EDUCATION FOR ZERO ENERGY BUILDINGS USING BUILDING INFORMATION MODELLING

Bojan Milovanović[1], Mergim Gaši[2] Sanjin Gumbarević[3] and Marina Bagarić[4]

[1,2,3,4] University of Zagreb, Faculty of Civil Engineering, Department of Materials
Fra Andrije Kačića Miošića 26, 10000 Zagreb, Croatia
e-mail: bmilovanovic@grad.unizg.hr, mgasi@grad.unizg.hr, sgumbarevic@grad.unizg.hr, mbagaric@grad.unizg.hr

SUMMARY: The construction industry across Europe is facing major challenges in achieving energy efficiency targets, in particular for Near Zero Energy Building (NZEB), but they are also experiencing a digital revolution, with Building Information Modelling (BIM). The Fit-to-NZEB, Net-UBIEP (Horizon 2020) and BIMzeED (Erasmus+) projects intend to improve the human-capital basis of the construction sector, which is identified as a strategic initiative by the European Commission, acting on Higher Education Institutions (HEIs) and Vocational Education and Training (VET) systems in Europe. These projects support the construction industry, through education and training to upskill on technical innovation and digitalization. Not only is digitalisation trainings an important focus for the progression of the construction sector, but providing a low carbon efficient economy requires the integration of BIM with nZEB design and development approaches. At EU level, the challenge remains to introduce relevant standardised environmental and energy efficient learning topics into mainstream training and degree courses at HEIs & VETs. This paper analyses the current situation in the Architecture, Engineering and Construction (AEC) industry in several EU countries and provides a possible solution for the abovementioned problems in the field of NZEBs and BIM. The analysis of current formal and informal educational programs in the AEC industry revealed that topics related to the deep energy renovation (DER) and NZEBs are not adequately covered, or not covered at all, resulting with a lack of qualified workers and professionals. Another major problem detected in the conventional project delivering is an absence of integrated or interdisciplinary approach between all the stakeholders. This paper will show how the competences of construction stakeholders in the field of NZEBs and BIM can be increased.

KEY WORDS: Competences; NZEB; Net-UBIEP; Fit-to-NZEB; BIMzeED; BIM.

1 INTRODUCTION

The construction industry presents a major opportunity to not only reduce energy demand, but also to improve process efficiency and reduce carbon emissions; but it is also traditionally highly fragmented and often portrayed as involving a culture of “adversarial relationships”, “risk avoidance”, exacerbated by a “linear workflow”, which often leads to low efficiency, delays and construction waste [1]. Original culture and practices of the construction sector is 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; also there is an increasing alignment of interest between those who design and construct a facility and those who subsequently occupy and manage it, and that demands dedicated skills and competencies to address multi-objective sustainability (including energy) requirements. 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 a NZEB project in order to reduce so called energy performance gap and to improve the quality of NZEBs.

This paper analyses the current situation in the Architecture, Engineering and Construction (AEC) industry in several EU countries as identified during the authors’ work within the consortia of the following three EU projects Fit-to-NZEB, Net-UBIEP (Horizon 2020) and BIMzeED (Erasmus+). These projects have a common denominator and that is to improve the human-capital basis of the construction sector, which is identified as a strategic initiative by the European Commission, acting on Higher Education Institutions (HEIs) and Vocational Education and Training (VET) systems in

Europe. The main aim of the paper is to establish outcomes of skill shortages in NZEB and BIM.

1.1 Nearly zero energy buildings

According to the International Energy Agency (IEA), the buildings and buildings construction sectors combined are responsible for over one-third of global final energy consumption and nearly 40% of total direct and indirect CO_2 emissions. Energy demand from buildings and buildings construction continues to rise, and to get on track with the Sustainable Development Scenario, IEA suggests that annual drops in energy intensity per square meter globally need to return quickly to at least 2.5% – the rates of the early 2000s [2]. This has resulted in a growing urgency to address energy and emissions from buildings and construction, to meet restrictive 2030 targets as specified by the European Union (EU). The EU Energy Roadmap 2050 [3] has rigorous demands and ambitious targets for the building sector. Buildings are deemed as a source of enormous untapped efficiency potential and obligatory construction of nearly zero energy buildings (NZEBs) and deep energy renovation (DER) of existing buildings is a definite direction to exploit this potential.

