IMPROVING ENERGY-EFFICIENCY SKILLS IN THE CONSTRUCTION SECTOR THROUGH TECHNOLOGY-ENHANCED LEARNING: THE CASE OF BIMPLEMENT PROJECT

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Abstract

The building sector offers a large untapped potential for cost-effective energy savings. One of the most challenging aspects of reducing energy use in the building sector lies in increasing the rate, quality and effectiveness of nZEB (nearly Zero Energy Buildings) construction and renovation.

The European Commission has underlined one of the barriers that hampers the development of nZEBs and effective renovations is the lack of adequate constructions skills. Improving the skills of the different building and trade professionals in the area of low carbon and energy-efficient construction is key to tackle this barrier. To improve this situation the BUILD UP Skills initiative was launched in 2011 and has been expanded under the European Horizon 2020 research and innovation programme with specific calls for projects on Construction Skills. The objective is to increase the number of skilled building professionals across the building value chain (designers, architects, engineers, building managers, technicians, installers, workers, apprentices and other building professionals) to ensure proper interactions between different trades and professions.

Since 2011, several projects across Europe have been funded to map the skills gaps and needs and provide building professionals and construction workers with the necessary training to meet the challenges posed by energy-efficiency regulations. Moreover, during the last period, the introduction of digital learning environments in the construction sector has gained importance.

The recent report titled "Supporting digitalisation of the construction sector and SMEs" states that the digitalisation of the construction sector is underway in Europe but at a slower pace than expected. The report also presents an overview and brief description of the recommended actions to improve the current state of digitalisation of the construction sector, among which is the following: "Provide lifelong (Digital) skills development for employees within the construction sector through trainings". New digital technologies, such as Building Information Modelling (BIM), have begun to transform the way that buildings are designed, built, operated and maintained [1].

This paper introduces the EU-funded H2020 project BIMplement whose main objective is to achieve an improved quality for nZEB construction and renovation by using BIM as a universal information carrier and enabler of the learning process within building projects and between building projects. BIMplement sets up large scale training, Continuous Professional Development and flexible qualification methodology integrating technical, cross-craft and BIM related skills and competences. The value of the BIMplement methodology is being tested in 50 construction or renovation projects in France, Spain, the Netherlands, Lithuania and Poland.

Keywords: Innovation, technology, research projects, BIM, digitalization, buildings, construction, skills, qualification, European Commission, H2020.

1 INTRODUCTION

Recent studies indicate that the construction, use, and maintenance of residential and commercial buildings are responsible for approximately 40% of final energy consumption in the EU. Of these buildings, approximately 75% are considered inefficient from an energy point of view [2]. Furthermore, there is an evident gap between the "designed" level of energy efficiency and the truly "built" level that results from the final work [3].

According to the World Economic Forum, construction labor productivity has stagnated or even decreased over the past 50 years [4]. Reasons for this are, among others, the persistent fragmentation of the industry; inadequate collaboration between the players; the sector's difficulty in adopting and adapting to innovative technologies; the difficulties in recruiting a talented and future-ready workforce; and insufficient knowledge transfer from project to project [5].
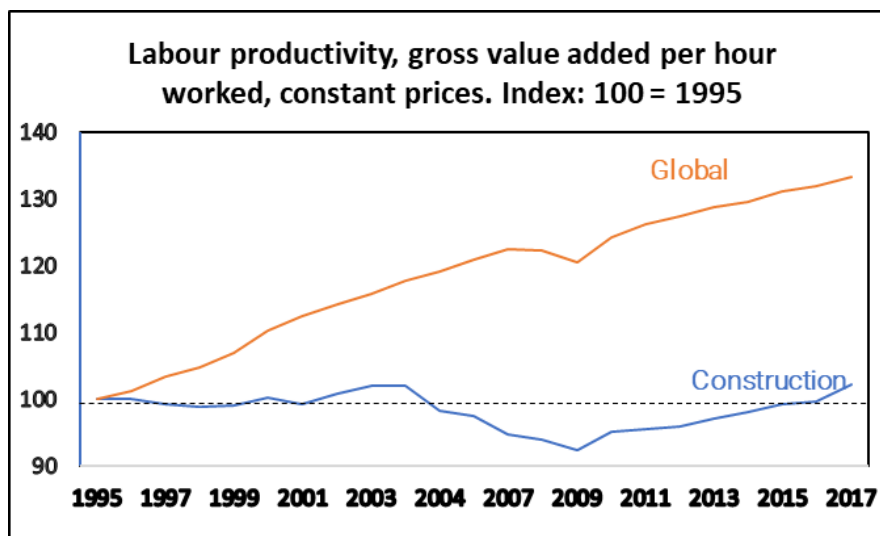

Figure 1. Own elaboration based on Organization for Economic Cooperation and Development (OECD) statistics.

