# 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 31st of December 2020 all new buildings are Nearly Zero-Energy Buildings (NZEB) and after 31st of December 2018, new buildings occupied and 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 paper analyses the current situation in the construction industry in Croatia and provides a possible solution for the abovementioned problem. Fit-to-NZEB and Net-UBIEP (Horizon 2020 projects) are dealing with the lack of education and competences in Architecture, Engineering and Construction (AEC) industry for delivering NZEBs. Fit-to-NZEB aims to increase knowledge of AEC engineers and workers in deep energy retrofit through the education in EQF levels 3-7, while Net-UBIEP seeks to develop the schemes for using Building Information Modelling (BIM) throughout the whole building lifecycle to increase building's energy performance. The integrated design process and strengthen control on the construction site, supported by BIM, should be carried out as they are the most critical parts in delivering NZEBs. Therefore, Fit-to-NZEB and Net-UBIEP projects can contribute to upgrading professional competences of all the stakeholders involved in the design and realisation of NZEBs.

***Keywords:*** *education in construction; nearly zero-energy buildings; net-UBIEP; fit-to-NZEB; BIMzeED; building information modelling;*

## 1. Introduction

To achieve 2020, 2030 and 2050 goals set by the European Union through the Energy Performance of Buildings Directive (EPBD) and Energy Efficiency Directive (EED), a large scale of Deep Energy Retrofit (DER) should be carried out. EPBD prescribes that by 31st of December 2020 all new buildings and all the buildings under major renovation should perform as NZEBs. The same applies to the buildings occupied and owned by the public authorities after 31st of 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 others to follow their example. The EED also set strict energy-efficiency targets on European building stock with demand for every EU Member to develop a program for deep energy renovation of the building stock up to 2050. As a result of the deadlines mentioned above, it can be concluded that the large number of NZEBs will be built from now, up to 2050. A question which arises is, are the engineers and workers in the

Architecture, Engineering & Construction (AEC) industry well prepared to fulfil such a demand? This paper describes the current situation in the AEC industry concerning Deep Energy Retrofit (DER) in Croatia and tries to provide a possible solution for increasing the competences of the AEC stakeholders through 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 the innovations in the AEC industry to achieve the NZEB performance. The interdisciplinary approach in all the building lifecycle, as shown in Figure 42 (from the early planning phases through the construction, commissioning, operation & 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 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 of occupants

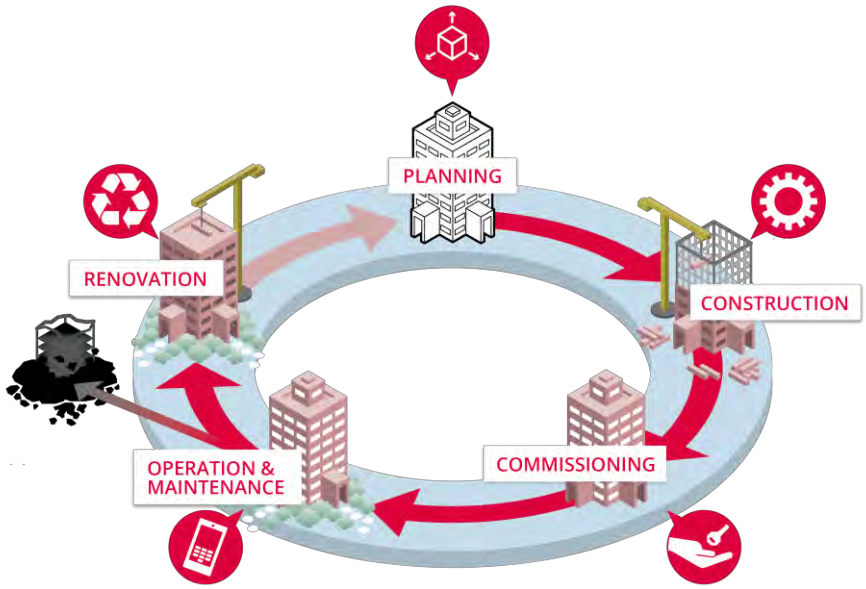



**Figure 42. Building lifecycle (source: https://hydronic-flow-control.com/en/page/our-services--building-life-cycle).**

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 paper, 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, Life Long Learning (LLL) courses are sporadic and lack a systematic approach.

