BIM-based EU -wide Standardized Qualification Framework for achieving Energy Efficiency Training

D2.1 – BIM for energy efficiency requirements capture

WP 2	**Leader: Cardiff University**
Task 2.1	**Leader: Cardiff University**
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Contents

Note: Annex B has been removed from the present public version of this deliverable as it contains personal information.

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Abbreviations

CA	Consortium Agreement
DoA	Description of the Action
GA	Grant Agreement
ICT	Information and Communication Technologies
PC	Project Coordinator
PSC	Project Steering Committee
QA	Quality Assurance
WP	Work Package
WPL	Work Package Leader
BIM	Building Information Modelling
EE	Energy Efficiency
EQF	European Qualification Framework
ToC	Table of Content
Mx	Milestone date designating the start of a given task
My	Milestone date designating the end of a given document delivery deadline
BEM	Building Energy Model
BIM	Building Information Modelling
CA	Consortium Agreement
DoA	Description of the Action
EE	Energy Efficiency
EPBD	Energy Performance Buildings Directive
EPC	Energy Performance Certificate
EQF	European Qualification Framework
GA	Grant Agreement
ICT	Information and Communication Technologies
KSC	Knowledge – Skills – Competencies

1 Executive Summary

The report D2.1 covers the phase of requirements capture of the BIMEET project. Whereas BIMEET project aims at offering specialised training and educational programs to support with BIM implementation agenda for energy efficiency in Europe, the current report is addressing the requirements elicitation phase. This phase involves training requirements collection and associated analysis in order to inform the training elaboration phase with regards to skills, competencies and required qualifications.

The report provides in-depth analysis and gaps identification in relation to skills and competencies involved in BIM training for energy efficiency prior to integration with following training models and strategies. Consultations and interviews have been used as a method to collect requirements and a portfolio of use-case has been created to understand existing BIM practices and determine existing limitations and gaps in BIM training.

2 Introduction

In this section we present the current state-of-the art in the field of BIM and associated construction applications with regards to energy efficiency and training.

2.1 BIMEET project

The aim of BIMEET is many-fold: (a) pave the way to a fundamental step change in delivering systematic, measurable and effective energy efficient buildings through BIM training with a view to effectively address European energy and carbon reduction targets; (b) promote a well-trained world leading generation of decision makers, practitioners, and blue collars in BIM for energy efficiency; (c) establish a world-leading platform for BIM for energy efficiency training nurtured by an established community of interest. These general aims translate into the following strategic objectives (STO):

- STO1: Screen and synthesize past and ongoing European, as well as national, initiatives and projects with a focus on 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.

- STO2: Benchmark existing 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.
  - ✓ This will include: (a) better determination of future capability needs; (b) clear routes of entry and clear career progression pathways; (c) clear, standard means of recognising competence; (d) exploring the scope to make apprenticeships more flexible; (e) an industry review of the current skills and capability delivery mechanisms; (f) review of approaches to career planning, training and development with a commitment to rationalise.

- STO3: Harmonize energy related BIM qualification and skills frameworks available across Europe (Objective 1) with a view of reaching a global consensus through our BIM for energy efficiency expert panel.
  - ✓ The focus is on setting up a mutual recognition scheme of qualifications and certifications among different Member States supported by an effective strategy to ensure that qualification and training schemes are sustained after the end of the project.

- STO4: Map identified skills, qualifications, and accreditation into a BIM for energy efficiency overlay with a total lifecycle and supply chain (including blue collar) perspective.
  - ✓ There are country specific delivery and process variations that will be considered to ensure successful take-up of the BIMEET training program at a national level.

- STO5: Adapt the BIM4VET platform (delivered in the context of a related ERASMUS+ ongoing project) to provide a robust computer-based online and open-access environment for BIMEET.
  - ✓ The BIM4VET platform is already providing: (a) BIM stakeholder competence matrix, (b) classification of BIM training curriculums in Europe,

(c) BIM qualification maturity assessment method, and (d) recommender system for BIM training selection.
  - ✓ The resulting BIMEET platform will be available on-line on an open-access mode, nurtured by an established community of interest underpinned by an adapted business model.

- STO6: Establish a governance, policy, and regulatory framework as well as adapted business models to ensure the long-term sustainability of the proposed BIMEET training agenda.
  - ✓ The consortium will be supported by a 200+ members of the BIMEET community of interest and a panel of experts (around 20 members).
  - ✓ The consortium members will adopt an incremental and participative approach engaging effectively all the above stakeholders.