European Energy Performance of Buildings Directive (EPBD, 2010/31/EC) (EPBD II) [4] sets out the definition for a building with nearly zero energy consumption (NZEB) 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*" [4]. Article 9(1) of the EPBD II [4] requires Member States to "ensure that by 31 December 2020, all new buildings are nearly zero-energy buildings; and after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings."

However, if we are to achieve 2030 and 2050 targets, an increase in competences (knowledge, skills, responsibility and autonomy) from across the sector, AEC professionals, policy makers, citizens, is paramount. Additionally, it has become clear that better management of the information during the whole life cycle of the NZEB is absolutely necessary in order to avoid mistakes and have trustful information at any time / when an intervention is necessary. Furthermore, according to Yang et al. [5], 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 [6]. This can be achieved by using BIM approach.

1.2 Building information modelling

Digitalisation of the AEC industry is a reality, the next revolution, is with Building Information Modelling (BIM) in the centre of it. BIM is improving methods of design, delivery and management of building assets, as it increases efficiency in how construction industry collaborates, communicates and interacts. BIM can act hand in hand with energy skills, it can provide a great opportunity to reduce the environmental impact of construction projects [7]. The acronym stands for both the building information modelling (the process) and building information model (the artefact), and the attention of the research community and software developers, alternates between the two. Initially, the challenge was the representation of buildings. As the representation matured, the attention shifted towards the processes in which these representations can be created, developed and used [8]. BIM is the pillar of the new way of working in the building sector (with all the information at hand), initiated and targeted by digitisation to optimise and manage the energy consumption of an NZEB. The BIM model of a building, when properly enriched with the correct data, and using appropriate BIM tools (software) can be used to simulate and test optimum design options; and to help deliver a more efficient building while at the same time having costs and time under control, and also reducing waste, CO_2 emissions and energy spent during construction. In use, BIM as built model with the same and even enriched data, can continue to be used to properly manage building assets.

The EU Energy Roadmap 2050 points out that an increasingly important feature of the required technology shifts with 2050 goals in sight is the use of information and communication technologies (ICT) in energy and transport and for smart urban applications [3]. BIM is the most effective supportive ICT technology for: sustainable energy, reducing carbon footprint and increasing the energy efficiency in construction sector.

2 CURRENT CONSTRUCTION MARKET IN EU WITH RESPECT TO NZEB AND BIM

The EU's building sector is responsible for 9% of the EU GDP [9] and providing 18 million direct jobs. It has to be said that out of these, specialised construction activities that include renovation work and energy retrofits account for two thirds of the overall employment in the sector. These activities are dominantly provided by SMEs.

An interesting perspective of the European NZEB construction market is the architects' one. The Architects' Council of Europe undertakes a biennial survey, the so-called ACE Sector Study [10], which collects and analyses statistical, sociological and economic data on the European Architects, the architectural market and the architectural practices and is based on responses from 30,000 Architects in 30 European countries. Surprisingly responses to this survey suggest that less work is being designed to NZEB standard than in previous years. In the previous surveys, 12 - 14% of respondents said that at least 50% of the total number of projects they had worked on in the previous 12 months were being designed as NZEBs; the 2018 figure is 11%. More work in Luxembourg and Austria than anywhere else is being designed to NZEB standards (Figure 1).