## 2. NZEB and BIM interdependence

The EPBD set 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 targeting family homes and multi-family housing, because the residential sector accounts for around one-third of 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 programs, 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 (Republic of Croatia, Ministry of Construction and Physical Planning, 2017) which includes a plan (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 paper, a very few NZEBs were designed and built in Croatia, and by following scheme shown in Figure 43 (Attia, 2018), their number will increase.

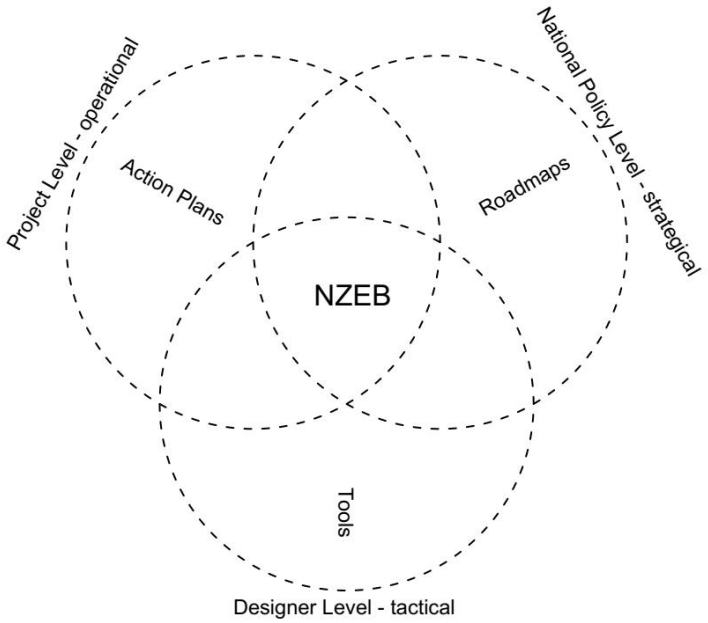



**Figure 43. Three measures to accelerate the implementation of NZEB (Attia, 2018).**

Construction projects are managed mainly by small and medium-sized companies, but they have a limited ability to catch up with the massive flow of the information and knowledge available today. *Building energy use optimisation* 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). An advanced NZEB design requires

practical and efficient information sharing among all the members from different disciplines in an Integrated Design Group (IDG) to make the decisions about selecting the right set of energy retrofit design options (Yang *et al.*, 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 lifecycle 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 throughout whole building lifecycle as well.

All stakeholders in AEC industry and wider should be educated explicitly in an integrated design approach using BIM to increase 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 AEC industry should includes improving competences of all stakeholders, workers, professionals and engineers regarding NZEB and BIM.

This paper will present current situation in Croatia AEC industry from three important aspects:

1. Competences of workers
2. Competences for DER projects
3. BIM competences for improving energy efficiency

Results from three EU funded projects will be used to assess situation in Croatian to make the roadmap for improving competences for delivering NZEBs.

## 4. Competence 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 the increasing demand for workers as a number of energy retrofitting projects grows. Moreover, professional high schools for education of workers in energy efficiency and construction are recording a decreasing number of students year after year. Thirty thousand workers are needed in the construction industry in Croatia to satisfy the current contracts (Bogdan, 2018). Analysis from 2016 (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) in order to achieve the 20-20-20 targets, under the assumption that 3 % of a building's heated usable floor area would be

renovated every year up to 2050. In a line with the EED (European Parliament and Council of Europe, 2012), the Croatian government developed its 2nd National Energy Efficiency Action Plan (NEEAP) (Republic of Croatia, Ministry of Economy, 2014) by which the government highlighted the need for policy action to make buildings more energy efficient in order to meet the national energy efficiency targets. Due to the lack of construction workers, the Croatian government has defined a permissible quota of 10 070 workers who can work in Croatia (Bogdan, 2018). 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. Even if there is enough number of workers (foreign and domestic), they must be educated for constructing NZEBs because the Vocational Education and Training (VET) programmes in Croatia related to NZEBs and DER are obsolete because they have not changed since 1996. Teaching materials used in VET programs for the AEC sector contain very little topics related to energy efficiency and DER. The educational system in Croatia is not producing workers and experts who could enter the construction market with enough knowledge and competences concerning BIM and NZEBs. As a consequence, a high number of low-quality projects are delivered (Figure 44) because even if the design is satisfying NZEB standards, buildings are not constructed according to required designed performances.

