A Virtual Collaborative Platform to Support Building Information Modeling Implementation for Energy Efficiency

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Ioan Petri[1], Ali Alhamami[1], Yacine Rezgui[1], Sylvain Kubicki[2]

[1] School of Engineering, Cardiff University
Cardiff, Wales, UK
{petrii, alhamamia, rezguiy}@cardiff.ac.uk

[2] Luxembourg Institute of Science and Technology (LIST). Luxembourg
{sylvain.kubicki}@list.lu

Abstract. There is increased interest in complying with the new regulations and policies associated with the climate change. In particular industries such as the AEC (Architecture, Engineering and Construction) industry seek to find new strategies and practices for facilitating sustainability but also new regulations to improve efficiency at the building level. Institutions and industrial bodies are now in the process of alignment with new legislative stipulations regarding carbon emissions with wider reflection into environment, social and economic models. At building level such strategies refer to decarbonisation and energy efficiency supported with data driven techniques enriched with virtual collaboration and optimization methods.

The increased interest of the research community in Building Information Modeling (BIM) has facilitated numerous solutions ranging from digital products, information retrieval, and optimization techniques all aiming at addressing energy optimization and performance gap reduction.

In this paper we present how a virtual collaborative system can be efficiently used for implementing BIM based energy optimization for controlling, monitoring buildings and running energy optimization, greatly contributing to creating a BIM construction community with energy practices. The solution described, known as energy-bim.com platform, disseminates energy efficient practices and community engagement and provides support for building managers in implementing energy efficient optimization plans.

Keywords: Virtual collaboration, Construction Community, Building Information Modeling, Energy Efficiency, Training.

1 Introduction

Research studies have reported that global warming has a significant impact of the building sector and lead to the appearance of several stringent regulations and implementation rules imposed by European and National bodies in the field of energy and construction [1].

Recent researching attempts aim at providing a fundamental step change in facilitating efficiency at the building level through BIM training with a view to effectively address European energy and carbon reduction targets. There is an increased interest in promoting a well-trained world leading generation of decision makers, practitioners, and blue collars in BIM for energy efficiency and establishing a world-leading platform for BIM for energy efficiency training nurtured by an established community of interest [2]. Benchmarks exist at Europe-wide BIM trainings across the building value chain (including lifecycle and supply chain), highlighting energy efficiency linkages, as well as qualification targets, delivery channels, skills, accreditation mechanisms, while highlighting training gaps and enhancement potential.

With such a complex reality in the construction, Building Information Modelling (BIM) is paving the way to more effective collaboration process between actors involved in building lifecycle [3]. BIM facilitates a more data driven modeling and analysis of the built environment during its entire life cycle from concept design to decommissioning (Figure 1). BIM brought the most transformative power into AEC/FM domain (Architecture, Engineering and Construction/Facility Management) during the last decade in terms of its fundamental life cycle and supply chain integration and digital collaboration [4]. BIM holds the critical key to revolutionize the construction industry, which is forecasted to reach over $11 trillion global yearly spending by 2020 [5]. Researching attempts aim to harmonize energy related BIM qualification and skills frameworks available across Europe with a view of reaching a global consensus through a BIM for energy efficiency External Expert Advisory Board (EEAB)[6].

This paper focuses specifically on using virtual collaboration to create a BIM community of professionals to enhance skills and enable BIM training and to enable in-depth analysis and gaps identification of skills and competencies involved in BIM training for energy efficiency. We have combined a number of different technologies such as semantic web, social networks, mobile applications towards a knowledge representation in order to address BIM for energy training and education.

Consultations and interviews have been used as a method to collect requirements and a portfolio of use-cases has been created to understand existing BIM practices and determine existing limitations and gaps in BIM training.

In Section 2, we will present background on collaboration and BIM training. Section 3 describes the proposed methodology and identified requirements. Section 4 presents the evaluation process and we conclude in Section 5.