In this scenario, the quality energy renovation of the existing building stock in the EU is seen as an opportunity for the construction sector. Improving quality control throughout the entire process can only be achieved with a fully qualified and competent work team, able to implement, execute and perform all necessary actions with a full understanding of the responsibility that their actions entail and coordination with the rest of the workers along with those who make up a value chain [6].

Figure 2. BIMplement project logo

BIMplement is a project financed by the Horizon 2020 programme of the European Union, with a duration of 36 months, in which 9 partners from 5 different countries participate: France, the Netherlands, Lithuania, Poland and Spain that started in September 2017.

The main objective is to improve the quality in the construction and renovation process of nearly zero energy buildings (nZEB) using BIM as a universal information carrier and facilitator of the learning process within projects and between projects.

BIMplement project is building on results and experiences of the **Build Up Skills (BUS) and H2020 Construction Skills projects** and is focused to the call EE14-2016 Construction skills.
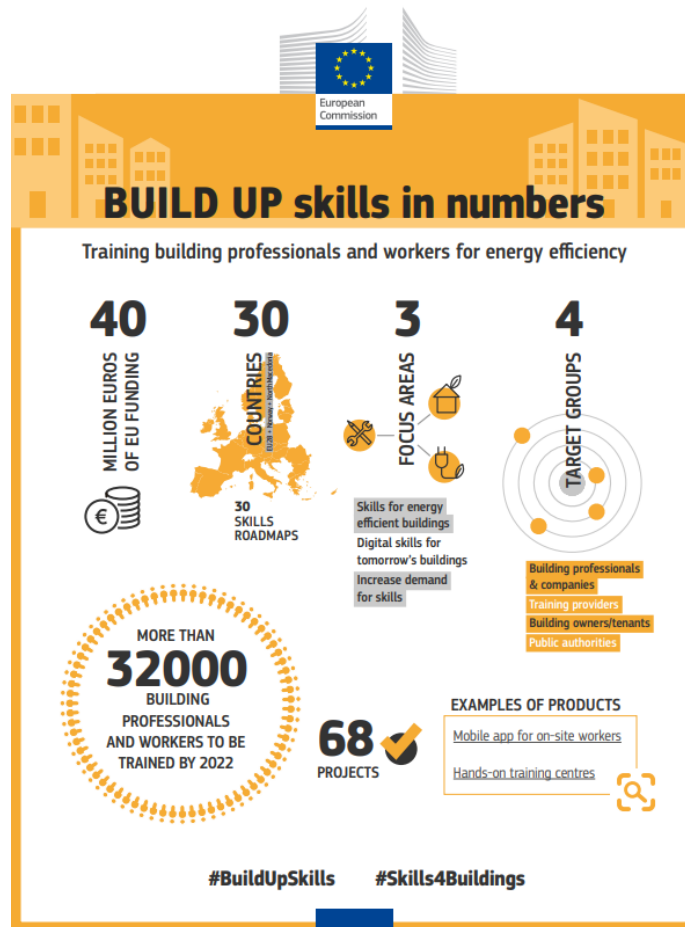
Figure 3. Infographic: Build Up skills in numbers

Moreover, the H2020 Programme supports BUS type projects and organizes regular exchange activities at EU level to promote the European dimension of this important initiative and to foster learning between the countries. This is the case of the so-called "BUS EU exchange meetings" that have been held since 2016 and in which the coordinators of ongoing projects participate to exchange experiences and to create synergies amongst the projects.

The BUILD UP skills exchange meetings have shown that there is a need for setting up a mutual recognition scheme of qualifications among different Member States but also that all professionals need to be aware of new materials and products, the integration of renewable energy sources, new systems or processes, such as standardisation and common voluntary certification of buildings, and the use of building information modelling (BIM) tools. [7].