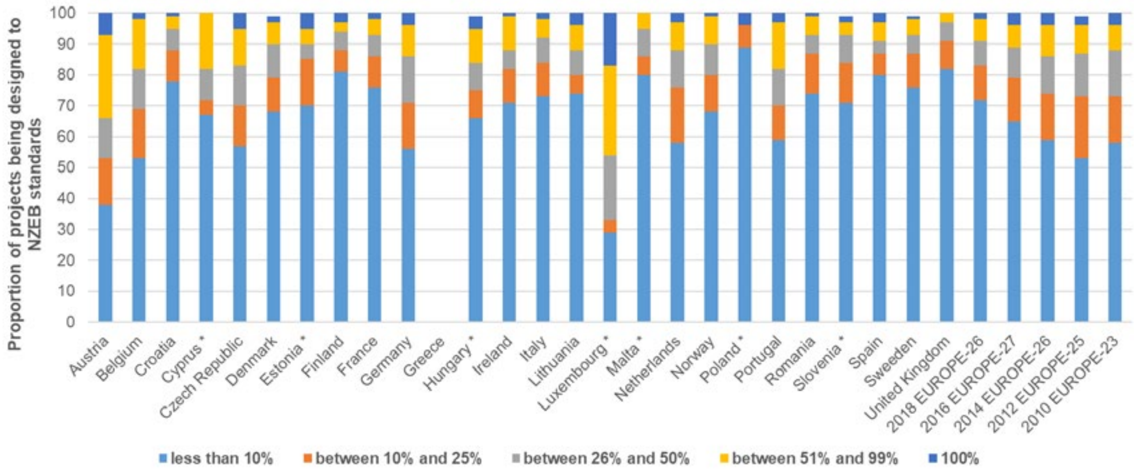

Figure 1: Proportion of projects architects are designing to nearly zero energy standards analysed by country

SMEs usually have a limited ability to follow the massive flow of information and knowledge now available and needed to design and construct NZEBs. Since the energy refurbishment works were mostly subsidised by the public funds there were a lot of interested investors and thus many companies enrolled in the field of energy efficiency who have a lot of self-confidence but realistically don't possess sufficient competences who are now also starting to deal with NZEBs. The lack of qualified workers is more than evident due to 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 (VETs) related to energy efficiency. One of the most significant problems of the construction market in most EU countries (all participants in construction projects) is the lack of competencies since educational system is not currently producing experts who could enter the construction market and have sufficient competences with respect to NZEB and BIM [11]. This claim is backed by the fact that the BUILD UP Skills initiative continued via the construction skills strand of the European Horizon 2020 research and innovation programme (H2020 EE4 Construction Skills). Aiming to support and further develop multi-country qualification and training schemes, and by the fact that the 2016 H2020 call approved five projects which started in 2017 out of which three projects are focussed on Building Information Modeling (BIM). [12].

The existing skills' shortages in both main contractors and specialist sub-contractors are also a significant factor driving increased costs. In some EU countries, there are a number of emerging occupations developed from the evolution of sustainable needs and the enforcement of energy efficient building regulation. In Ireland, the newest emerging occupations are within the NZEB areas, where a number of courses to train consultants and tradespeople in NZEB construction are underway. These include *NZEB professional consultant, NZEB professional design consultant, NZEB craftworkers and operatives, NZEB for craftworkers, NZEB for construction workers, Environmental Certificate for Professionals*.

From the existing experience of the authors of this paper that both construction of NZEBs and DER proved to be a complex process for construction industry in general. It demands a change of business as usual procedures of everybody involved, including architects, civil and mechanical engineers, site managers as well as construction workers (craftsmen).

Looking at the construction sector, experience has shown that a number of challenges still exist and endanger the policy goals of the EC. The construction industry needs to be able to deliver DER as well as newly build NZEBs using innovative technologies which are key in addressing new approaches for energy efficient buildings [13]. On the other hand, there is a lack of qualified and skilled workforce, which would deliver high quality NZEBs in which occupants would have healthy living conditions [13], without any construction faults occurring in use, and delivering designed energy consumption. Improving the competences of middle- and senior-level building professionals, including various trade professionals (construction workers), in sustainable energy efficient construction is therefore of key importance. It is envisioned that increasing the knowledge and skills of craftsmen about new technologies, cross-crafting good practices as well as worst practices will result with a higher level of energy performance in buildings, as well as avoiding inadequacies caused by poor practices [14]. Additionally, objectives and consequently up-skilling is regarded as an upstream measure, as outlined by a respective recent European study [15]