2 Related Work

The building domain is extremely dynamic with knowledge and technical solutions evolving continuously, all related to a general objective of reducing energy in the building environment. Such performance management objectives have been also stipulated into the European Union regulation with particular emphasis on energy reduction, cost effective solutions and climate change strategies [6]. The dynamics of the construction market has been statically forecasted to grow in the next decade [7]. Countries such as UK have developed strategies to address these objectives: (a) 33%

reduction in both the initial cost of construction and the whole life cost of assets; (b) 50% reduction in the overall time from inception to completion for new build and refurbished assets; (c) 50% reduction in greenhouse gas emissions in the built environment; (d) 50% reduction in the trade gap between total exports and total imports for construction products and materials [8], [9].

With the new technological developments it has become possible to address the energy demand, maximize the efficiency with optimization methods in building lifecycle and remove carbon footprint. This requires collaboration between various factors and actors involved in the process of construction and analysis of each building construction stage with identification of associated requirements and optimization objectives [10], [11].

To facilitate the development of performance management strategies for the built environment, companies and industrial organizations need to adhere to the digitalization process and to find new collaboration mechanisms involving virtual reality, community involvement and training strategies for roles and skills required for the construction process. BIM for energy represents a strategic field of research that industry seeks in adopting mainly focusing on the definition of levels for competencies and skills that are required within organizations.

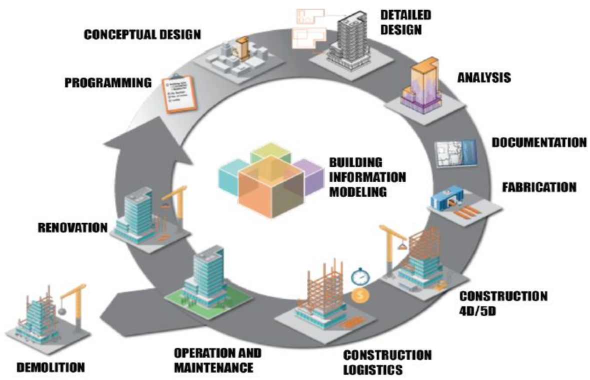


Fig. 1. BIM uses across building lifecycle: it presents the entire life cycle of projects from concept design to decommissioning.

Engagement with BIM practices has an implication on the organisation level but also represents a concept that actors involved in the construction industry need to understand. BIM represents a technology but is also referring to behaviours, culture, and set of values and experiences that can be identified in an institution in order to promote reliable construction and address sustainability.

3 Methodology

The research methodology proposed in this paper utilizes a methodology that is organized in two parts: (a) qualitative data analysis and (b) quantitative data analysis to elicit BIM training requirements for energy efficiency in the construction sector.

3.1 General Methodology

The requirements gathering studies employed extensive consultations including: (1) a user engagement instrument in the form of an online virtual collaborative platform to support with the requirement capture activity of the project while maximizing users' engagement by the creation of a community of practice around the theme of BIM for energy efficiency, (2) an online Europe-wide BIM use-case collection template and questionnaire (November 2017– February 2018) from which 38 best practice use-cases have been collected,(3) experts panel consultations in Europe comprising 1 workshop (c.**40** participants in total),(4) a series of 15 semi-structured interviews with key industry representatives (December 2017– February 2018) ,and (5)other focus meetings with project partners.

These consultation studies have been facilitated by an open community of users that share resources and experiences related to BIM energy training supported by **energy-bim.com.** The objectives of the consultations were to determine best practices, regulation awareness and gaps in BIM for energy efficiency domain and to determine a set of training requirements. The subsequent combined consultations explored stakeholders' knowledge, understanding, and behaviors, and helped identify key barriers to BIM applicability for energy efficiency. A number of **40** experts took part in the consultations (workshop), including: construction companies and practitioners, advisory groups, professional organizations, consultants, policy makers and education and training bodies.