Building Information Modeling (BIM) provides a new collaborative work methodology for the construction sector that is revolutionizing the way of working, especially in the collaboration among the agents involved in the different construction processes.

Working at BIM means having a single model from which to generate and manage all the project information throughout its entire life cycle. Architects, engineers and construction professionals have a methodology that allows them to operate together in real time. Any change or information introduced in the model modifies the set of affected elements automatically.

In addition, the use of the BIM methodology increases the productivity of construction and provides: cost savings, better management of construction and operation, higher environmental quality and greater transparency and collaboration among professionals.
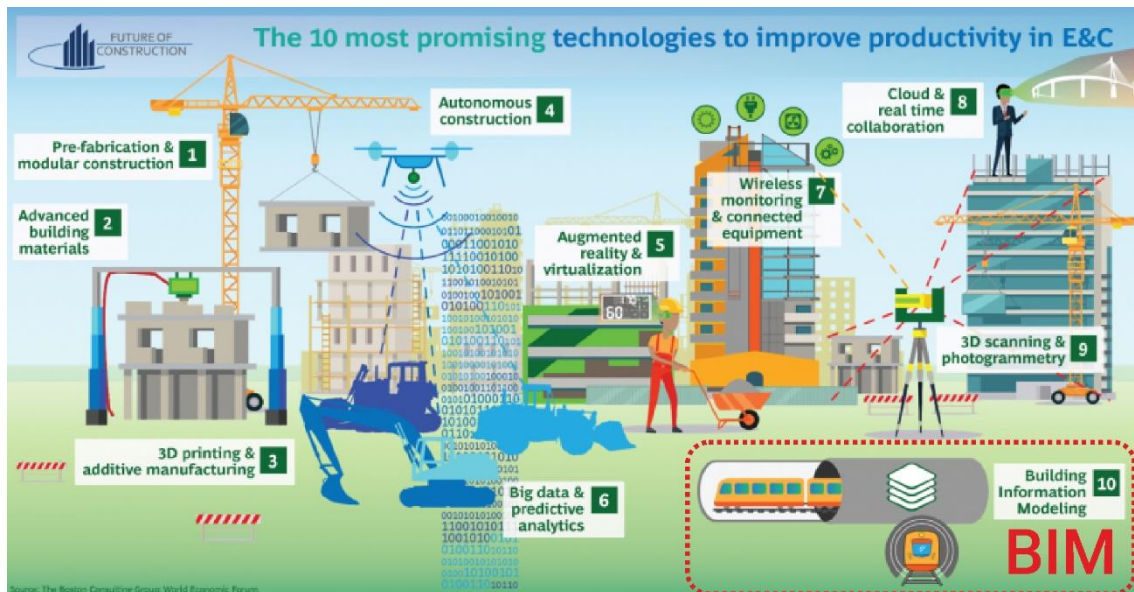
Figure 4. Source: The Boston Consulting Group; World economic Forum

For these reasons, the BIMplement project uses BIM as a universal information carrier and enabler of the learning process within projects and between projects. As using BIM is new for many SMEs, BIMplement combines the upskilling in using BIM with the Just-in-Time and Just-in-Place upskilling on nZEB related topics.

Upgrading or setting up large-scale qualification and training schemes that promote the digitization of the sector goes hand-in-hand with initiatives that increase the demand for skilled building professionals, creating new job opportunities and boosting Europe's economic competitiveness. [7].

2 METHODOLOGY

Concerning the methodology, BIMplement fully builds on the available results of the related Build Up Skills (BUS) and Construction Skills projects in combination with a direct implementation of the methodologies combining quality assurance with large scale qualification schemes. This is brought into practice on local and regional scale, by demonstrating, testing and validating the methodology and effectiveness of qualification schemes in real projects.

One of the main sources is the PROF/TRAC project in which all technologies and professions (on medium and senior level) for nZEB are mapped as well as a methodology for skills mapping and identification of skills gaps. Moreover, the PROF/TRAC open data base on teaching and training materials was used.

2.1 Development phase

BIMplement has developed and implemented a quality-oriented Qualification Framework. It consists of descriptions of competences, skills and knowledge needed in order to connect available knowledge such as learning content and quality inspections to the BIM-model, the building process and the actors involved.