- STO7: Disseminate within and beyond Europe the resulting BIMEET platform and training program.

BIMEET endeavours to enhance the skills, qualifications and capabilities of construction practitioners (from high professionals to blue collar workers), thus increasing market penetration and adoption of key technological development in BIM, given the timeliness of the need for training in combined green and functional performance engineering. There are several areas that are key to the potential growth of BIM for energy efficiency and its impact on the green building marketplace:

- Multi-disciplinary integrative capacity of BIM: BIM provides a unique opportunity to integrate data, information and underpinning processes across lifecycle and supply chains. This will promote informed and energy efficient design interventions.
- Informed sustainability design: BIM contributes to sustainable lifecycle decisions and processes as it leverages on the capability of the complete construction value chain thus optimizing design decisions on complex issues such as energy efficiency.
- Modelling standards: BIM is currently promoting the development and adoption of a wide range of standards and best practice guide as evidenced by BIM adoption dynamics in Europe.
- Increase of BIM use for retrofit: there is an increasing trend for use of BIM in large as well as smaller projects with a sought benefit of maximizing energy efficiency and sustainable outcomes. Recognition of the appropriateness of BIM for small retrofit projects is also critical given the dynamic growth anticipated in the green retrofit market in the existing domestic stock across Europe.
- Using BIM for building performance monitoring: there is an increasing evidence of the value BIM tools during the operations and maintenance phase of a project, with the view of reducing the endemic gap between predicated and actual energy consumption in buildings.
- Training support & communication tool: As BIM embraces building products and processes, it constitutes a useful support for training, and to communicate the best practices for energy efficient and high-quality construction, in particular to on site staff.

This report focuses specifically on objective no. #2, and as such report provides in-depth analysis and gaps identification in relation to skills and competencies involved in BIM training for energy efficiency prior to integration with following training models and strategies. Consultations and interviews have been used as a method to collect requirements and a portfolio of use-case has been created to understand existing BIM practices and determine existing limitations and gaps in BIM training.

2.2 Background

Global warming has drastically increased the pressure to reduce energy use in buildings. In the EU, energy for the building sector represents more than 40% of Europe's energy and CO2 emissions (European Commission 2005). The European Commission has defined a clear 2020 target to reduce by 20% the energy consumption and the CO2 emissions and increase by 20% the share of renewable energies. These objectives have been translated into stringent regulations and policies at the European and National levels. For instance, the recast of the Energy Performance of Buildings Directive (2010/31/EU) imposes stringent energy efficiency requirements for new and retrofitted buildings.

The global construction market is forecast to grow by over 70% by 2025 (Global Construction Perspectives and Oxford Economics 2015). Several countries have already set-up the target to achieve sizeable objectives, such as the UK Construction agenda: (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.

The construction industry hence presents a major opportunity to reduce energy demand, improve process efficiency and reduce carbon emissions; but it is also traditionally highly fragmented and often portrayed as involving a culture of "adversarial relationships", "risk avoidance", exacerbated by a "linear workflow", which often leads to low efficiency, delays and construction waste. The process of designing, re-purposing, constructing and operating a building or facility involves not only the traditional disciplines, but also many new professions in areas such as energy and environment (Rezgui 2011); also there is an increasing alignment of interest between those who design and construct a facility and those who subsequently occupy and manage it, and that demands dedicated skills and competencies to address multi-objective sustainability (including energy) requirements.

In this context, Building Information Modelling (BIM) is paving the way to more effective multi-disciplinary collaborations with a total lifecycle and supply chain integration perspective. BIM is the process of generating and managing data and information about 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. BIM holds the critical key to revolutionize the construction industry, which is forecasted to reach over $11 trillion global yearly spending by 2020 (Cummings and Blanford 2013).