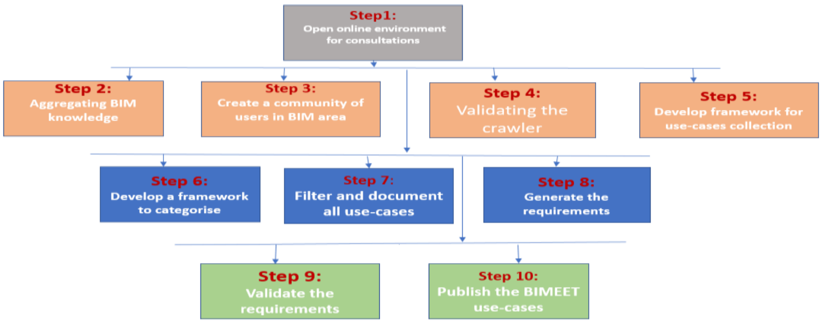


Fig. 2. General requirements methodology

The results of the use-cases and interview analysis are presented in Section 4. The detailed steps adopted in the methodology are as follows (see Figure 2): (i) Adapt an existing web portal to carry out the study consultation while maximizing continuous engagement with our Expert panel and Community of Practice, (ii) Develop a Web Crawler that aggregated BIM related knowledge and stores it adequately to enable searches and authoritative URIs as input, (iii) Invite partners, expert panel members, and community of practice members to register on study portal to provide authoritative sources of information, (iv) Provide an implicit validation of the crawler, (v) Develop a framework to categorise all retained use cases using 2 dimensions, i.e. lifecycle (from Briefing to Recycling) and supply chain (i.e. Architects, Structural engineers, to blue collars), (vi) Develop a template to report selected use cases, implemented directly on the study portal. The template involves a field to categorise the use case for further retrieval, (vii) Filter and document all retained use cases on the portal, (viii) Generate the study requirements, (ix) Validate the requirements using our Expert Panel, (x) Community exposure by publishing the study use cases widely inviting people to register if they want to access study materials.

3.2 Supportive Virtual Community Platform for BIM Requirements Capture

To support with the methodology and create a dynamic community for capturing requirements for BIM training we have adapted and re-developed a web solution that provides integrated access to building information modelling (BIM) resources (Figure 3).

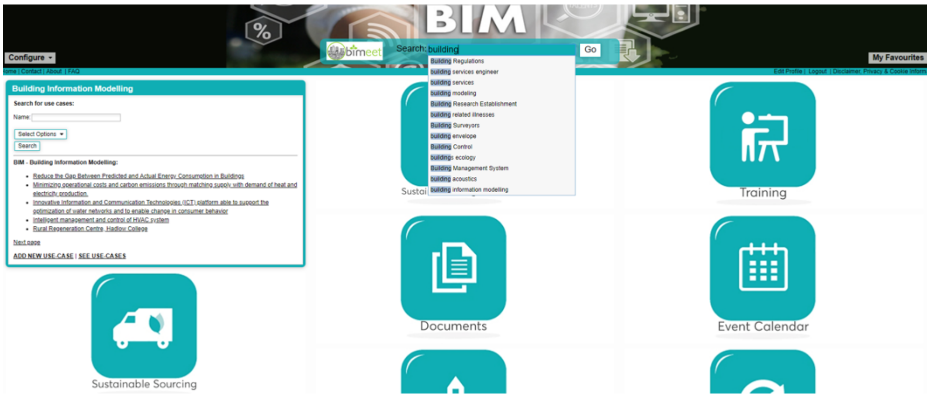


Fig. 3. The virtual collaboration platform interface**:** [www.energy-bim.com]

This platform has a number of underpinning services and an ontology and has helped in the process of BIM training requirements for energy efficiency but also aims at solving the key issue of knowledge dissemination in, and stakeholder collaboration and engagement with, BIM practices and construction. The objective is to identify gaps and requirements as an initial phase but also to support with the project implementation phase in providing construction professionals with the necessary training to offer effective BIM expertise for energy efficient and low carbon solutions, while creating a virtual collaboration framework for BIM industry professionals (see Fig. 4).