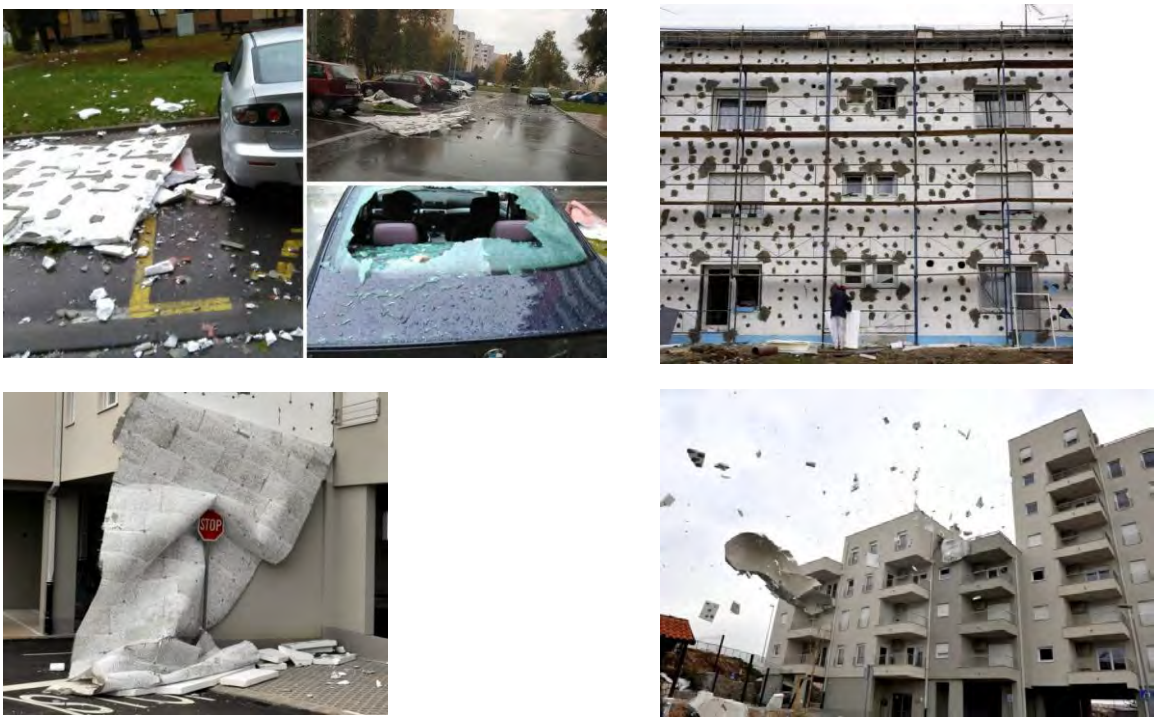



**Figure 44. Examples of low-quality construction work and its consequences.**

From the 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" (Republic of Croatia, Ministry of Construction and Physical Planning, 2017), in order to increase the number of qualified workers for energy refurbishment of old buildings and construction of new

NZEBs. There are regulations for installers of RES systems too, and several training centres providing education are also established.

## 5. Fit-to-NZEB - competences for DER projects

Fit-to-NZEB is a Horizon 2020 project which has a goal to increase 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 should be achieved through the unique educational programs developed by the consortium which will contribute to both the quality and scale of the DER. The consortium developed an innovative European Qualifications Framework (EQF) level 3-7 training schemes for building retrofitting up to an NZEB level. Those training programs have been organised in the countries across Europe with a conventional structure, learning outcomes and defined competences. The program was delivered by the Universities, professional high schools, Vocational Training Centres (VTC), and through "on-the-job" training and validation programs (*Objectives & results - Fit-to-nzeb*). The partner countries performed an analysis of the existing training and educational programs for DER in order 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 programs. In the EQF 3-5 systems (secondary and high education) principles of DER are not included in the official training programs at all. In the EQF 6-7 (higher education) there are fragments of DER topics represented by the certain topics without a systematical approach and the connection between them. Above mentioned problems are the main reasons why Vocational education solved the lack of qualification concerning DER. Vocational training is divided into two parts – training concerning AEC workers (EQF 4-5) and training for supervising professionals (EQF 6-7). However, this training is not harmonised and does not provide a formal DER qualification in the national qualification frameworks of the partner countries. As the analysis had shown the necessity of developing a unique DER program for each EQF level, the Fit-to-NZEB project delivered all the necessary requisites (Table 33) for the introduction of educational content regarding DER and NZEB at all the educational and training levels in South-eastern Europe (Milovanović *et al.*, 2019).

