course stimulates discussion. This standpoint is confirmed by their strong disagreement (24%) and disagreement (56%) with the statement that attendance to the lectures is not necessary to learn the content and that the distance course would also be satisfactory. The preference of students to participate in the lectures and other training activities, shows that they prefer the chance to discuss their problems during exercises, design work with their peers and lecturers.

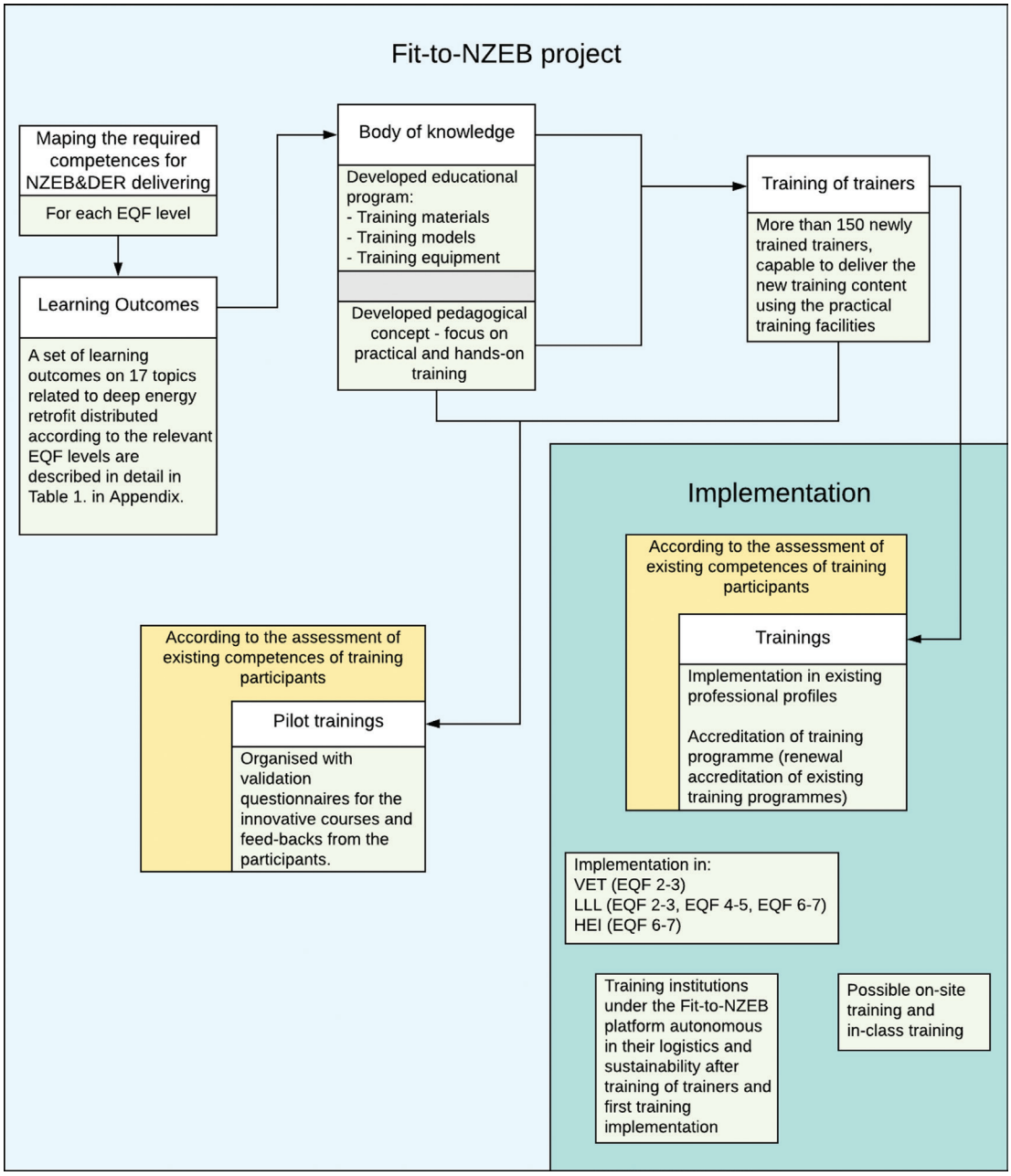

Fig. 6: The roadmap for increasing the competences in DER by the project Fit-to-NZEB.

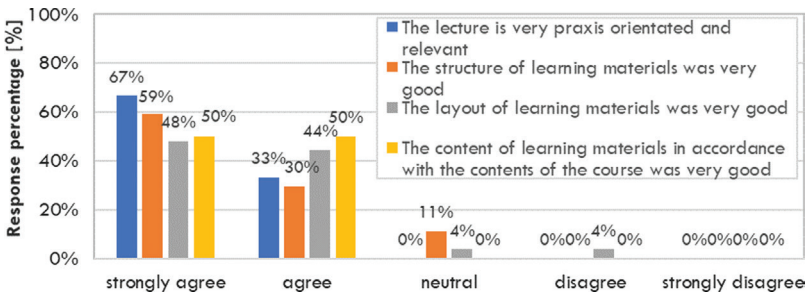

Fig. 7: Feedback of students on the structure, layout, content of learning materials and the practicality of training course.