Edit Profile | Change Password | Change Search Preferences | Change Display Settings

Add New Site:

http:// [Add Site]

Site Name	Status	Number of Pages
My Sites:		
http://www.adveranda.com	Site not yet indexed ✕	
Core Sites:		
http://www.energysavingtrust.org.uk	Last updated:2012-11-01	3874 pages Reset
http://www.oneplanetproducts.com	Last updated:2012-11-01	171 pages Reset
http://www.ciria.org	Last updated:2012-11-01	1 pages Reset
http://www.ice.org.uk	Last updated:2012-11-01	3650 pages Reset
http://www.greenspec.co.uk	Last updated:2012-11-01	740 pages Reset
http://www.defra.gov.uk	Last updated:2012-11-01	8518 pages Reset
http://www.wrap.org.uk	Last updated:2012-11-01	207 pages Reset
http://www.carbontrust.co.uk	Last updated:2012-11-01	1991 pages Reset
http://www.bre.co.uk	Last updated:2012-11-01	35 pages Reset
http://www.bsria.co.uk	Last updated:2012-11-01	952 pages Reset
http://www.ihs.com	Last updated:2012-11-01	666 pages Reset
http://www.decc.gov.uk	Last updated:2012-11-01	685 pages Reset
http://www.architecture.com	Last updated:2012-11-01	6477 pages Reset
http://www.wholebuild.co.uk	Last updated:2012-11-01	480 pages Reset
http://www.rics.org/uk	Last updated:2012-11-01	348 pages Reset
http://eca.co.uk	Last updated:2012-11-01	44 pages Reset
http://www.cibse.org	Last updated:2012-11-01	1 pages Reset
http://www.buildingsmart.org.uk	Last updated:2012-11-01	16 pages Reset
http://www.labc.uk.com	Last updated:2012-11-01	1 pages Reset
http://www.ccinw.com	Last updated:2012-11-01	81 pages Reset
http://wales.gov.uk	Last updated:2012-11-01	0 pages Reset
Indexes Awaiting Approval:		
http://www.adveranda.com	Approve Index	Delete Index

Fig. 4. Sources Aggregation: The authorative URIs have been provided by BIMEET project partners and validated based on their relevance.

The search service As part of the platform, we have implemented a search service that performs semantic searching on the BIM knowledge base from a set of authoritative URIs. The submitted BIM query has associated ontological artephacts that are then expanding in creating a framework of dependencies and concepts which have been developed based on a crawling process. The sources have been automatically retrieved and validated with support from the consortium of partners (see Figure 4).

For testing and validation of the searching system, we have relied on the group of experts (External Experts Advisory Board) and partners involved in the requirement assessment phase, plus an increasingly expanding constituency as the platform is extended to further users. For collecting best practices use-cases in the field of BIM for energy a template has been designed and implemented and exposed online for users to submit their cases.

The Professional Networking Service: has been created on the hypothesis that social network activity is now increasing in relevance and useful insights can be drawn from analysis of such social network graphs. This service supports collaboration with Twitter and LinkedIn credentials and contributes to the process of knowledge creation for any BIM building project.