**Table 33. Developed topics for DER with short descriptions (Milovanović *et al.*, 2019).**

| Topic and subtopic |
|---|
| 1. Basics of building physics<br>1.1. Passive house principles<br>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<br>Situation and sizes of openings/shading and natural ventilation |
| 3. Building envelope<br>3.1. Thermal insulation<br>3.2. Minimizing thermal bridges |

3.3. 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
   4.1. Energy cooperatives
   4.2. Distributed energy production systems and energy

Understanding the nZEB Neighbourhood. Energy cooperatives as isolated business or connected to a local smart grid or to the national grid. Distributed energy sources. Microgrid solutions. District level distribution grids. Impacts and benefits of the grid integration of the 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
   6.1. MVHR
   6.2. Heating and Cooling
   6.3. DHW
   6.4. Automation – Regulation
   6.5. 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 ofbuildings of historic value – suitable materials and techniques.

8. RES in building renovation
   8.1. 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.

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, CO2 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 component and alternative solutions. |
| 13. Energy efficiency and building renovation policies<br>National and EU strategic goals; financing schemes and opportunities; relevant legislation acts in nZEB construction and DER. |
| 14. Achieving measurable results<br>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<br>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<br>16.1. Quality assurance<br>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<br>Ecology as a starting point for energy efficiency in building; climate change and CO2 levels; building materials |

Developed compendium of competences is intended for the developers of new training and educational programmes on NZEB renovations. Elaborated learning outcomes can be applied to the development of a wide range of training programmes of vocational or specialised education for AEC specialists so here are the training programs developed by project Fit-to-NZEB described in details in (Milovanović *et al.*, 2019):

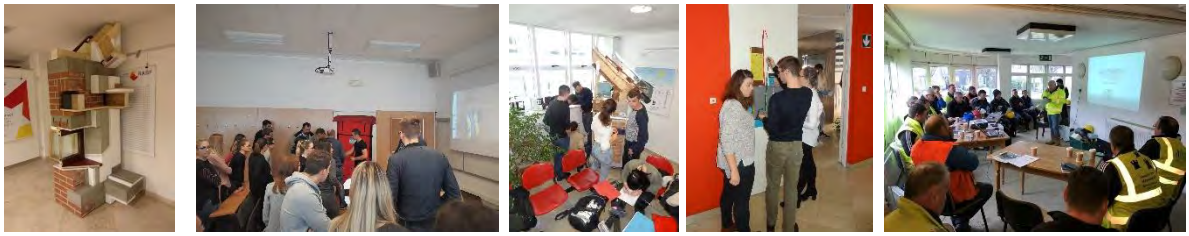
"EQF level 6-7: A design-focused training programmes on DER for higher education, 60 hours of training (30 theoretical hours and 30 practical hours), with all necessary requisites.

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 countries created training models which represent parts of a real building in order to show good examples of constructed building details. The models were used for practical training demonstration. Visualisation by developed models (Figure 45) during the training programs is an essential method for better learning outcomes.



a) b) c) d)

**Figure 45. a) example of the training models, b) execution of the university training – blower door, c) university training – minimising thermal bridges, d) on the job training in Ireland (Milovanović *et al.*, 2019).**

## 6. Net-UBIEP - BIM competences for improving enrgy 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 design process (by 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 current initiatives towards BIM standardisation through Croatian Standards Institute, but currently, there is no national standard which 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 *et al.*, 2017) by Croatian Chamber of Civil Engineers, but they are quite general and do not describe BIM professional profiles in details.

