2019-09-26

Improving the Sustainability of the Built Environment by Training its Workforce in More Efficient and Greener Ways of Designing and Constructing Through the Horizon2020 BIMcert Project

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Recommended Citation

McAuley, B. et al. (2019). Improving the sustainability of the built Environment by Training its Workforce in More Efficient and Greener Ways of Designing and Constructing Through the Horizon2020 Energy BIMcert Project. *Proceedings of the CitA BIM Gathering*, Galway 26th September, pp 63-70. doi:10.21427/391f-zx44

Improving the Sustainability of the Built Environment by Training its Workforce in More Efficient and Greener Ways of Designing and Constructing Through the Horizon2020 BIMcert Project

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Abstract−The construction industry consumes up to 50% of mineral resources excavated from nature, generates about 33% of CO^2 present in the atmosphere and is responsible for 40% of total global energy through both construction and operation of buildings. The realisation that current pervasive construction practices now face globalization, sustainability, and environmental concerns, as well as ever-changing legislation requirements and new skills needed for the information age has resulted in technologies such as Building Information Modelling (BIM) becoming a key enabler in navigating these barriers. To assist in overcoming these barriers, a number of funding initiatives have been put in place through Horizon 2020 with a focus on BIM, due to it having the potential to rapidly produce energy outputs that enable design teams to analyse and compare the most cost-effective, energy-efficient options. One of these initiatives, the BIMcert project, aims to educate all areas of the supply chain in the use of BIM, to achieve better energy efficiency during the design, construction and ongoing maintenance of an asset. The goal is to develop more efficient and relevant training programme materials that integrate concepts of sustainability and renewables with practical application and integration with technology. The first stage of this project involved a

detailed and exhaustive process that was used to establish the proposed curriculum, methodologies, concepts, and pilot training material. This paper will explore stage 2 of the BIMcert Project were a series of workshops across the consortium's jurisdictions were used for the rigorous evaluation of pilot training material. The paper will also discuss how the developed training material has assisted in improving the sustainability of the built environment by training its workforce in more efficient and greener ways of designing and constructing through the use of BIM processes.

Keywords− Building Information Modelling, Sustainability, Education, Horizon 2020

I INTRODUCTION

The construction sector is now responsible for one-third of global carbon emissions, one-third of global resource consumption, 40% of the world's energy consumption, 40% of global waste generated and 25% of the world's total water consumption [1]. Increasing energy efficiency and reducing energy consumption are some of the leading research objectives in the Architecture, Engineering and Construction (AEC) industry and have been backed by international strategies, such as the 2020 Climate & Energy Package, which aims for a 20% increase in energy efficiency and a 20% reduction in CO2 emissions, based on a 1990 report [2]. Reaching these figures are made more difficult as a result of clients, consultants, and contractors not willing to change their attitudes and culture by exploring new territories and adopting new ideas and practices [3]. This is made more difficult as the relationships required for the delivery of the constructed product among main contractors and subcontractors are often weak and difficult to manage [4]. The construction supply chain has a reputation for low-trust and adversarial trading relations between supply chain stakeholders [1]. This leads to typical examples of on-site problems such as a lack of information sharing, poor communication between project actors, as well as project members not always sharing the same understanding of the construction project process [5]. If energy targets are to be met then key supply chain stakeholders, namely, the developers, architects, consultants, contractors, and suppliers must harmonize their conflicting interests and coherently implement green practices with each other [1].

In recent years, to try to harmonise the construction sector and offer more rewarding methods of doing business, Building Information Modelling (BIM) has become prevalent. BIM is a collaborative process in which all parties involved in a project use three-dimensional design applications. BIM is now seen as the centrepiece of the industry's digital transformation [6]. Furthermore, BIM can be used to model buildings and sequentially perform multiple analysis, enabling energy performance predictions that can be applied to compare design alternatives, allowing for an improved final decision [2]. BIM-based energy modelling provides several benefits including more accurate and complete energy performance analysis in early design stages, improved lifecycle cost analysis, and more opportunities for monitoring actual building performance during the operation phase [7]. With a rapidly changing climate and global energy crises, the ability to use BIM tools to obtain architectural designs that offer environmental effectiveness has become a leading issue in the contemporary architectural and construction industries [8].