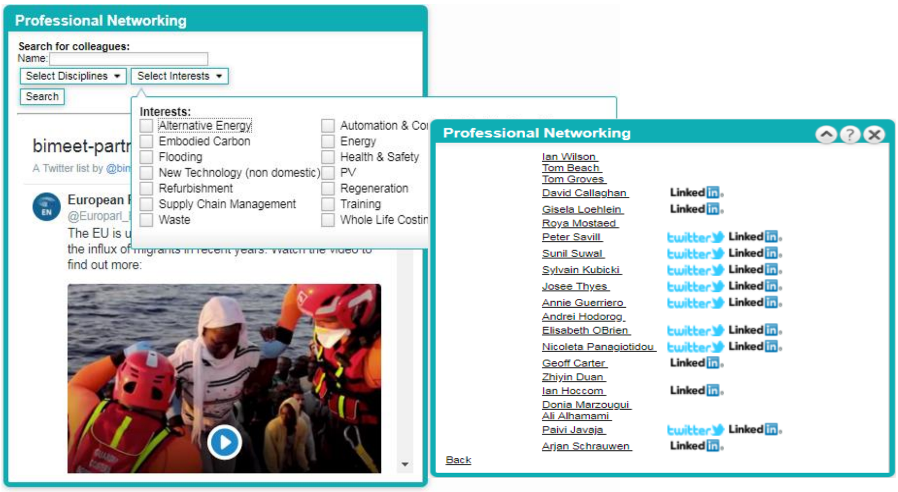


Fig. 5. Professional networking service: Presenting a searching results of individuals and experts in the field of BIM

4 Evaluation

In this section we present the evaluation of our collaboration process undertaken through the virtual platform in transferring knowledge between individuals and also automated gaps and skills identification in the field of BIM for energy. We present results of the requirement capture process, based on 6 months of work on collecting data and sources, as facilitated by the virtual platform and associated community followed by several requirements collected for the training process.

4.1 Use-case Collection

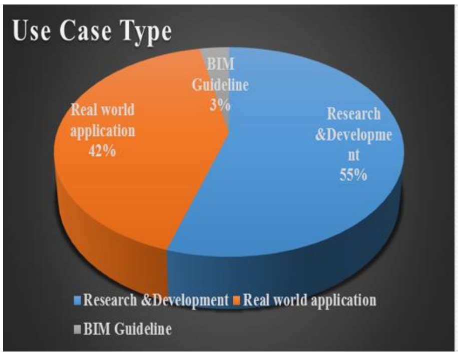
The objective of this study is to demonstrate how virtual collaboration can support BIM based energy-efficient design, construction and building maintenance in many ways. In principal, BIM can boost and ease energy-efficient building on the basis of better data exchange and communication flows, and in practice for example by accelerating energy simulations and searching for beneficial solutions, supporting end users' involvement, requirement setting and commissioning, and by providing an opportunity for systematic maintenance management. Amidst the positive impacts brought about by BIM, AEC/FM industry can leverage BIM for greater energy efficiency in new designs as well as in retrofit and renovation projects. The study demonstrates the strengths of virtual BIM collaboration in energy-efficient building by collecting and providing use cases. Table 1 shows two examples of use-cases where life cycle applicability is aligned with eight work stages of RIBA plan of work 2013.

Table 1: BIM based best practice use-cases

Variables/ Use-Cases	Use Case 1	Use Case 2
Title	Reduce the Gap between Predicted and Actual Energy Consumption in Buildings: KnoholEM project	BIM-based Parametric Building Energy Performance Multi- Objective Optimization
Use Case Type	Research & Development	Research & Development
Target Discipline	Facility Management	Architectural Design
Target Building Type	Public	Domestic
Lifecycle Applicability	In Use	Concept Design, Developed Design
Brief Description	This study presents a novel BIM-based approach with the objective to reduce the gap between predicted and actual energy consumption in buildings during their operation stage[12].	An integrated system is developed for enabling designers to optimize multiple objectives in the early design process [13]. A prototype of the system is created in an open-source visual programming application - Dynamo, which can interact with a BIM tool (Autodesk Revit®) to extend its parametric capabilities.
Impacts	The use of BIM has helped achieve a reduction of 25% energy compared to baseline figures.	The use of a BIM model to generate a multiplicity of parametric design variations for simulated and procedural analysis is a viable workflow for designers seeking to understand trade-offs between daylighting and energy use.

4.2 Platform Supported Use-case Type Analysis

We have applied our automated analysis utilizing the web-platform on 40 use-cases collected from users in European countries. The results reported in this section present the distribution based on criteria such as: discipline, building type, impact, lifecycle stage.