Digitalisation of the construction sector is increasingly recognised as a potential game changer for the sector, which could contribute significantly to sustainable development and the EU 2020 Strategy [16]. For instance, it is estimated that full-scale digitalisation in non-residential construction would lead to annual global cost savings of EUR 0.6 trillion to EUR 1.0 trillion (13% to 21%) in the engineering and construction phases and EUR 0.3 trillion to EUR 0.4 trillion (10% to 17%) in the operations phase [17]. The European Commission (EC) has thus supported, promoted and developed several policies and initiatives aiming to foster the digitalisation in the construction sector. These include inter alia the Strategy for the sustainable competitiveness of the construction sector and its enterprises (2012) [16], the EU BIM Task Group [18] and the upcoming EU Digital Construction platform which is intended to serve the purpose of facing the main challenges related to the uptake of digital tools in support of the digital evolution of the sector. In 2014, the EU commission issued directive 2014/24/EU [19], which recommends member states use building information electronic modelling tools in public construction projects. This clearly suggests a trend towards a unique construction market in the EU enhanced by BIM–based methodologies. As a result, the construction industry in EU Member States, has gradually adopted digital innovations, with BIM being a frontrunner [20]. However, there are significant differences in BIM acceptance levels across the EU, clearly demonstrated by the fact that BIM has been mandatory in some EU countries (such as UK, France, Denmark, Austria, Spain, Norway, Finland) for almost a decade whereas the legislative framework for BIM is still a matter of discussions and pilot projects in other nations [21]. The works of various BIM organizations and initiatives, standardizations, and expert groups aiming to carry out the EU directive indicate that BIM is becoming an important national issue in the EU. According to International BIM Report 2016 [22], the usage of BIM is increasing and within five years it is expected that its usage in design professions in most world countries will be over 80% [22]. In 2016, the usage of BIM in different countries was: UK 50% (74% in 2018 [23]), Canada 71%, Denmark 81%, Czech Republic 30% and Japan 49%. It was expected in [22] that by 2021 that the usage will be as follows: UK 95%; Canada 71%; Denmark 93%; Czech Republic 90% and Japan 88%. In BIM frontrunner countries BIM standard has been introduced, while in other ones BIM is yet to be defined as a standard regardless of its implementation level. There are several reasons for these variations of BIM maturity across regions. Some researchers suggest that these differences are associated and influenced by the institutional forces and national policies and mandates in different countries. However, it is important to acknowledge that differences are influenced by the socio-technical factors and the cultural and social contexts in each region as well as team experiences. Differences can also be impacted by the type of project, its scale, income, the level of complexity and the requirements of clients [24]. However, it is possible to conclude that BIM will inevitably be used in the future of all construction sectors (e.g. education, practice, legislation, public procurement process, contracting, etc.) [21].

However, there are still challenges in achieving a fully integrated collaborative multidisciplinary mode of operation. A change in working processes and an integration of BIM with individual business processes is needed [25] to achieve greater collaboration and communication across disciplines [26]. Fostering collaboration in BIMbased construction networks is a top priority for construction project managers [27]. The current adoption of BIM in the construction industry does not exploit the technology's functions to its full potential [28]. The slow pace of BIM adoption can be ascribed to the lack of clarity on how BIM can be integrated with the current business practice [26]. The ACE Sector Study [10] has determined that only a small minority, 14%, of practices are not aware of BIM, while around 2/3 of practices are aware of BIM but do not use it.

It can be concluded from [20] that government policies and initiatives aiming to foster BIM implementation should be comprehensive, including public procurement, education and development, and standardisation. By doing so, governments are combining a top down and bottom-up approach: on the one hand they adopted public procurement amendments/regulations requiring BIM for public infrastructure projects. On the other hand, they provided downstream investments to foster research and development around BIM, which come to support companies' efforts to implement it. This way, governments managed to ensure a balance between additional requirements and incentives for the industry [20].

3 ESTABLISHED OUTCOMES OF SKILL SHORTAGES IN NZEB AND BIM

In most European countries, gaps exist in official educational programmes for professional education of EQF 3-7 levels in the field of NZEB, resulting in skill shortages of construction professionals constructing NZEBs. The mismatch is being created between learning outcomes and competences gained by students in educational institutions (both HEI and VET) and competences needed by the construction sector in the field of NZEB. This means that in many EU countries educational institutions often provide obsolete training related to BIM.