However, if BIM for energy analysis is to be adopted within a project, the developer / client is vital for creating green supply chains, as their green building requirements will play a pivotal role in the green behaviour of other downstream supply chain stakeholders [1]. Energy problems tend to happen in the local construction sector mainly because of inefficient use of energy and lack of skills among construction industry participants [3]. The World Economic Report states that a lack of employees with sufficient BIM skills within the industry is delaying BIM adoption. This is leaving organisations with three options for increasing their BIM talent pool: hiring new talent with the required skills; upskilling the existing workforce; and simplifying BIM technology and processes to reduce required skills. The report stresses that education must be reformed to provide prospective employees with necessary BIM skills, as well as the interdisciplinary skills needed for BIM collaboration [6]. To assist in overcoming these barriers, the Horizon 2020 BIMcert project will educate all areas of the supply chain in the use of BIM, to achieve better energy efficiency during the design, construction and ongoing maintenance of an asset [9].

II BIMCERT BACKGROUND

Horizon 2020 is the biggest EU research and innovation programme ever with nearly €80 billion of funding available over seven years (2014 to 2020). An initial funding call, as part of this programme, was made available with a focus on supporting innovation through research by way of demonstration of more energy-efficient technologies and solutions. The BIMcert consortium, consisting of industry and academia who are experts in providing BIM solutions, skills and training for the construction industry, backed up by a Technical Advisory Board consisting of stakeholders and external experts,

responded to the call. The consortium put forward a proposal to enable the development of a method, materials and micro accreditation for upskilling across the construction supply chain to allow BIM techniques and technologies to be utilised to address energy efficiency requirements.

BIMcert's goal is to develop more efficient and relevant training programme materials that integrate concepts of sustainability and renewables with practical application and integration with technology, as based on real-life industry needs and limitations. The BIMcert consortium consisting of members from Northern Ireland (Belfast Metropolitan College and Construction Industry Training Board (CITB)), Republic of Ireland (Technological University (TU) Dublin and Future Analytics Consulting), Portugal (CERIS/Instituto Superior Técnico), Macedonia (Institute for Research in Environment, Civil Engineering and Energy (IECE)), and Croatia (Energy Institute Hrvoje Pozar (EIHP)) established five core objectives consisting of:

1. To **improve the sustainability** of the built environment by training its workforce in more efficient and greener ways of designing and constructing through the use of BIM processes, better materials, products, and energy sources.
2. To engage with the **entire construction sector supply chain** via BIM to develop more extensive European links and to encourage a system of peer support across states of varying maturity concerning the delivery of more energy efficient new and renovated buildings.
3. To encourage **greater workforce mobility**, continuous upskilling, and better employability for all levels of an employee in the construction sector.
4. To **create clear pathways of development for individuals and SMEs to upskill** from any starting point of knowledge to any required level of the individual or collaborative expertise in support of sustainable energy efficient construction.
5. To **develop a pan-European framework** for recognition and accreditation of BIMcert's micro accredited learning modules that will combine to build towards fully standardised skills recognition linking within existing national and European initiatives and frameworks of accredited courses and awards.

The consortium established a series of work packages which are to be conducted in five stages:

- **STAGE 1** – **State of the Art:** an open approach to gather state of the art information through direct engagement with project stakeholders across Europe to ensure that the skills gaps identified by SMEs about the implementation of BIM technologies and methods in support of improved energy efficiency in the construction sector are correct.
- **STAGE 2** - **Development:** development of the BIMcert platform, which will provide information about the project, share BIMcert outputs, and support stakeholders' communication and collaboration.
- **STAGE 3** - **Testing:** the rigorous evaluation of the curriculum, the learning materials, and the proposed platform.
- **STAGE 4** - **Accreditation:** accreditation of the proposed BIMCert training units and courses.
- **STAGE 5** - **Exploitation and Dissemination:** the exploitation and dissemination of the project through a broad-ranging outreach campaign.