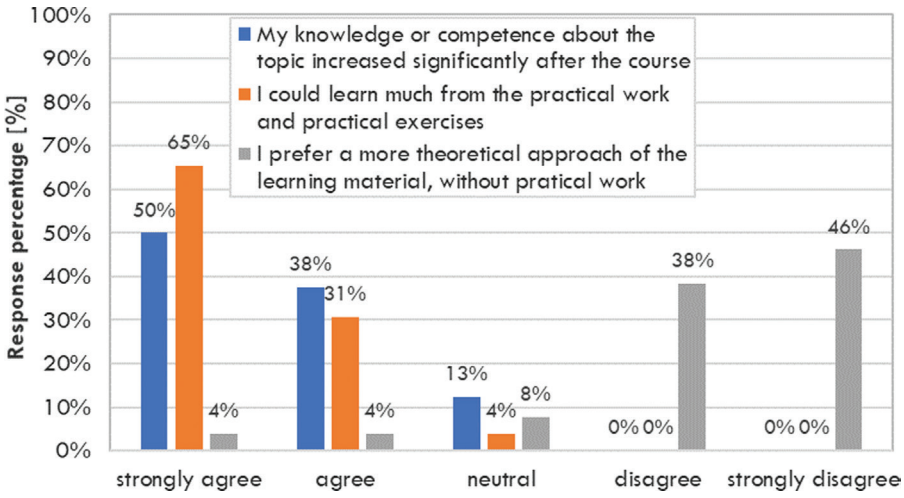

Fig. 8: Feedback of students on their view on the progress they have made during the course (regarding competences) and preferences on the practical and theoretical approach.

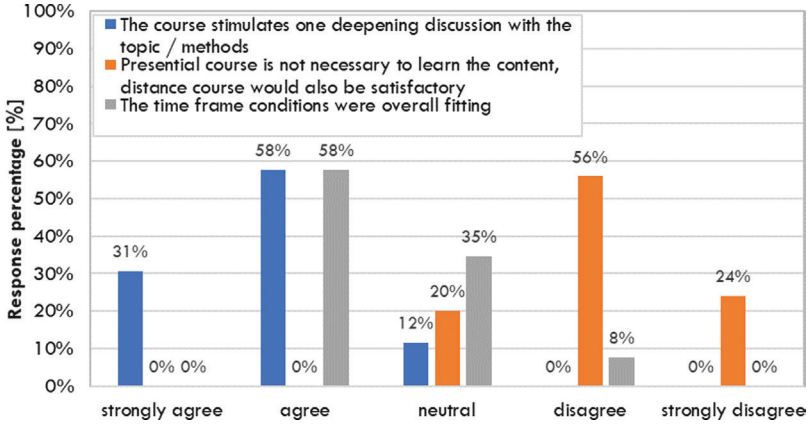

Fig. 9: Feedback of students on their view regarding discussion possibilities with teachers and peers as well as the suitability of the time frame to the presented topics.

Regarding the time frame conditions, 58% of students agree they were adequate, 35% of students remained neutral while 8% of students disagree with the statement that the time frame was overall fitting. The reason for such a position of students could be that for some topics, there was too little time to give an in-depth overview of the topic. Also, the design work was time-consuming, as majority of topics had to be lectured before they could implement the knowledge gained into their specific design which they had to finish before the end of the semester.

Figure 10 shows that students attending the Fit-to-nZEB training course held by UniZG found the training course to be very good (strongly agree 62% and agree 38%), and additionally, students feel that comparing to other courses, this course presented new approaches (e.g. practical work) (75% strongly agree and 25% agree).

The students were also asked a question on improvements they could suggest for possible implementation in the future to the existing training course. There was only one answer to this question, and the suggestion was for the lecturers to develop additionally written (printed) training materials besides the handouts from the presentations, videos, demonstration models, samples of components and materials.

6 Net-UBIEP – BIM competences for improving the energy efficiency

In Croatia, BIM is used by early adopters and primarily restricted to architectural design offices. BIM usage also lacks interdisciplinary collaboration within the BIM

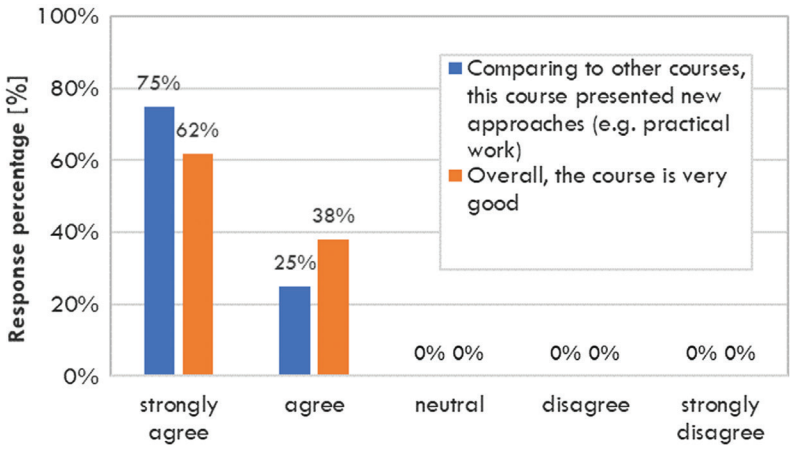

Fig. 10: Feedback of students on their overall view of the training course.