The starting scheme came from previous H2020 projects such as PROF/TRAC and national BUILD UP Skills projects in the Netherlands, France, Spain and Lithuania. The qualifications for working on airtightness and ventilation were enriched with skills and competences needed for performing a high-quality job in a nZEB project that is using BIM.

Unit of Learning Outcomes (ULO's) have been formulated, which are components of a qualification consisting of a coherent set of knowledge, skills and competence (including responsibility) that can be assessed and validated.

Project phase	Tasks	Sub-tasks	ULO Nr.
execution fase		**Making holes in wall(s) and/or floor(s)**	
		check/mark position and dimensions of the recess in the wall	12.1
		make the recess or correct the sizes if necessary	12.2
	Install air ducts		
		construct the duct system (supply and discharge)	13.1
		fix ducts in floors against flooding	13.2

Nr.	Fields of knowledge /Course	Knowledge	Skills	Competentence	Actor
		ULOs for the NZEB Ventilation			
12.2	ho wa	knowledge of making holes in walls/floors	drilling techniques	necessary	Constructor
13.1	installing ducts	knowledge of airtight of connecting ducts	know how to make airtight connections and the difference between the types of ducts	constructing a duct system	Installer
13.2		knowledge of fixing ducts against flooding	know how to fix ducts against flooding	fix ducts in floors against flooding	Constructor
13.3		knowledge of measures during pouring concrete of floorslab	know how to pour the concrete	produce the adjoining screed / finishing passages in walls	Constructor
13.4		knowledge installing supply valves and preset them	influence of valve on airflows in rooms and influence of air speed on comfort	set up and mount supply valves	Installer
13.5		knowledge of making airtight connections in ducts	necassaty of airtight connections	make airtight connections	Installer
13.6		knowledge installing exhaust valves and preset them	influence of valve on airflows in rooms and influence of air speed on comfort	set up and mount valve	Installer
14.1	Mount centrally ventilation unit	knowledge of vibration-free assembly of units	describe the mounting of the ventilation unit	mounting the ventilation unit	Installer
14.2		knowledge of airtight of connecting ducts	know how to make airtight connections and the difference between the types of ducts	connecting the ventilation unit to the duct system	Installer
14.3		knowledge of waste water systems	know how to connect the unit to the waste water system	system	Installer / adjust expert
14.4		knowledge of airtight connecting ducts	know how to make airtight connections and the difference between the types of ducts	assembling silencers between unit and duct system	Installer
14.5		vapor-tight insulation	insulating air ducts and know when and how to do so vapor-tight	isolating channels from the outside to the unit in systems with heat recovery	Installer / isolator
14.6		knowledge of building decree regarding electricity	making a safe and reliable power supply and/or data communication	construct facilities such as electricity and data cables	installer / electrician

Figure 5. Unit of Learning Outcomes (ULO's)

2.2 Implementation phase

The BIMplement methodology addresses the entire value chain of the building sector and all professions involved. To keep focus the general implementation within this project is dedicated to the professions and skills involved in realizing ventilation systems and realizing an air tight building. The reason for selecting these two specific topics is that both ventilation and air tightness have a large impact on both energy use, indoor air quality, thermal comfort and health.

Learning and project results are used to create three different kind of learning loops within the project, between projects and within the value chain:

1. Single-loop learning: if an activity is performed correct or if a model, material or method is applied well.
2. Double-loop learning: if the model, method, material or activity can be improved.
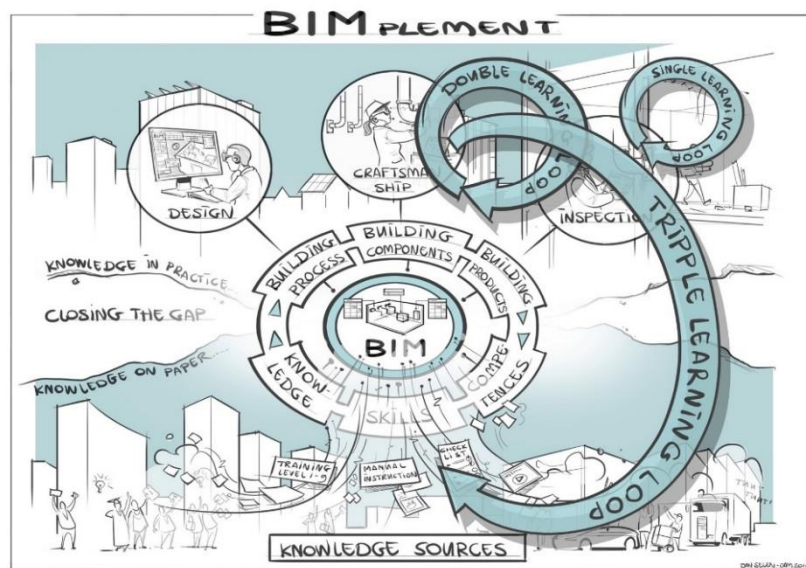3. Triple-loop learning: if the model, material, method or activity is the right solution.