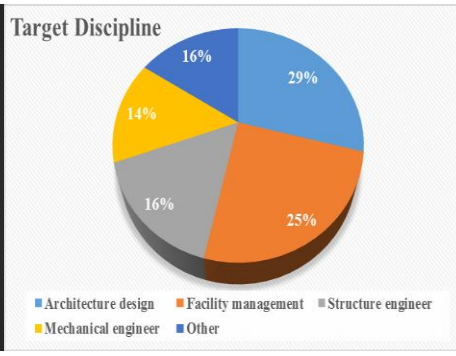
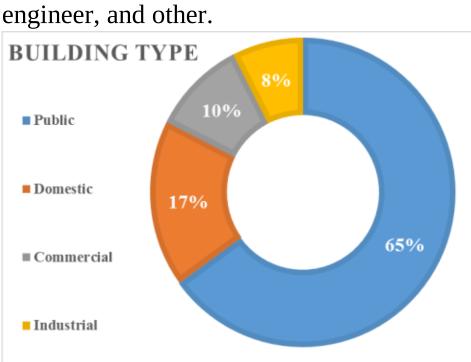


Fig. 6. Use-case type analysis of useBIM for Energy Efficiency

Fig. 7. Target Discipline analysis of use BIM for Energy Efficiency

Use-Cases type analysis: In this part we are interested in identifying what is the overall distribution of use-cases collected in relation to the use-case type. There are three types of use cases in this evaluation which are:1) Research &Development, 2) Real world application and 3) BIM Guideline. As per the analysis, it can be observed that Research &Development covers a number of 17 use cases, and Real-world application has 13 use cases and BIM guideline has only 1 use-case (at the time of writing this paper, additional ones are expected in this category) (see Figure 6).

Target discipline analysis: The portfolio of use-cases is structured based on the target discipline. Figure 7 presents the distribution of use-cases based on the target discipline. Architecture design and Facility management discipline projects use BIM more frequently whereas structure engineer and mechanical engineer projects utilise BIM in a lower percentage. In the analysis we have used different target disciplines such as architecture design, facility management, structure engineer, mechanical engineer, and other.



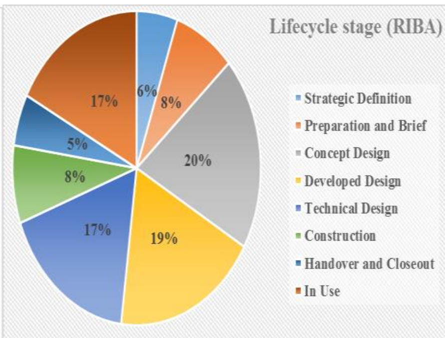


Fig. 8. Building type analysis of use BIM for Energy Efficiency:

Fig. 9. Lifecycle stages analysis of use BIM for Energy Efficiency

Architecture designers are targeted by 29%, facility management by 25% whereas the structure and mechanical engineers are targeted by 16% and 14%, respectively.

Building type analysis: In this part we assess the use-cases based on the type of building project where BIM has been utilized. As reported in Figure 8, the majority of projects are for public buildings whereas domestic, commercial and industrial building seem less popular in adopting BIM. From the set of building types that we have used in our evaluation, the most popular are public buildings whereas domestic building, commercial building, and industrial building have lower percentage. As reported in Figure 10, 65% of these use cases have applied BIM in public building, 17.5% in domestic building, and the rest of them in commercial and industrial buildings.

Lifecycle stage analysis: For the analysis, we have used RIBA stage life-cycles and this part aims at determining associated life-cycle stages of each BIM best practice use-case. Figure 9 shows that, 56% from the recorded projects use BIM for energy efficiency in the design stages in lifecycle of the project, whereas in-use stage identifies 13% in the lifecycle of the projects.

Target discipline and Impacts: The first variable used for the analysis is the target discipline which we compare with the impacts to find the corresponding association between the target discipline and the impacts of use cases. Figure 10 shows that the majority of use cases that implement BIM for energy efficiency are associated with the facility management discipline. However, there are a number of use-cases that implement BIM for energy efficiency methodology for multiple disciplines with great impacts on energy and water savings.