design process (Croatian Chamber of Architects) with very little knowledge of collaboration formats (e.g. BCF, .ifc, .gbXML) and standards (e.g. buildingSMART standards, BSI BIM standards) for the information transfer between the stakeholders. There is also no sign of BIM in Croatian construction legislation. There are some initiatives towards BIM standardisation through Croatian Standards Institute, but currently, there is no national standard that defines requirements for BIM professional profiles. BIM professional profiles, with their responsibilities and BIM competences, are scarcely defined in "General guidelines for BIM approach in civil engineering" (Jurčević, Pavlović and Šolman, 2017) by Croatian Chamber of Civil Engineers, but they are quite general and do not describe BIM professional profiles in detail.

Net-UBIEP is a Horizon 2020 project that aims to increase the energy performance of buildings by BIM usage through all the building life cycles. In each phase of the building life cycle, it is crucial to consider all the energy aspects to decrease the environmental impact of a building during its life cycle (*NET-UBIEP project | Build Up*). BIM will allow simulation of the energy performance of buildings and check many variant solutions by using different materials and components in every iteration in all phases of life cycle. The project proposed BIM qualification models to spread a better understanding of energy-related issues so both existing and new buildings will have better energy performance. Public administration, professionals (engineers/architects), technicians (installers/maintainers) and tenants/owners/building administrators were involved in the Net-UBIEP activities (*Project | Net-UBIEP*). The project promoted the philosophy that each stakeholder should understand which information he/she needs to manage so other stakeholders could use it during the life cycle of a building. Within the Net-UBIEP project, the list of competences related to energy performance needed for each BIM profile was defined. Competences on energy performance for each BIM profile were then mapped according to the defined target group. The integrated BIM qualification models have been validated through the project through delivering of different training activities (seminars/classroom courses/e-learning courses) addressed to at least six BIM professional profiles: BIM manager, BIM evaluator, BIM coordinator, BIM expert, BIM facility manager and BIM user. The training schemes were developed and validated through a survey carried out by the project partners.

After the process of validation by all the project partners had finished, the proposal for standardisation of the developed training schemes was proposed to bSI, a public interest-oriented non-for-profit consensus-based standards development organisation with vision, mission and programmes dedicated to advancing open interoperability in BIM. After a successful process of revision on delivered materials, bSI and Net-UBIEP signed the memorandum of understanding by which they agreed to form a cooperation to develop a new module for the bSI individual qualification programme in the area of energy performance. This work will be carried out principally by Net-UBIEP in coordination with the Professional Certification Steering Committee at bSI. Since the project Net-UBIEP developed the necessary learning outcomes, a body of knowledge and a question database, the consortium has also been put in charge to put them in line with bSI requirements.

6.1 The roadmap for implementing BIM to increase the energy performance

To increase competences concerning BIM and building energy performance, the project partners followed the next roadmap (Figure 11).