The work stages run in parallel and are all critical to each other's success. The paper by McAuley et al. (2019) focused on stage 1 which will be briefly discussed in the next section to provide context to the reader on how the pilot materials were created [9]. This paper will focus on stage 3 with stage 2, 4, and 5 outside of scope, however, references will be made to them throughout.

a) Stage 1 Results

The first stage of this project involved a detailed and exhaustive process comprising of a pan-European wide survey to ascertain the current level of BIM maturity, knowledge, and understanding within built environment practitioners and academia. The results from the survey were cross-referenced with five workshops that were held within the project stakeholders' jurisdictions. The results highlighted that all respondents recognised that BIM training is required at all levels within their organisations with a necessity to raise awareness of BIM as a sophisticated sustainable, supportive software, not only for modelling and visualisation tools but furthermore by developing training modules to facilitate the trend. The results from the survey and workshops were used to establish the basis of what training courses should be designed that best-matched industry needs.

A state-of-the-art literature review of the current global status of BIM with regards to education and what pedagogical methodologies are being applied to deliver these courses was performed in parallel. The survey and workshop findings were aligned with the results from the state-of-the-art literature review where it was found that the most suitable pedagogical approach would involve a scaffolded learning environment guided by a series of instructor-led live lectures. This could be complemented through problem-based learning, design for disassembly, and guided self-learning, which would create an active learning environment. Different teaching approaches comprised of narrative videos and live lectures with a focus on the student engaged in self-guided learning through problem-based learning before they advance.

The initial findings for the suggested training courses and methodologies were tested through a series of

reality check workshops. The outcomes from the reality check workshops resulted in the establishment of the final training descriptors, including learning outcomes, suggested syllabi, methodologies and delivery details.

The consortium members decided that the best way forward was to break the development of the curriculum into three strides. Figure 1 identifies the units and courses that best reflect the needs of the industry from the consultation process. The learner initially accesses the BIMcert portal and will be presented with one of two options. If the learner selects Option A, then they must take the BIM Ready training unit plus online assessment. If the learner has prior knowledge of BIM they can choose Option B which will enable them to take the online assessment without enrolling in the training unit. Successful completion of the assessment in either case grants access to Stride 2. This entry unit is critical to ensuring that all learners have a basic understanding of BIM before they select their next unit within Stride 2. The BIM Ready unit is also vital here as it will serve as a diagnostic tool to assist the leaner in the selection of the next unit.

It was agreed to break Stride 2 into three separate sections. Within Stride 2A, the learner can select many standalone units that will introduce them to BIM principles, digital skills, and modelling techniques. The following training units have been developed, as part of Stride 2A in response to the survey and workshops findings.

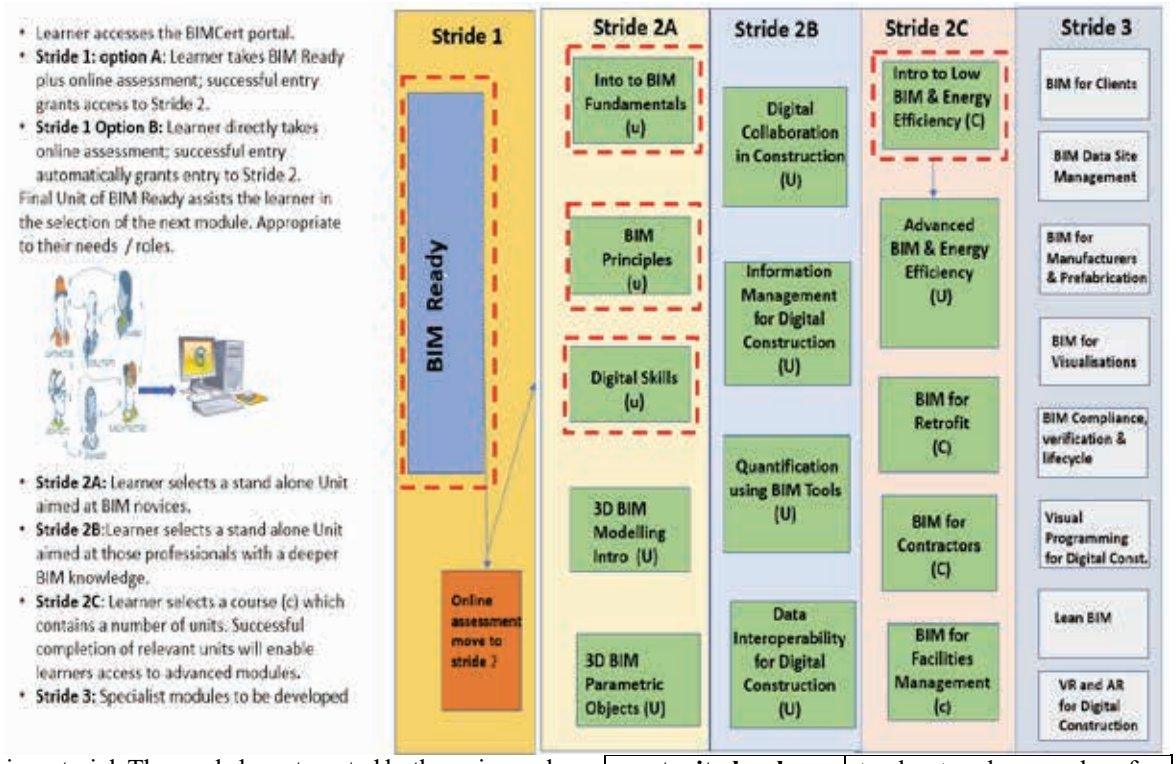
- **Introduction to BIM Fundamentals:** This training unit will enable the learner to develop a fundamental understanding of the information communication technology (ICT) skills required for working within digital construction.
- **Introduction to BIM Principles:** This training unit will allow the learner to develop a fundamental understanding of BIM and associated workflows.
- **Digital Skills:** This training unit will enable the learner to develop a fundamental understanding of the use of digital skills for construction sites.
- **3D BIM Modelling**: This training unit will allow the learner to develop the fundamental skills for three dimensional (3D) BIM using industry standard software for their particular profession.
- **3D BIM (Parametric) Objects:** This training unit will enable the learner to develop the fundamental skills to create BIM objects using industry standard software.