To this day, BIM has been implemented more and with more powerful results for some building types. Especially certain cases of retail and office buildings provide good examples how BIM has supported demanding requirement management, simulations and searching solutions for ambitious energy targets. For instance, availability and use of BIM data aid towards 25% of energy reduction in facility management (use case 1). Likewise, BIM has been effectively used in a Shopping Center (use case 4) using around half the energy of a typical development, results associated with commercial buildings report about 50% energy saving and 50% saving in water consumption.

In other hand, using RIBA Plan of Work for lifecycle applicability we can observe also associations between lifecycles and BIM impact on energy efficiency. It reflects increasing requirements for sustainability and BIM and it allows simple, project-specific plans to be created. The RIBA Plan of Work organizes the design process into different stages including briefing, designing, constructing, maintaining, operating and using building. According to these stages, various ways of use and levels of impact can be identified for the use of BIM for energy efficiency.

No.	Use cases/ Target discipline	Architecture design	Facility management	Structure engineer	Mechanical engineer	Other	Impacts
1	Reduce the Gap Between Predicted and Actual Energy Consumption in Buildings		■				Reduction of 25% energy compared to baseline figures.
2	Minimizing operational costs and carbon emissions through matching supply with demand of heat and electricity production.		■				Leading to a 32% increase in profit and 36% reduction in CO2 emissions.
3	Intelligent management and control of HVAC system		■				Up to 30% of Energy Saving Up to 30% Emission reduction
4	Friendly and Affordable Sustainable Urban Districts Retrofitting (FASUDIR) - Heinrich-Lubke housing area, Frankfurt, Germany		■				GWP reduction of 60%. Operational energy consumption reduction of 35%
5	Friendly and Affordable Sustainable Urban Districts Retrofitting (FASUDIR) - Budapest Residential District		■				Operational energy reduced by 35% and energy running costs reduced by 35%
6	An innovative integrated concept for monitoring and evaluating building energy performance (the gap between predicted and actual building energy performance is addressed by the project).		■				Achieve building energy performance
7	Parametric design of a shelter roof in urban context	■	■	■	■	■	Early BIM for parametric optimization through simulations
8	Building As A Service	■	■	■	■		Optimize energy performance in the application domain of non-residential buildings
9	Delivering highly energy efficient hospital centre		■				41% reduction in fabric loss heat, 29% reduction in carbon emissions,15% reduction in overall energy usage
10	Shopping Center using around half the energy of a typical development	■	■	■	■	■	50 % energy savings , 50 % savings in water consumption
11	Design of energy-efficient library with high architectural goals	■	■	■	■	■	Energy optimization results impacted for the building and HVAC design
12	Use of Optimization tool to compare hundreds of concepts energy efficiency before actual design	■					Use of Optimization tool has the potential to save money and time while directing to more optimal energy efficiency solutions.

Fig. 10. Relevance between target discipline and the impacts: This figure shows how the impact evolves with different disciplines.

5 Conclusion

In this paper we present a virtual collaboration platform addressing the requirements elicitation phase for determining gaps and new strategies in delivering BIM training for energy efficiency. We have used a participative and incremental approach and involved the project's External Expert Advisory Board with a view to reach key stakeholder communities in order to help identify and then screen / analyse past and ongoing projects related to energy efficiency involving aspects of BIM. Our analysis and studies aimed at assembling evidence-based quantitative / measurable scenarios and use cases that demonstrate the role of BIM in achieving energy efficiency in

buildings across the whole value chain. We have recorded a number of 38 best practices use-cases from the field of BIM for energy efficiency and conducted automated in depth-analysis to understand which are the gaps in BIM training and possible areas of improvement. These use-cases are published and maintained on the study platform (www.energy-bim.com) and accessible to potential users across Europe. The resulting evidence has been structured by stage and discipline, highlighting stakeholder targets ranging from blue collar workers to decision makers.
In future we are aiming at consolidating this community of BIM professionals that can share experiences and contribute to the development of building digitalization process with emphasis on BIM skills and competencies and associated training. We intend to create a framework for training BIM professionals for energy efficiency based on an assessment of desired skills and training objectives.

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