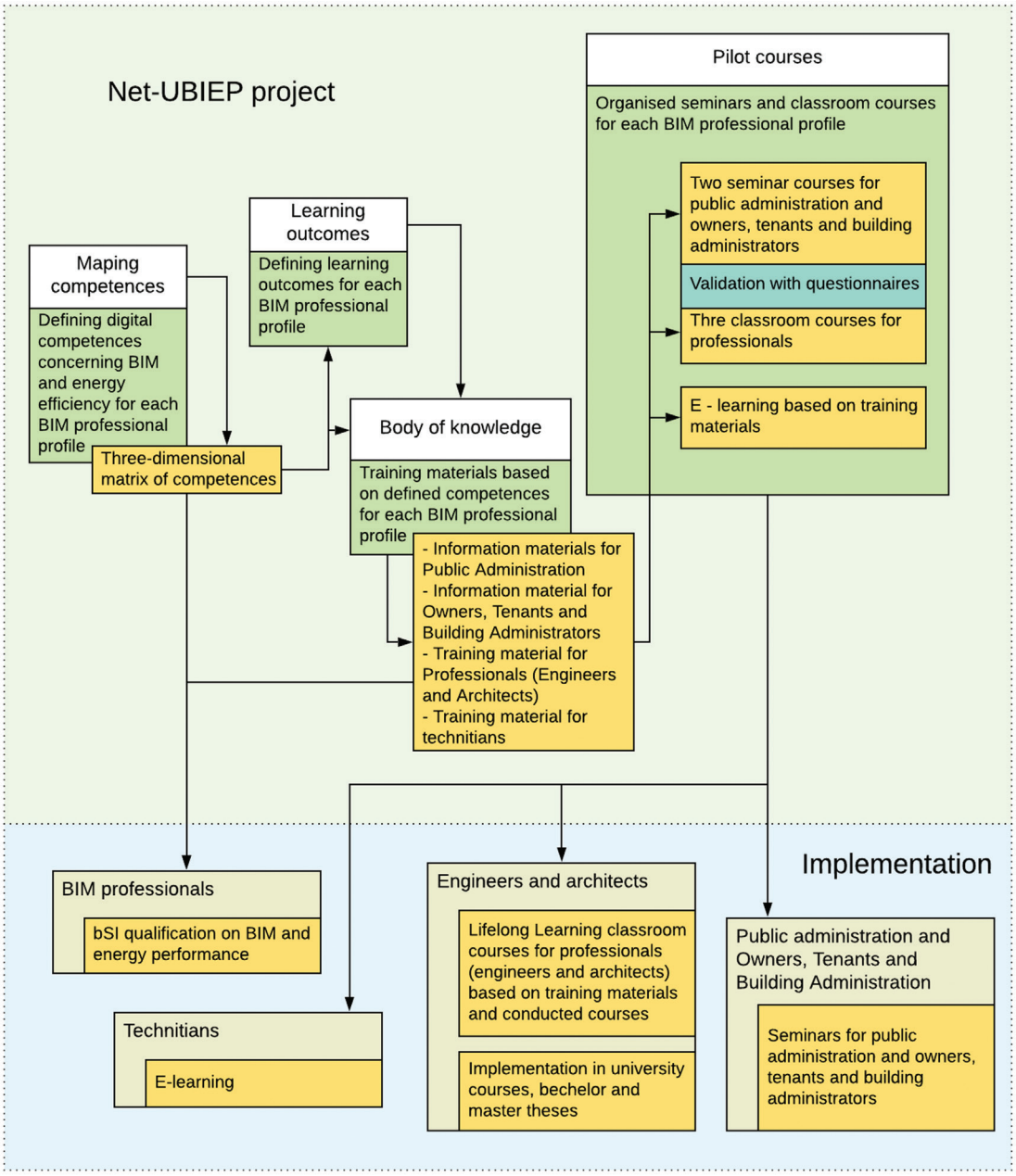

Fig. 11: The roadmap for increasing competences concerning BIM and building energy performance.

The project partners have developed the definition of the digital competences needed to increase the energy performance of a building for each target group. By the research (Net-UBIEP, 2018), each project partner assessed the needed level of these competences grouped by the building life cycle phases for each target group (strategic design, preparation and briefing, concept design, developed design, technical design, construction, handover and closeout and in use). After assessing the needed competences, the three-dimensional matrix of competences was developed (Figure 12) and used for creating training and information materials.

As a final goal of the Net-UBIEP, training and information materials were developed: information material for public administration and owners and training material for professionals and technicians. Concerning the developed materials, every project partner had organised the pilot trainings and seminars which were validated by the participants. Within the project and based on training materials, the partners developed e-learning platforms. Based on four levels of interactivities (Muqeet, 2018) that can be used in online courses, Faculty of Civil Engineering (University of Zagreb) as a project partner developed

Level 3 e-learning course on the MoD web platform. The e-learning course is designed to be freely available for all interested parties (with a mandatory free registration) and was designed with a total estimated workload of 24 hours for the learners. It is an asynchronous online teaching content to provide the learners with the opportunity to follow the lessons independent of teachers (e-learning administrators) at any time they wish, and as many times they need to do it to gain needed knowledge and skills. The Croatian Net-UBIEP e-learning course is characterised by extensive use of e-learning tools such as recorded lectures, short quizzes (tests and games) where learners can perform self-evaluation as well as video demonstrations and chat rooms and forums where learners can communicate with their peers and teachers (instructors). The modules contain a number of e-lessons where learners listen to recorded presentations, can follow recorded step-by-step video demonstrations on BIM tools for different applications related to energy efficiency and NZEB to perform hands-on exercises with different BIM software and discuss the related issues in an online forum.

Project activities (classrooms, seminars and e-learning courses) resulted in spreading knowledge on BIM and how its usage can improve the energy efficiency of buildings. Within organised classroom courses, 428 AEC professionals (civil engineers and architects) were educated by applying the knowledge based on developed training materials exactly for them (92 professionals in Croatia). The project consortium also educated 565 people from the group public administration, owners, tenants and building administrators within organised seminars based on training materials developed for that group (56 in Croatia). In Figure 11 in implementation part, it can be seen that project results are still part of education based on developed training materials no matter that project ended in January 2020. In a case of Croatia, education is implemented in free of charge e-learning course, then in seminars that will be organised for public administration, owners, tenants and building administrators, and also in LLL courses for professionals (civil engineers and architects). The project results were also used for developing the new module for bSI qualification programme, as already mentioned, which will spread the knowledge developed within the project on a global scale.

6.2 BIM and NZEB-related questionnaires

Faculty of Civil Engineering (University of Zagreb) as the project partner institution provided a survey amongst the Croatian AEC professionals to map BIM competences and to validate the training materials. Pre-training questionnaires were filled before every training so the profile and the competences of a group could be seen. After the questionnaire was carried out, training based on the information materials for each target group started, after which a post-training questionnaire was performed.