Stride 2B represents units aimed at those more experienced BIM users who wish to advance their knowledge in BIM, e.g., interoperability, collaboration processes, etc. While learning outcomes are developed for these training units, it is not the intention of the BIMcert consortium to develop them any further during this iteration of the Horizon 2020 project. Stride 2C offers learners the choice of one or more courses, which consists of a series of units. Each unit within a course represents a specific learning outcome (LO). This LO / unit will be offered as an individual micro size training option, to ensure that the BIMcert can attract learners who require specific areas of knowledge but do not have the time to complete a standard unit (Stride 2A and 2B) consisting of a series of LOs. After completion of all units associated with the course, the learner will receive a higher award. The learner can take advanced units once they finish the relevant Stride 2C course units, i.e., Advanced BIM & Energy Efficiency. As with Stride 2B, it is not the intention of the consortium to develop all of the courses in this stride. Stride 3 represents a more discipline-focused stride that represents current specialisations of BIM usage, tools, and concepts. The range of units can be expanded or adjusted in the next stage of the BIMcert project in response to market needs.

III METHODOLOGY

A total of five trial workshops were held across the partner jurisdictions. The workshops were hosted both within the partner city bases and online. A variety of material from a selection of LOs from the BIM Ready (Stride 1), BIM Fundamentals (Stride 2A), BIM Principles (Stride 2A), Digital Skills (Stride 2A), and Introduction to Low Energy Building Construction Course (Stride 2C) was developed for testing. The BIMcert consortium selected these particular learning units because these have the potential to impact significant numbers of construction site workers across Europe rapidly.
Figure 1 BIMcert Learning Pathways

In addition, the material could be delivered through instructor-led live lectures which would enable the opportunity for the lecturer/trainer to engage with the class. It was also the intention to develop material that could be used for guided self learning, to gain an insight into how potential users would interact with



this material. The workshops targeted both novice and groups of people *au fait* with BIM from designers and architects to contractors and engineers, as well as policy makers and professional associations (chambers) of engineers and industry. The overarching purpose of the workshops was to establish if the pilot material was adequate to meet the needs of the industry.

IV DEVELOPMENT

A total of 132 physical and 8 online attendees across the five cities participated in the testing of the pilot material. The following section will provide a review of the developed pilot material, workshop structure, and results.

a) Pilot Material

As discussed previously, it was agreed as part of Stage 1 that a selection of material was to be developed from the chosen training units. As each training unit had a series of LOs, it was deliberated amongst the consortium which ones would create the most significant impact during the trials. Table 1-5 details the LOs selected for further development.