Net-UBIEP is also a Horizon 2020 project which aims to increase the energy performance of buildings by BIM usage through all the building lifecycles. In each phase of the building lifecycle, it is crucial to take into account all the energy aspects in order to decrease the environmental impact of a building during its lifecycle (*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 lifecycle. The project proposes BIM Qualification Models to spread a better understanding of energy-related issues so that both existing and new buildings will have better energy performance. Public Administrations, Professionals (Engineers/Architects), Technicians (Installers/Maintainers) and Tenants were involved in the Net-UBIEP activities (*Project | Net-UBIEP*). Each stakeholder will have to understand which information they need to manage so other stakeholders could use it during the lifecycle of a building. The integrated BIM Qualification Models have been validated through the project thanks to the delivering of the different training activities (Seminars/Classrooms, Courses/E-Learning, Courses) addressed to at least six BIM Professional Profiles: BIM Manager, BIM Evaluator, BIM Coordinator, BIM Expert, BIM facility manager, BIM user. The training schemes were developed, and they are under the

process of validation through a survey carried out by the project partners in the moment of writing this paper. After the process of validation is done by all the project partners, all partners will propose ways of standardisation of the training schemes to find a broader acceptance at European and international level through the regulatory organisations. List of the competences related to energy performance needed for each BIM profile was defined. Competences on energy performance for each BIM profile are mapped to the defined target group.

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) each project partner assessed the needed level of these competences grouped by the building lifecycle phases for each target group (Strategic Design, Preparation and Briefing, Concept Design, Developed Design, Technical Design, Construction, Handover and Closeout, In use). After the assessing of needed competences, three-dimensional matrix of competences was developed (Figure 46) and used for creating training and information materials.