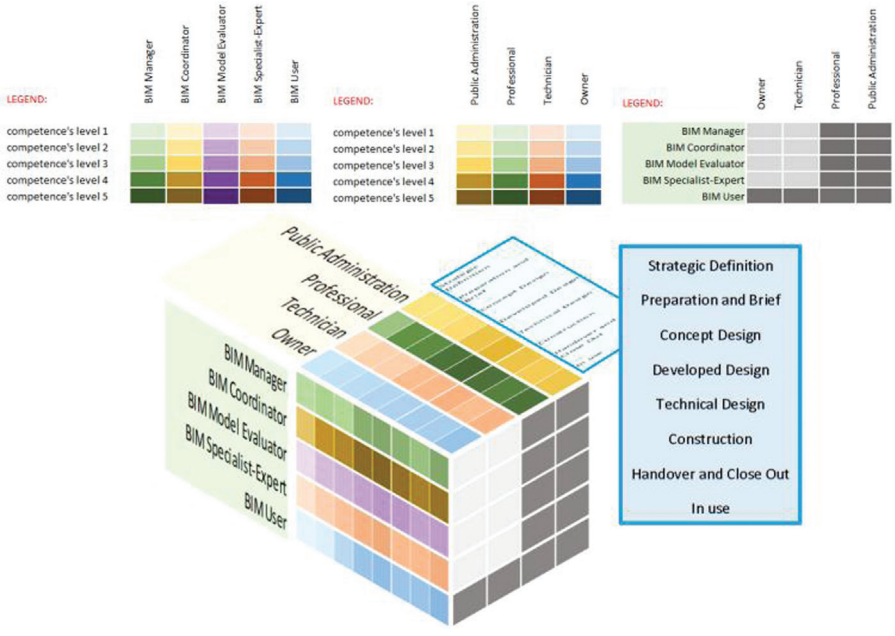

Fig. 12: The three-dimensional matrix of competences for BIM-AEC stakeholders.

For the sake of brevity, this article does not show all the results. Only results that show how well the participants accept BIM are presented. The rest of the survey results can be seen in the project reports.

From 92 training participants, 54.8% came from the AEC industry, 22.6% from public authority sector and 22.6% from other sectors (e.g. facility management and owners). Participants could choose whether or not they will answer the question because the questionnaire was held by the dynamic response system VoxVote. This is a reason why the number of responses is not constant. The majority of the participants deal with the residential sector (40 responses, Figure 13), mostly on projects with a budget under 250,000 € (Figure 14).

Concerning the BIM usage and BIM competences, Figure 15 shows that only 37% of participants use or intend to use BIM in their companies, and from those who use it, the majority (62%) have less than 1-year experience in BIM (Figure 16).

According to the participants, it is important (or very important) that specific departments and/or ministries mandate the use of BIM to encourage its implementation on energy efficiency related projects (68%, Figure 17). The reason for this might be that almost half of the participants (45%, Figure 18) assess that the implementation costs outweigh the benefits of BIM-use, and the others who experienced the benefits of BIM want it to be mandatory so they could collaborate with more people who will

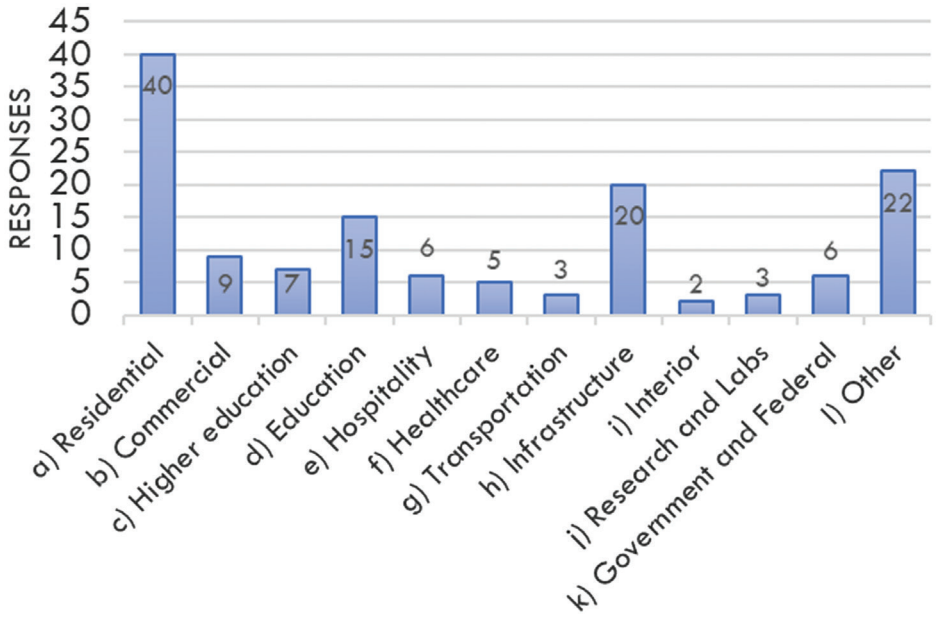

Fig. 13: Types of construction projects on which participants work on (multiple choice questions).

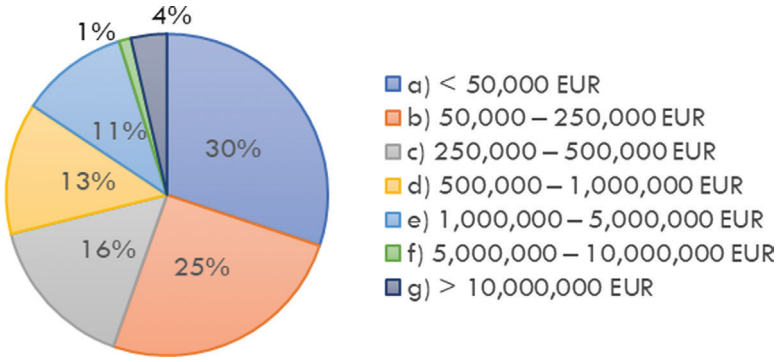

Fig. 14: Typical project value range (no. of responses: 83).