Figure 6. BIMplement learning loops to reduce the gap between designed and actual performances of buildings

2.3 Pilots, demonstration and validation phase

To verify the established matrix and qualification framework, the methodology was tested and validated in a total of 50 construction and renovation projects in France, Poland, Lithuania, the Netherlands and Spain. France undertook most of the pilots, some 30 - 35 projects approximately, which served as a model or reference to the rest of the countries that carried out 5 projects each.

Each project has been analyzed from two points of view: on the one hand, the quality of the project's 3D or BIM model, which has often been improved by the course coordinator or Master Trainer. On the other hand, the level of maturity in BIM and knowledge of the agents in nZEB, ventilation and air tightness, without forgetting the established connections and real dialogue between the parties for smooth and effective communication.
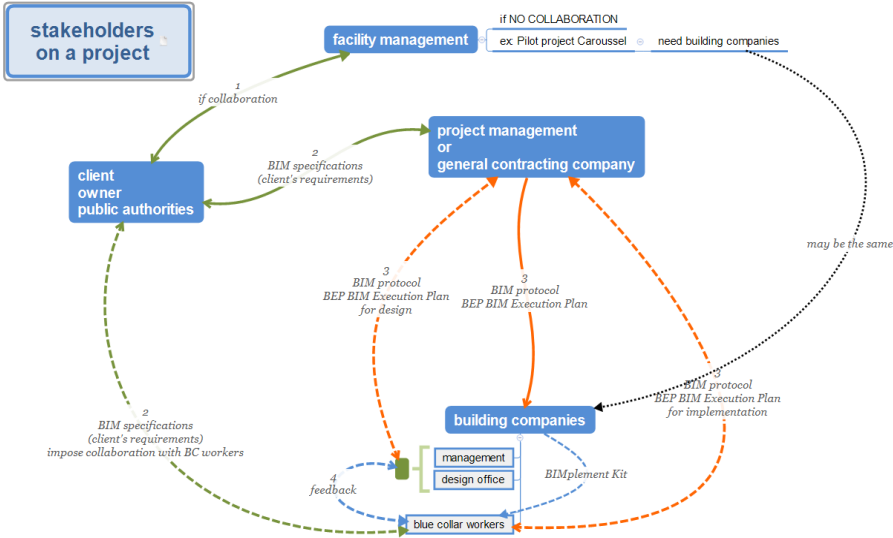
Figure 7. Identification of the stakeholders involved in the project and relationships between them

This valuable information has been the starting point to develop personalized educational content for each pilot. Each country made optimal use of existing training infrastructure and contents or has even developed new tools adapted to its regional context. For example, many of the French pilots have used the "Praxibat" portable containers that already existed in which the airtightness of different products and solutions have been truly experienced on-site by blue-collar workers. In Spain, on the other hand, an application that already existed called "Catalogue of construction elements" has been improved and in its new version the library of elements and products it contains can be downloaded in iFC so that they can be imported from any BIM modeling program.

Figure 8. The "Praxibat" mobile centre in France

Figure 9. Screenshot of the Spanish application "Catalogue of construction elements"

2.4 Exploitation and replication phase

An exploitation strategy has been developed for further exploitation and replication of the project to increase the number of skilled building professionals and craftsmen across the building value chain. This exploitation plan facilitates:

- the upscaling of the methodology to other /new topics
- sustaining the used content within existing tools
- upscaling the action to other countries by a free and open methodology, implementation services and a shared open development platform.