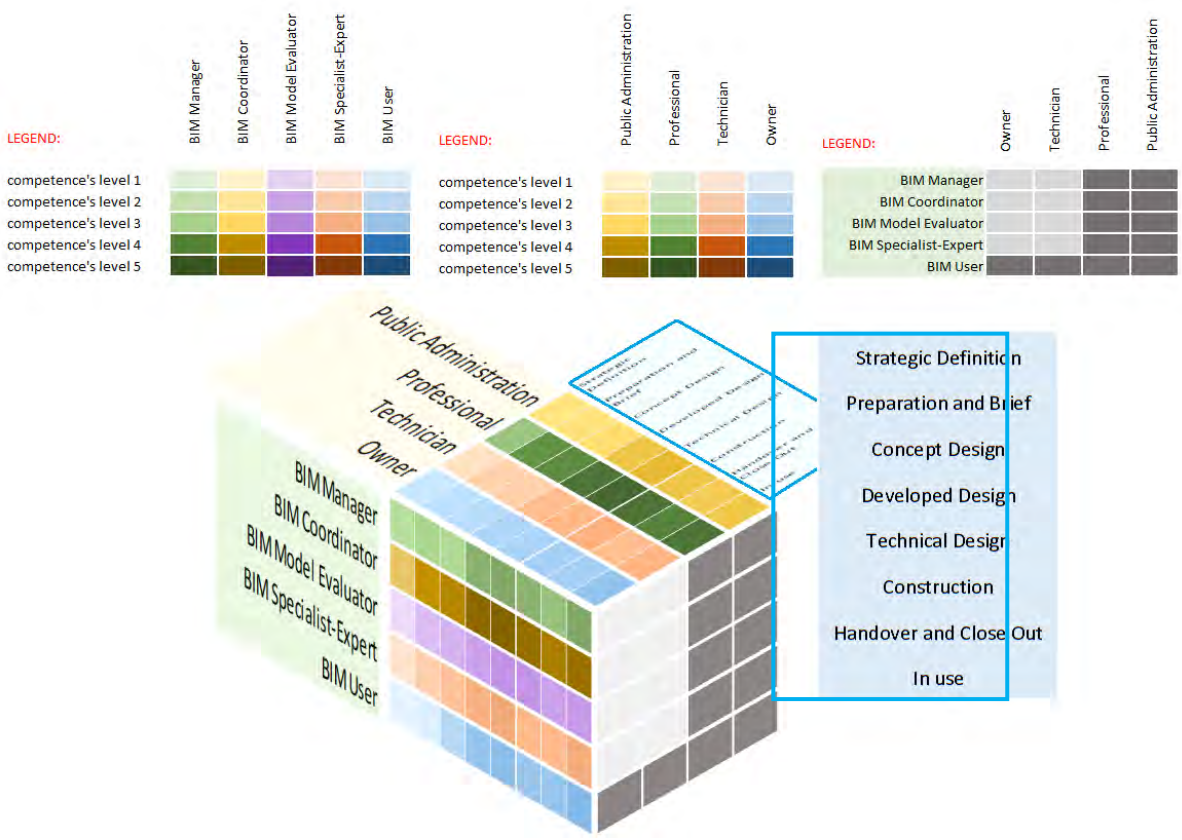



Figure 46. The three-dimensional matrix of competences for BIM-AEC stakeholders.

As a final goal of the project Net-UBIEP, training and information materials were developed: Information Material for Public Administration, Information Material for Owners, Training Material for Professionals, and Training Material for Technicians. Concerning the developed materials, every project partner has organised pilot trainings and seminars which were validated by the participants.

Faculty of Civil Engineering (University of Zagreb) as the project partner institution provided a survey amongst Croatian AEC professionals in order to map BIM competences and to validate the training materials.

Pre-training questionaries were filled before every training so the profile and the competences of a group could be seen. After the questionary was carried out, training based on the *training and information materials* for each target started, after which a post-training questionary was performed. For the sake of brevity, this paper 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.

In the pre-training survey up till now participated 93 participants mostly coming from engineering companies involved in residential projects, value under 1.000.000 EUR. (**Error! Reference source not found.**, **Error! Reference source not found.**, Figure 47). In this sample only 38% companies use BIM Figure 48 but most of them only one year (Figure 49) and on small projects Figure 50. This we found unusual because BIM shows its full potential for projects with a higher value, because of the possibility of storing and organising a high amount of different information. It is interesting that 62 % of projects on which BIM was used are related to energy efficiency. Another interesting information is that none of the participants who use BIM is working on NZEB project for new buildings (Figure 51).

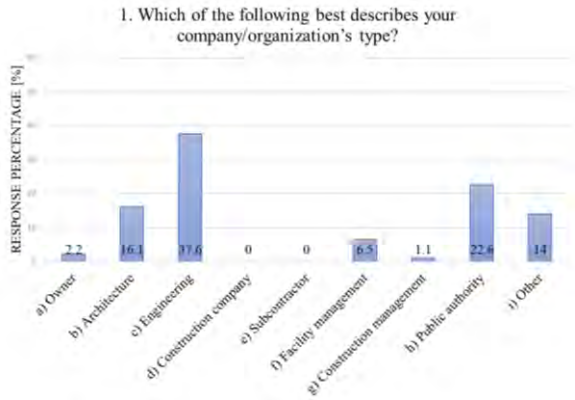



Figure 6. The profile of AEC professionals who attended the survey.


Figure 7. Types of construction projects on which participants work on.