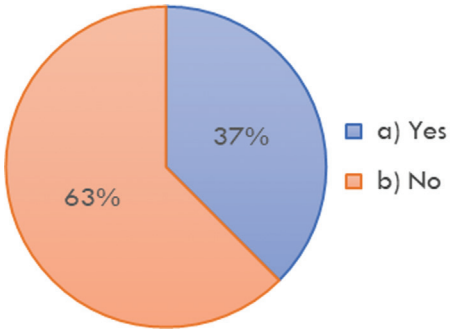

Fig. 15: Percentage of training participants who use or intend to use BIM in their companies (no. of responses: 83).

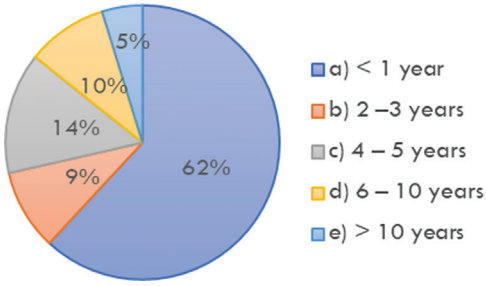

Fig. 16: Participants' experience in BIM (no. of responses: 21 – those who use BIM).

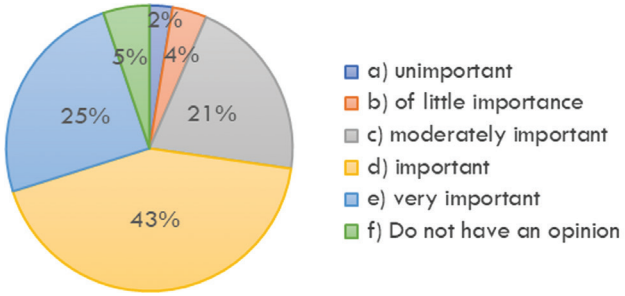

Fig. 17: How important is that specific departments and/or Ministries (responsible for energy efficiency in buildings) mandate the use of BIM to encourage its implementation on energy efficiency related projects? (no. of responses: 77).

provide smoother information transfer between different stakeholders.

Even though the majority of the participants do not use BIM, they assess (80% of the participants) that companies and organisations which will not adopt BIM quickly enough will be left behind and/or struggle to survive (Figure 19). Figure 20 shows the assessment of the participants related to benefits in energy efficiency for companies that will implement BIM.

Concerning education in BIM without using specific software, 90% of the participants found it useful, but 49% of the participants (although they find this kind of

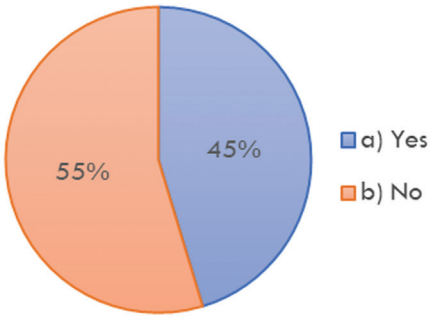

Fig. 18: Does the implementation costs associated with BIM (e.g. hardware, software and training) outweigh benefits from BIM? (opinion from the participants, no. of responses: 69).

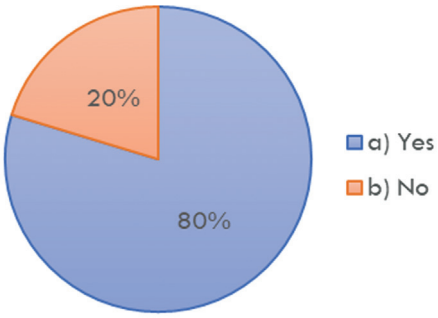

Fig. 19: Will the companies/organisations be left behind and/or struggle to survive if they do not adopt BIM quickly enough? (no. of responses: 69).

education useful) need more training on specific BIM software (Figure 21).

When comparing Figure 22 with Figure 23, it is evident that training participants correlate their energy savings due to applying their newly gained BIM competences with increased productivity due to the use of BIM.

7 Conclusion

This article described the problems in the AEC industry in Croatia concerning the DER and delivering NZEBs. The analysis of current formal and informal educational programmes in the AEC industry revealed that topics related to the DER and NZEBs are not adequately covered, or not covered at all, resulting in a lack of qualified workers and professionals. Another major problem detected in conventional project delivery is an absence of an integrated or interdisciplinary approach between all the stakeholders. Introducing the BIM approach and defining new BIM competences can overcome this problem. Through the preliminary survey research within the Net-UBIEP project, it can be concluded that, in Croatia, BIM is not efficiently