LO	Description
An introductory self-study tool covering subjects such as: what is BIM, BIM process, BIM maturity levels, BIM terms, benefits & barriers, etc.	A free self-study and knowledge diagnosis tool to introduce you to BIM and/or provide assessment and recognition of prior knowledge, while getting on track to be ready for BIMcert upskilling and using BIM within your professional role.

Table 1 BIM Ready (Developed by Belfast Metropolitan)

LO	Description
Define what BIM is and explain key terminology	Instructor-led live lecture presentation at all workshops. Presentation material to explain the basic principles of BIM and summarise the common terminology associated with BIM.
List the benefits & value of a BIM workflow	Instructor-led live lecture presentation at all workshops. Presentation material to summarise and list the overall benefits of BIM, particularly concerning specific roles in the construction industry and energy management.

Table 2: BIM Fundamentals training materials (Developed by Belfast Metropolitan)

LO	Description
Explain the context and essentials of BIM.	Instructor led live lecture presentation at all workshops. Presentation material to explain key terms and definitions within BIM, summarise BIM maturity levels, explain the impact of BIM maturity Level 2 requirements for project delivery.

Illustrate the benefits of BIM to the construction sector.	Instructor led live lecture presentation at all workshops. Presentation material to articulate the benefits of BIM to the construction sector.

Table 3: BIM Principles training materials (Developed by TU Dublin)

LO	Description
Describe the use of digital skills and devices in construction.	Online guided self-learning training materials demonstrating how to analyse the use of digital skills and devices in construction.
Define how to use digital skills and devices to access digital information.	Online guided self-learning training materials demonstrating how to access BIM models and information.

Table 4: Digital Skills Training materials (Developed by TU Dublin)

LO	Description
Outline the key principles of system thinking.	Instructor led live lecture presentation at all workshops. Presentation material to demonstrate the key principles of system thinking.
Illustrate how BIM can be utilised in low energy building construction.	Live demonstration of software and plug-in(s) to show energy assessment/simulation to address how BIM tools can reduce energy loss

Table 5: Intro to Low Energy Building Construction Training materials (Developed by the Institute for Research in Environment, Civil Engineering and Energy)

It was agreed to host the pilot material on the BIMcert webpage (https://energyBIMcert.eu) where attendees were expected to complete an evaluation form to provide feedback on the training material. The final established material is to be hosted on the BIMcert Platform to be developed by IST of the Universidade de Lisboa for the final stage of trials in October.

b) Workshop Structure

The workshops took place from January to April 2019 within the five key stakeholder jurisdictions and were led by FAC. They were conducted in English with translation support from consortium partners IST (Lisbon), IECE (Skopje) and EIHP (Zagreb) where needed. The agenda for the workshop covered the following in all five test sites:

- Demonstrate a sample of the training materials.
- Simulate a live version of how to access materials online.
- Simulate BIMcert live webinars, including a live session with a tutor.
- Facilitate Q&A sessions with demonstrators.

All participants had access to sample materials before during and after the trial, to enable them to experiment, use and most importantly give their feedback to facilitate improvement. Each of the workshops broadly followed the following agenda:

1. The workshop was opened by FAC who provided instructions on how to access the materials, as well as discussing the curriculum development and learning pathways.

2. As the BIM Fundamentals and BIM Principles were covering topics that were of similar context Belfast Metropolitan and TU Dublin worked in unison to ensure presentations and materials did not duplicate each other. The BIM Fundemetals LOs delivered by Belfast Metropolitan consisted of two separate presentations which focused on;
   1) define the context and essentials of BIM and explain key terminology; and
   2) list the benefits and value of a BIM workflow.

   The software Kahoot (https://kahoot.it/) was used at the end of this presentation to enable an online interactive assessment component to the workshops and thereby integrating gamification aspect to the trialling process.

3. The BIM Principles LOs delivered by TU Dublin consisted of two separate presentations which focused on;
   1) explaining the impact of BIM matury Level 2 requirements for project delivery; and
   2) illustrating the benefits of BIM to the construction sector.

   TU Dublin also created self-guided learning material for the Digital Skills LOs for;
   1) demonstrate ICT file management; and
   2) demonstrate the use of digital design review tools to access and evaluate a BIM model.

4. The Introduction to Low Energy Building Construction LOs delivered by IECE consisted of a presentation which focused on outlining the key principles of system thinking. The second LO was delivered through a pre-recorded instructional video to illustrate how BIM can be utilised in low energy building construction.