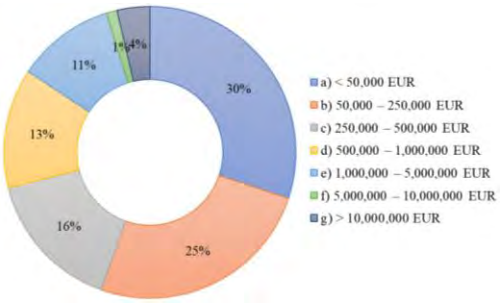



**Figure 47. Value range of the projects on which participants work on.**

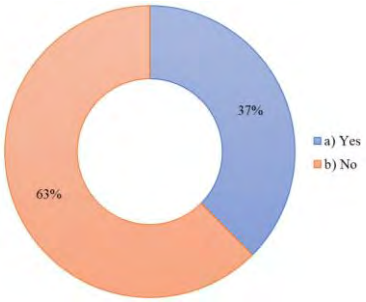



**Figure 48. Percentage of training participants who use or intend to use BIM in their companies.**

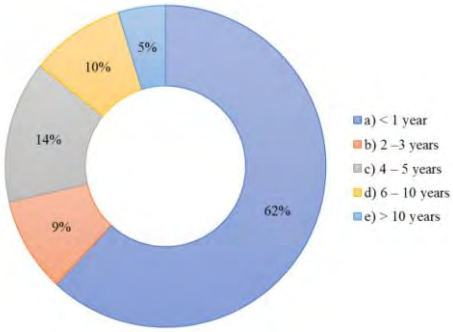



**Figure 49. Experience of participants in BIM whose companies implemented BIM.**

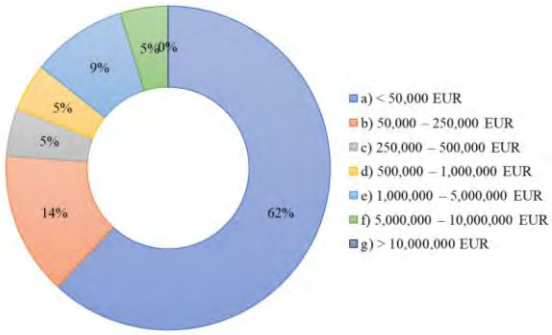



**Figure 50. Project value on which participants work, for those who use BIM.**

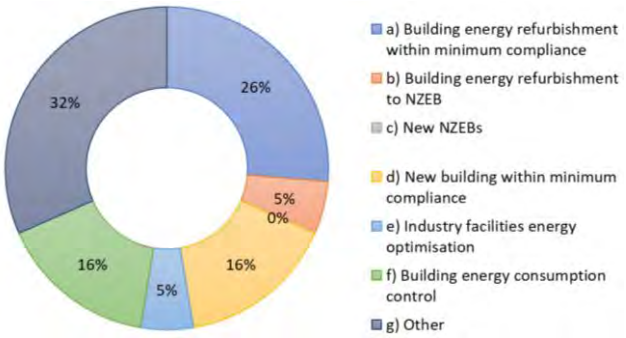



**Figure 51. Relation of the BIM projects to energy efficiency, for those who use BIM.**

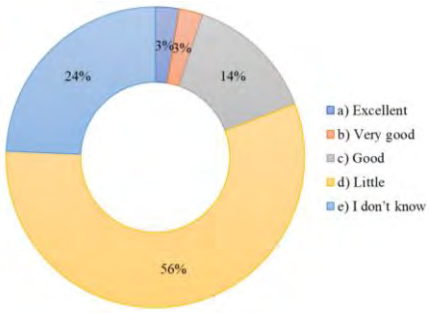



**Figure 52. Competences in BIM of the participants.**

In pre-training questionarie self-assessment of competences for BIM resulted with only 6 % of the participants with BIM competences rated as excellent or very good (Figure 52), 70 % of them with good or poor, and 24 % could not rate their competences.

## 7. Conclusion

This paper described problems in the AEC industry in Croatia concerning the DER and delivering NZEBs. 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. Another major problem detected in the conventional project delivering is an absence of integrated or interdisciplinary approach between all the stakeholders. Introducing BIM approach and defining new BIM competences can overcome this problem.

Through the preliminary survey research, it can be concluded that, in Croatia, BIM is not efficiently used in projects concerning NZEBs as only 37 % of participants use BIM and 62 % of those who use it have less than one-year experience in BIM. Problems will be experienced in a more meaningful manner after 31$^{st}$ of December 2020 as a massive deployment of NZEBs will start, both because of lacking qualified workers and increasing demand for delivering NZEBs. It is clear that BIM must be used in delivering NZEBs as better *information management* could be provided in order to store approved information through NZEB's lifecycle 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 in order to find a cost-optimum.

Fit-to-NZEB training programs will increase competences in constructing NZEBs, and Net-UBIEP in designing, constructing, maintaining, and demolishing buildings by using BIM in all building's lifecycles. Concerning Croatian AEC stakeholders who participated training courses it can be seen that the 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.

Another important European project has started recently. It is an Erasmus+ project BIMzeED which is closely related to the Net-UBIEP project. The BIMzeED project will try to overcome mismatched skills and improve competences of Trainers, SMEs, site managers, craftworkers and other experienced operatives in the current European AEC industry concerning BIM and NZEBs. Improving mismatched skills and competences will lead to better employability (esspecially for young people) and decrease of greenhouse gas emissions.

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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