Due to the fact that there is a significant variety of approaches to NZEB definition in the different EU countries, it can be concluded that such widely different approaches will likely have a significant effect in determining the focus placed in different countries and even regions on specific topics relating to NZEB.

When employers are looking to hire additional construction staff they are mostly interested in the practical skills of the interviewee and less interested in their qualifications. Employers see little value in pure theoretical training and often practical training is a requirement, but this practical training should be as short as possible and as cheap as possible in order to drive significant numbers of workers to education. This produces a mismatch in the requirements for the increase of construction quality by the investors and the interest of design and construction company who often do not value upskilling and competences required to build NZEBs. Professionals concerned with advancing their skills seek for flexible, company specific, training which should preferably be practical on-site training.

There are no examples of a nationally coordinated approach to training construction workers, designers and other stakeholders concerning NZEBs or DER. Several training providers in different countries offer courses on energy efficiency, but few and scarce training is available on NZEB.

Regarding skills shortages, there is very little reference to airtightness training which could in turn have profound implications on achieving the construction quality and functioning of NZEBs due to the fact that airtightness is one of the benchmark quality indicators of a deep retrofit project and yet legislation in most EU countries does not require a high standard in this regard.

Moreover, the shortage of competences in the area of internal insulation is significant and since there is a great risk of creating mould in NZEB and DER projects if insulation application is not carried out in accordance with building science recommendations – the probability of occurrence of construction damage is high.

Since the definition of competences except knowledge and skills comprises also responsibility, it seems that a module on 'understanding the consequences of poor workmanship' should be a crucial element in any NZEB or DER training. It seems that that there is a gap in competences of significant number of stakeholders working in the field of NZEB on their responsibility, i.e. what consequences could result from their actions.

Whilst many of the energy efficiency training programmes intended to architects (designers, supervisors) and civil engineers (designers, construction managers, supervisors) focus on improving the performance of the building envelope, there is often little mention of mechanical systems such as domestic hot water generation, storage and circulation as well as heat recovery ventilation (MVHR). Off-course these stakeholders do not have to become experts in the mentioned topics but have to have basic competences in the field. This can also be identified as skill shortage and a gap in the competences of stakeholders in many EU countries. Furthermore, the overlap between different trades (cross-crafting) is rarely covered in NZEB and/or DER training programmes.

Crucially, the gap and shortage of competences of many designers, construction managers and workers are connected to the comfort of the inhabitants and building users. The focus of trainings should extend from 'just' energy efficiency to include comfort, indoor air quality and risk of mould and condensation.

Lack of knowledge, trust, and communication between various stakeholders of the lifecycle stages of a building have also been identified as a barrier for full NZEB implementation or as one of the reasons for the underperformance of NZEBs and sustainable buildings. 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. It is evident from this that introducing BIM would be beneficiary to NZEB design, construction and facility management process, since BIM is actually a process for creating and managing all of the information about a project, leading to an output known as a Building Information Model, which contains digital descriptions for every aspect of the physical project. Another advantage of BIM is that it supports an integrated design process, but some gaps were identified in the competencies of various stakeholders.

The gap in BIM is that integrated design courses (especially those which include specific skills to cope with NZEB challenges in cross-disciplinary teams) are scarce throughout EU educational institutions, and there are a lot of experts having little or no knowledge on integrated design. Construction companies need a single integrated platform to optimize performance across the complete lifecycle of their assets. One platform that comprises all elements from design, procurement, and implementation, through to the commissioning, operation, and maintenance of smart services. In many EU countries, and among many stakeholders there is still a large knowledge gap around BIM processes and data and its importance to the future of the construction industry. It has to be said that BIM also poses a challenge, because making it work requires a considerable upfront effort not just to adopt the technology but also to acquire relevant know-how, set standards, find the right strategic positioning, and align stakeholders.