5. Belfast Metropolitan demonstrated the introductory self-study BIM Ready.

6. The remaining time was left open for discussion and feedback from the audience.

Evaluation questionnaires were used to gather feedback from end-users about their experiences, as well as documented feedback from the audience at the end of the workshop. FAC and CITB were responsible for collating this data, and this section of the paper draws from the findings of their report.

While the delivered material was in general well received, some specific comments were recorded from each workshop. The key findings from the Macedonia workshop indicated that there should be a correlation with relevant national standards for construction and energy efficiency, that could be a basis for the adoption of BIM. The training materials that were presented were found appropriate and understandable. However, it was suggested to split them into smaller learning units. Some of the attendees recommended enriching the learning content with more information on BIM in energy efficiency by presenting on a prototype case study. In Croatia, the attendees requested more information on real case studies, BIM objects, libraries, and for a focus on how to extract data from BIM models with more interaction between the lecturers. In Ireland, where BIM is at a more advanced maturity, key comments included the need for more practical application within the materials. Other suggestions were to reduce the learning scope/content to make it more attractive to blue collar workers/skilled trades people. In Portugal, there was a request for material that focused on ISO 19650, case studies and in general more information on certification pathways, as well as the use of interactive tools such as Kahoot or other interactive mediums via the BIMcert Platform. Finally, the UK workshop found that the material should be more practical in terms of how exactly BIM will improve the workflow, reduce text on slides, and explore how BIMcert can be used for Continuous Professional Development (CPD) points.

In summary, the results from the workshop found that awareness has raised since the last round of workshops conducted in stage 1, which was partially due to BIMcert but reported skill level remains comparably static. Contractors still reported being reluctant. The attendees requested better use of case studies to be included in models and tools to exemplify real-life applications of BIM. Stage 1 results found that there was a reluctance to engage with IT as a medium for learning which emerged again at this testing stage. However, the demonstrations of how this IT works and will be integrated into the curriculum has allayed some fears. It was found that the BIM supply chain is still congested, which is a significant factor in preventing uptake and upskilling. Overall, BIMcert is seen as a positive and viable enabler/facilitator of BIM upskilling if mapped to certification and standards clearly.

d) Parallel Work packages

While the workshops were being hosted, there was a series of other work packages working in parallel. This included the IST and iNESC-ID Lisboa, who are responsible for the final BIMcert platform. The platform is being designed in tandem with the material to ensure that users can access the training units and have clarity on their learning pathways. The platform will operationalise gamification theory and application to ensure that users have an interactive and unique BIM training experience. EIHP were also promoting the workshop through social media, as well as using a number of dissemination channels to boost the project's profile and communicate its capability continuously. FAC and TU Dublin worked with EIHP and the full consortium to produce a project video, which can be accessed here:

https://youtu.be/gs6lqXZiaH4

A work package has also been dedicated to seeking accreditation for training units before the final set of trials in October. Accreditation work was ongoing during the workshops, spearheaded by Belfast Metropolitan with input from all project partners. IECE were also establishing metrics to demonstrate how the project could validate its training targets. These parallel work packages are outside the scope of this paper but will be explored in future reports, conference and journal papers released by the consortium.

V CONCLUSIONS

BIMcert demonstrates a focused response to assist in upskilling the supply chain by offering just in time training that has been adapted into micro size training units. This will ensure that users have a wide selection of training options that will be accredited before the final release on the BIMcert platform. By building on these training units, it will offer supply chain members the opportunity to demonstrate to potential employers that they have fundamental capabilities to work within a digitally focused environment. Further to this, they will also be educated within sustainability and energy focused construction, as all the proposed training units will have LOs within them to demonstrate/explain how BIM can be used in this context. It is predicted that the BIMcert consortium will upskill 1,000 people by the end of the project (January 2020). This significant training key performance indicator demonstrates the confidence and expected impact the project intends to make in its first cycle.

VI NEXT STEP

The next set of trials will begin in October and will test both the refined material and BIMcert Platform. The project is to be completed by January 2020 and will be celebrated with a conference to be held in Belfast. Our ambition is to catalyse a shift to a more

energy-efficient construction sector, reduce the effects of the sector on climate change and provide upskilling pathways to workers that have previously not had access to digital training platforms.

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