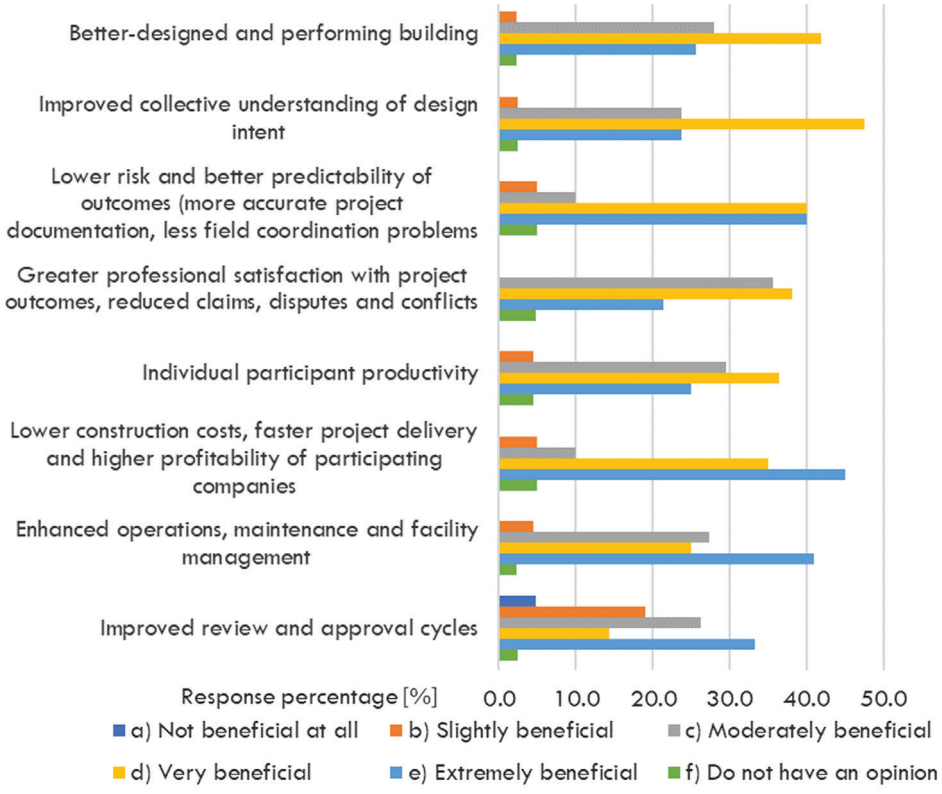

Fig. 20: Assessment by the participants in which project benefits specific to energy efficiency will their company achieve as a result of using BIM. (no. of responses: 40).

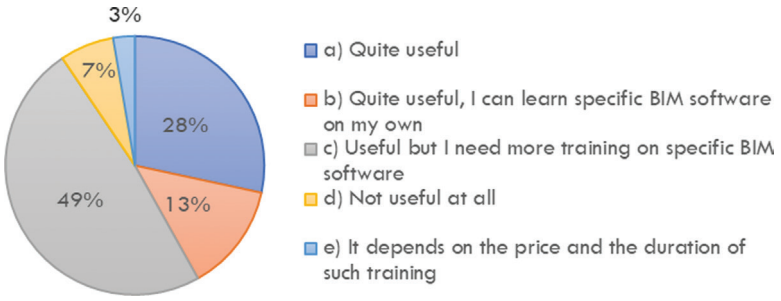

Fig. 21: What do You think about formal education about BIM, advantages of BIM and BIM processes? (without using specific software, no. of responses: 74).

used because only 37% of participants use BIM and 62% of those who use it have less than 1-year experience in BIM. Participants mostly come from the AEC industry (54.8%) and public authority sector (22.6%). Concerning Croatian AEC stakeholders who participated training courses, it can be seen that most of them were very satisfied with the course (86% have rated the course as "Excellent" or "Very good"), but 61% of them think that the training materials lack practical examples of BIM usage, which will be tackled in the future.

Problems concerning NZEB delivery will be experienced in a more meaningful manner after 31 December 2020 as a massive deployment of NZEBs will start, both because of the lack of qualified workers and the increase in demand for delivering NZEBs. BIM must be used in delivering NZEBs because better information management could be provided to store approved information through NZEB's life cycle so mistakes concerning information loss could be minimised. Another reason for BIM usage while designing and delivering NZEB is the possibility of testing more variant solutions to find a cost optimum.

Fit-to-NZEB training programme will increase the competences in building NZEBs, and Net-UBIEP in designing, constructing, maintaining, and demolishing

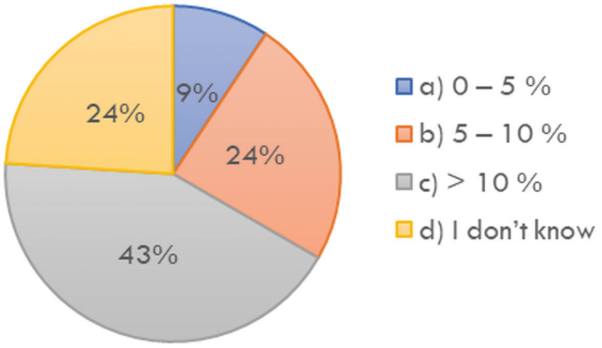

Fig. 22: Assess how much can you increase your productivity by using BIM after the training course. (no. of responses: 75).