Collaboration between designer and operator at handover is limited to the seasonal commissioning and exchange of basic information, building on documentation created without the needs of the end-user fully considered. Widespread application of BIM for purposes outside design development is unlikely to happen without corresponding and relatable standards for information management, in the areas to which it's applied. Addressing the barriers identified here would simplify this process and enable more effective utilisation of design and operational data in ongoing performance management.

It is evident that in the case of many early adopting countries the following happened, BIM implementation succeeded at the design, engineering and construction phases, while its use is limited when it comes to the operation and maintenance phases. Reinforcing the capacities of public and private sector actors and their understanding of BIM is of crucial importance, but it has to be said that BIM education is not only a technical issue. It is not only about training workers to use BIM software, but also changing the working methods and process in a company. BIM education is hence about management change, stakeholder's awareness and their real need has to be tackled.

A research was performed within the project BIMzeED which quantified existing competences in NZEB and BIM by surveying stakeholders. In the surveys that were distributed to educators and construction stakeholders, respondents needed to assess their knowledge and skills and also knowledge provided by existing education programs according to the scale provided in Figure 2. The educators that completed the surveys are mainly HEI professors and VET teachers who have some experience teaching energy efficiency and BIM related topics, the survey was conducted on 60 educators. In total, there were 237 respondents from construction industry where 63.7% of respondents have more than 5 years of work experience. The 47 responders in the educational provision were not administration staff but the teachers from existing HEIs and VETs in the partner countries, and this was important in order to receive better quality data.

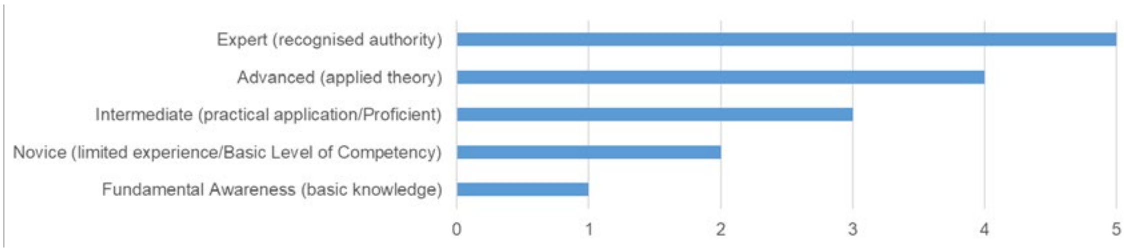

Figure 2 The scale of grading competences

Table 1: Overall score in the fields of NZEB and BIM

	NZEB			BIM		
Questionnaire	Average	Min	Max	Average	Min	Max
Education provision	2.65	2.11	3.17	3.12	2.33	3.94
Educators	2.53	1.79	3.39	2.29	1.94	2.87
Construction stakeholders	2.57	2.06	3.26	1.84	1.60	2.25

Even though the difference is not significant, in the NZEB field, education provision is offering more knowledge and skills than educators and construction industry stakeholders actually declare they possess (Table 1). As it can be seen from the scale above, this score is just little higher than basic level of competence with limited experience. It is deemed that for general improvement the competence level needs to be at least 3.5 on average. That would mean that we need to raise all competence in education provision up to the "Intermediate" or "Advanced" level. In the field of BIM, the difference between competences offered by education programs and competences of educators and construction industry stakeholders, is significant. (Table 1) The education programs offer competences which are a level higher than competences possessed by educators and construction stakeholders which is in turn just little higher than basic level of competence with limited experience. It was established that BIM competence level threshold should be at least 3.5 on average. BIM education almost meets that threshold, but educators and construction industry stakeholders need to raise up to the "Intermediate" or "Advance" level.

Table 2 shows that currently among the NZEB educators there is the largest gap in NZEB competences connected to Use and maintaining, and tendering and contracting. When we come to all participants there is the largest gap in pre-design group of NZEB competences. Table 2 shows that currently among the BIM educators, the biggest gap is in the BIM competence group "Initiation – Integration and communication" and the smallest is in the BIM competence group "Monitoring and controlling". Looking at all participants in all groups the gap is significant but again the biggest and the smallest is in the same BIM competence groups as for BIM educators.