3 RESULTS

The main achievements and results obtained from the BIMplement project are listed below:

- Qualification framework improved with BIM materialized in a guide or manual that will have a version as a computer tool. This guide will contain instructions on how to apply the methodology and qualifications framework in other countries and for other requirements beyond ventilation and air tightness.
- Skills and professions matrix: mapping of the additional skills and competencies necessary to optimize ventilation and air tightness of the EECN, linked to the professional profiles involved in all phases of the project.
- Inventory of tools, didactic contents and learning methods usable in BIMplement.
- Document or guide for trainers or professionals in charge of transmitting the knowledge and added value of the BIMplement methodology. This document includes the aforementioned contents: qualification framework, matrix and inventory of contents and learning methods.
- Validation in 50 experimental projects in 5 European countries: France, Lithuania, Poland, the Netherlands and Spain.
- Around 1200 trained professionals distinguishing between 1000 operators and 200 medical technicians.

4 CONCLUSIONS

Nearly Zero Energy Building (nZEB) construction and renovation need an enhanced systematic approach for the **quality control** of the entire process. This is the first prerequisite to reduce the gap between designed (predicted) and actual performances of buildings, both in terms of energy efficiency and in indoor environmental quality. The most important part of this enhanced quality control approach is a **fully qualified and equipped workforce**, capable to implement, execute and perform all the

necessary labor actions with a full understanding of the responsibility of their own profession and actions, as well as the relation with the other involved professions and actions within the value chain. BIMplement project offers **a methodology to create and standardize the needed qualifications and a range of learning tools** to unlock and implement these qualifications. To be future-ready subject specific qualifications are enriched with the skills and competences needed when performing the job in a nZEB project that is using BIM. By using a standardised methodology **the created qualifications are transparent and comparable between EU member states**, thus facilitating and providing EU mobility.
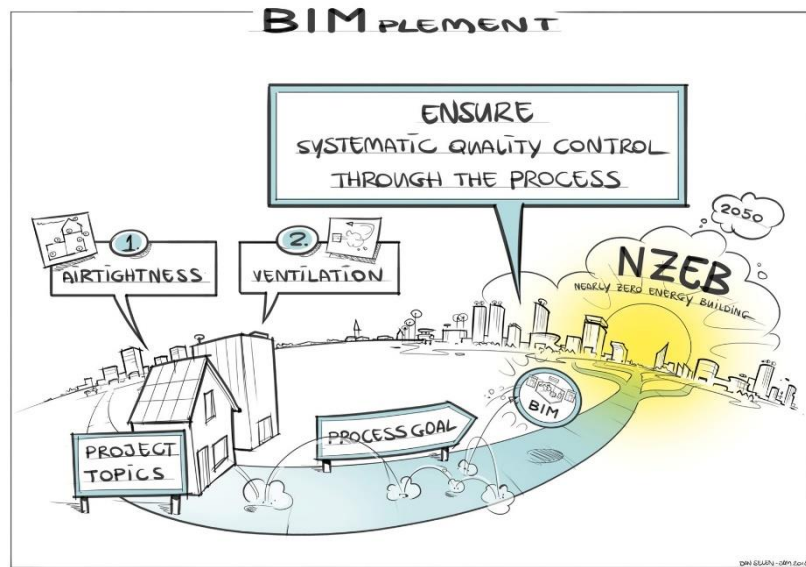

Figure 10. BIMplement project: Enhanced quality control for nZEBs

ACKNOWLEDGEMENTS

REFERENCES

[1]   European Comission, 2019, Supporting digitalisation of the construction sector and SMEs.

[2]   European Comission, 2017, Good practice in energy efficiency: For a sustainable, safer and more competitive Europe, Directorate-General for energy, Brussels.

[3]   de Wilde, P., 2014, The gap between predicted and measured energy performance of buildings: a framework of investigation, Automation in Construction Volume 41, pages 40-49.

[4]   World Economic Forum, 2017, Shaping the Future of Construction: inspiring innovators redefine the industry.

[5]   Navarro, M., 2018, Build Up portal: Benefits of BIM and its level of adoption in European countries, EASME.

[6]   Tisov, A. et. al, 2018, volume 55, pág. 7-10, Rehva Journal: introduction to the H2020 BIMplement project.

European Comission, Construction skills: Equipping building professionals with new skills to achieve European energy targets