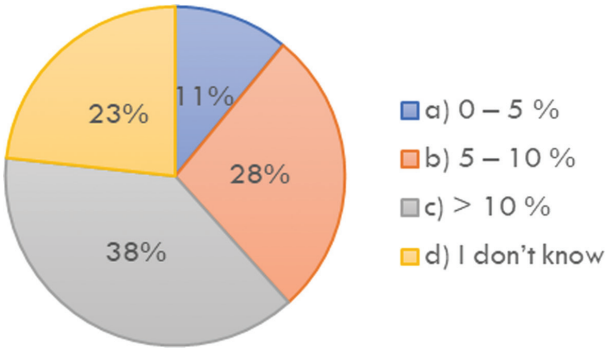

Fig. 23: Assess how much energy do you expect to save by applying the knowledge you gained during this BIM training. (no. of responses: 73).

buildings by using BIM in all building's life cycles. It is necessary to somehow connect these two projects to increase the quality of delivered NZEBs. This connection might be provided with another important European project that started recently. It is an Erasmus+ project BIMzeED (Education for zero energy buildings using BIM) which is closely related to the Net-UBIEP project. The BIMzeED will try to overcome mismatched skills and improve competences of trainers, site managers, craft-workers and other experienced operatives in the current European AEC industry concerning BIM and NZEBs. Improving mismatched skills and competences will lead to better employability (especially for young people) and consequently decrease of greenhouse gas emissions due to better optimisation, design, construction and management of NZEBs.

All three projects, Fit-to-NZEB, Net-UBIEP and BIMzeED, are dealing with the different aspects of energy efficiency. Improving competences of all the stakeholders in the AEC industry by combining activities of all three projects will undoubtedly increase the quality of NZEBs.

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Appendix

Tab. A1. Developed topics for DER with short descriptions (Milovanović, Bagarić, et al., 2019).

Topic and subtopic
1. Basics of building physics 1.1. Passive house principles Basics of building physics needed to understand the interrelations of the major principles in DER. Introduction to the passive house principles and how they work together
2. Optimal solar gains Situation and sizes of openings/shading and natural ventilation
3. Building envelope 1.2. Thermal insulation 1.3. Minimizing thermal bridges 1.4. Highly efficient windows Building envelope exterior and interior insulation. Thermal bridges through structural building elements, windows and doors, through cracks and gaps in building envelope. Use of highly efficient window frames/insulating doors/positioning of windows and doors.
4. NZEB Neighbourhoods 1.5. Energy cooperatives 1.6. Distributed energy production systems and energy Understanding the NZEB Neighbourhood. Energy cooperatives as isolated business or connected to a local smart grid or the national grid. Distributed energy sources. Microgrid solutions. District level distribution grids. Impacts and benefits of the grid integration of distributed energy production. Energy Management Systems (EMS). Assessment of the extended built boundary and energy balance of the bounded area.
5. Airtightness, vapour and moisture movement, wind tightness Infiltration and/or exfiltration heat losses, quality assurance and blower door test. Vapour movement through the construction fabric, relevant properties of different materials.
6. Building services 1.7. Mechanical Ventilation with Heat Recovery (MVHR) 1.8. Heating and Cooling 1.9. Domestic Hot Water (DHW) 1.10. Automation – Regulation 1.11. Lighting Emerging technologies in building services for high performance residential projects.
7. Conservation of historic building fabric Different levels of conservation, concept of authenticity, technical concerns in DER of buildings of historic value – suitable materials and techniques.
8. RES in building renovation 1.12. Long- and short-term energy storage Installation of RES systems in DER without interfering with NZEB principles and requirements. Possibilities of long and short-term storage of energy in the building.
9. Cost-effectiveness Provision of solutions with proven cost-effectiveness within the whole life cycle of the building, economic efficiency of a package of measures.
10. Planning and design instruments Nationally recognized software tools/other available software planning tools. BIM tools.

(*Continued*)

Tab. A1. Continued.

Topic and subtopic
11. Comfort, health and safety requirements in buildings, incl. indoor air quality 11.1. Summer comfort/passive cooling 11.2. Fire protection Comfort, health and safety requirements in buildings, indoor air quality, condensation, humidity and mould appearance, CO2eq levels, draught elimination, productivity and health impact, light, acoustic. Fire protection issues. Summer comfort.
12. Step-by-step retrofit plans Economic assessment, energy audit, design and implementation issues. Step-by-step strategies as well as suitable components and alternative solutions.
13. Energy efficiency and building renovation policies National and EU strategic goals; financing schemes and opportunities; relevant legislation acts in NZEB construction and DER.
14. Achieving measurable results Energy audits; required parameters of the building components; energy performance certificates (EPC). Monitoring and evaluation of the results of the retrofit projects. International retrofitting standards (e.g. EnerPHit).
15. Engaging stakeholders Benefits of energy efficiency to different target groups – energy and financial savings, increased comfort, sanitary and health conditions, better indoor air quality, ecological and climate change mitigation, broader economic and social benefits, energy security, etc.
16. Project management 16.1. Quality assurance Introducing basic principles – Initiating; Planning; Executing; Monitoring; Controlling of project. Increase knowledge of investment efficiency, multicriteria assessment, life cycle assessment, energy efficiency legislation used for project management and evaluation.
17. Ecology and sustainability Ecology as a starting point for energy efficiency in building; climate change and CO2eq levels; building materials.