Table 2: Current gap in the fields of NZEB and BIM

	Groups of competences	Education provision	Educators	Educators training gap	All participants	Training gap
NZEB group of competences	General NZEB	2,89	3,05	0,16	2,96	0,07
	Pre-design	2,77	2,64	-0,13	2,45	-0,32
	Design	2,61	2,50	-0,11	2,40	-0,21
	Tendering/contracting	2,46	2,13	-0,33	2,39	-0,07
	Realization and Commissioning	2,45	2,23	-0,22	2,47	0,02
	Use and maintaining	2,38	1,95	-0,43	2,38	0,00
BIM group of competences	Introduction to BIM	3,53	2,66	-0,88	2,13	-1,40
	Project start-up	3,38	2,45	-0,93	1,95	-1,43
	Tendering	3,11	2,33	-0,79	1,83	-1,28
	Initiation (Integration and Communication)	3,51	2,27	-1,25	1,94	-1,58
	Planning (Integration)	3,17	2,21	-0,96	1,80	-1,38
	Planning (Scope, Time, Cost, Quality, Risks)	2,85	2,11	-0,74	1,74	-1,11
	Monitoring and Controlling	2,48	2,13	-0,35	1,66	-0,83
	Execution/Operation	2,85	2,11	-0,73	1,65	-1,20

The reader can use this data to get an idea of the real situation in the BIMzeED project countries and to create a remediation measures and targeted training activities as was done in the BIMzeED project in the partner countries.

4 CONCLUSIONS

BIM has a number of socio-technological advantages not only at the technological level, but also the process level, and can complement the way that architectural design artefacts are created, but also can profoundly change the collaborative process associated with the act of building. It is also clear that 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. Moreover, it is essential that educational institutions bring up professionals with such competences. New technologies require talent with substantially different skills from those the AEC workforce possesses today. BIM requires experts with skills in artificial intelligence, data analysis and programming. New job profiles and sought-after skills could help to bring more women and young people (new talents) into the industry and to close the talent gap. In some countries (i.e. Ireland) new occupations are emerging within the NZEB areas. This paper analyses the current situation in the AEC industry in several EU countries and several EU projects and provides a possible solution for the training problems in the field of NZEBs and BIM. The analysis of current formal and informal educational programs in the AEC industry revealed that topics related to the DER and NZEBs are not adequately covered, or not covered at all, resulting with a lack of qualified workers and professionals. This paper shows which groups of competences of construction stakeholders in the field of NZEBs and BIM should be increased as a solution to the identified gaps.

BIMzeED training programmes are going to be designed with intention to 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, it must not be introduced to the detriment of a poor theoretical basis. 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. BIMzeED structured the training material and content using common learning units (LUs) with flexible standardised delivery (in class, on-line and on-site) suitable for HEI and VET training. The initial training content will include nZEB related subjects with BIM maturity. The training content will be developed and delivered in a Blended Learning format supported by a E-Learning portal, and once finalised the LUs will be made available as Toolkits to potential students, HEIs, VETs and SMEs.

ACKNOWLEDGMENTS

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

REFERENCES

[1] Cardif University: *BIMEET D2.1-BIM for energy efficiency requirements capture*
[2] International Energy Agency: Tracking buildings. IEA. Available at: https://www.iea.org/reports/tracking-buildings [Date accessed: February 8, 2020]
[3] European Commission: *Energy roadmap 2050*
[4] European Parliament and the Council of the European Union: *Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast)*. European Parliament
[5] Yang, X.; Ergan, S.; Knox, K.: Requirements of Integrated Design Teams While Evaluating Advanced Energy Retrofit Design Options in Immersive Virtual Environments. *Buildings* 5(4):1302–20, (2015). Doi: 10.3390/buildings5041302
[6] Cromwijk, J.; Mateo-Cecilia, C.; Jareño-Escudero, C.; Schröpfer, V.; Op't Veld, P.: An Introduction to a Novel and Rapid nZEB Skill-Mapping and Qualification Framework Methodology. *Buildings* 7(4):107, (2017). Doi: 10.3390/buildings7040107
[7] BIMcert Team: BIMcert: Answers to the European audience. BUILD UP The European Portal for Energy Efficiency in Buildings. Available at: https://www.buildup.eu/en/news/bimcert-answers-european-audience [Date accessed: February 8, 2020]
[8] Turk, Ž.: Ten questions concerning building information modelling. *Build Environ* 107:274–84, (2016). Doi: 10.1016/J.BUILDENV.2016.08.001
[9] European Commission; Internal Market Industry Entrepreneurship and SMEs Directorate General; Energy Directorate General; Joint Research Centre (JRC): The European construction sector - A global partner:16, (2016)
[10] The Architects' Council of Europe: *The architectural profession in Europe 2018 - a sectoral study*
[11] European Commission: *CORDIS results pack on construction skills*. Brussels, Belgium
[12] Trinomics: *Final report on the assessment of the BUILD UP Skills Pillar II*
[13] Lindkvist, C.; Karlsson, A.; Sørnes, K.; Wyckmans, A.: Barriers and Challenges in nZEB Projects in Sweden and Norway. *Energy Procedia* 58:199–206, (2014). Doi: 10.1016/J.EGYPRO.2014.10.429
[14] Bean, F.; De Groote, M.; Volt, J.: *Opening the door to smart buildings, Driving the transition with EU directives*

[15] Concerted Action - Energy Performance of Buildings: *Implementing the EPBD – Featuring Country Reports*. Lisbon
[16] European Commission: *Strategy for the sustainable competitiveness of the construction sector and its enterprises*. Brussels
[17] Boston Consulting Group: Digital in Engineering and Construction. Available at: https://www.bcg.com/industries/engineered-products-infrastructure/digital-engineering-construction.aspx [Date accessed: April 27, 2019]
[18] EUBIM: EU BIM Task Group. Available at: http://www.eubim.eu/ [Date accessed: April 27, 2019]
[19] European Parliament Council of Europe: *Directive 2014/24/EU of the European Parliament and of the Council of 26 February 2014 on public procurement and repealing Directive 2004/18/EC*
[20] European Commission: *European Construction Sector Observatory Building Information Modelling in the EU construction sector*
[21] Galić, M.; Venkrbec, V.; Chmelik, F.; Feine, I.; Pučko, Z.; Klanšek, U.: Survey of accomplishments in BIM implementation in Croatia, the Czech Republic, Germany, and Slovenia. *Number* 15, (2017). Doi: 10.13167/2017.15.3
[22] Malleson, A.; Kato, H.; Popíšilová, B.; Watson, D.; Friborg, G.: *NBS International BIM Report*
[23] NBS: *National BIM Report 2018*
[24] Azzouz, A.; Hill, P.; Papadonikolaki, E.: Which countries have the highest levels of BIM adoption in Europe? | BIM+. Available at: http://www.bimplus.co.uk/people/which-country-most-bim-mature-europe/ [Date accessed: February 10, 2019]
[25] Arayici, Y.; Egbu, C.; Coates, P.: Building information modelling (BIM) implementation and remote construction projects: issues, challenges, and critiques. Title Building information modelling (BIM) implementation and remote construction projects: issues, challenges, and critiques. *J Inf Technol Constr* 17:75–92, (2012)
[26] Gu, N.; London, K.: Understanding and facilitating BIM adoption in the AEC industry. *Autom Constr* 19(8):988–99, (2010). Doi: 10.1016/J.AUTCON.2010.09.002
[27] Oraee, M.; Hosseini, M.R.; Papadonikolaki, E.; Palliyaguru, R.; Arashpour, M.: Collaboration in BIM-based construction networks: A bibliometric-qualitative literature review. *Int J Proj Manag* 35(7):1288–301, (2017). Doi: 10.1016/j.ijproman.2017.07.001
[28] Eastman, C.M.; Teicholz, P.; Sacks, R.; Liston, K.: *BIM handbook: a guide to building information modeling for owners, managers, designers, engineers and contractors*. Second edition. Hoboken: John Wiley & Sons.