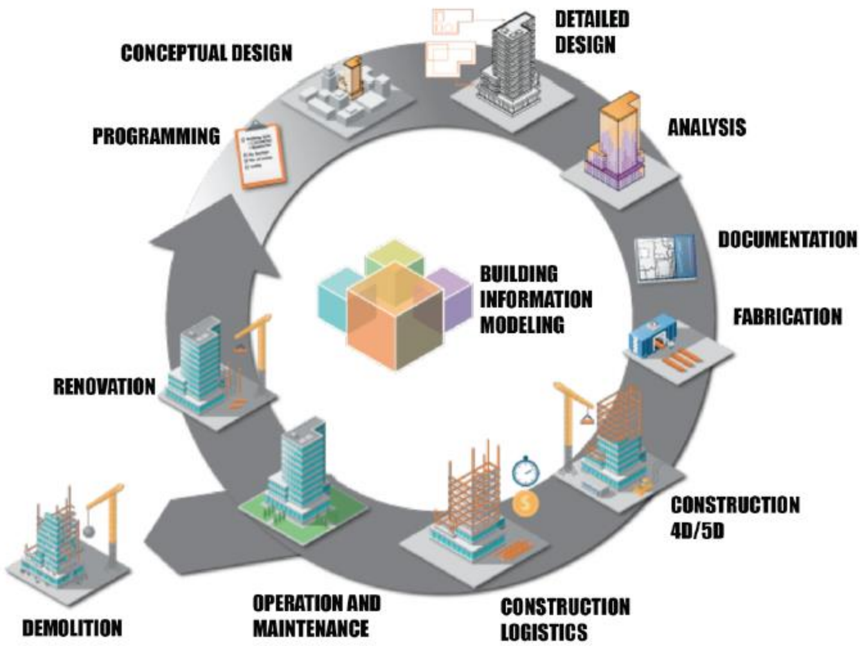

Figure 1: BIM uses across building lifecycle (Image Autodesk)

In order to bring about the transformation in our built environment as spelled out in the vision for Horizon2020 and set the sector firmly on a path towards competitiveness and sustainable growth, the European Commission's modern industrial policy recognizes the strategic importance of the construction industry, as witnessed by the Public Private Partnership Energy Efficient Buildings launched under the Recovery Plan in FP7 and now supported in H2020. The Construction industry in Europe has a wide range of training and education providers with an equally diverse set of training courses. It is essential to improve the breadth, depth, quantity and quality of educated and trained professionals in the built environment that can support an effective BIM agenda across Europe.

In fact, a number of training and education offerings concentrated on quite a narrow band of the industry; main courses focus on design and construction and not on briefing or planning and the impact of BIM to improving the operations of assets. Also, training courses largely target technical users rather blue-collar workers or management teams and strategic roles in organisations. In addition, BIM education and training is focused on Buildings, and rarely Infrastructure.

2.3 A review on BIM

BIM (Building Information Modelling) sits at the heart of digital transformation across the built environment. For the construction industry it provides a critical opportunity to significantly improve performance and stimulate more innovative ways of delivery and operation

BIM is a collaborative way of working that facilitates early supply chain involvement, underpinned by the digital technologies which unlock more efficient methods of designing, creating and maintaining our assets BIM provides a digital representation of the physical and functional characteristics of an asset to support reliable decision making and management of information during its life-cycle. At its core, BIM uses 3D models and a common data environment to access and share information efficiently across the supply chain and so boost the efficiency of activities around asset delivery and operation. By helping the entire supply chain to work from a single source of information, BIM reduces the risk of error and maximises the team ability to innovate.

On a global level, there are multiple definitions of the term BIM and what this means. There are even three separate definitions of the acronym which are:

- Building Information Model
- Building Information Modelling
- Building Information Management

Globally, the industry tends to refer to BIM as Building Information Modelling, but the definition of even what this means is varied. There are various methods of describing BIM as a software solution, a process or methodology and there are also multiple BIM maturity levels which define where projects or companies are along their BIM journey. There is presently no internationally agreed definition for BIM or the associated maturity levels, although the work by the UK in its BIM definitions is being taken to ISO 19650 Organization of information about construction works -- Information management using building information modelling. This should aid in developing a standard definition.

2.3.1 Building Information Model

The term Building Information Model is used to describe the virtual model of a building and, unfortunately, the term has become synonymous with using a specific software application to create a model to produce traditional drawings. Therefore, architects and designers may state that they are “doing BIM” if they create a 3D model and issue their drawings from this model. In the UK, the definitions of Building Information Model relate to describing the three generic parts of the model which relate to the Graphical, Non-Graphical Information and Documentation.

2.3.2 Building Information Modelling

Building Information Modelling relates to the process of constructing the Building Information Model, which is dependent upon the deliverables required. How a model is constructed to produce 2D drawing deliverables can be different to modelling for visualisation purposes. When the specified BIM dimension is 4D to analyse time, 5D for cost management or 6D for facilities management purposes then the modelling methods and the required levels of information within the model will change dramatically.

2.3.3 Building Information Management

The UK government’s BIM Level 2 mandate (where public-sector work requires fully collaborative 3D BIM with all project and asset information, documentation and data being electronic) defined the delivery of BIM through the British Standard 1192 series of documents as Building Information Management. This defines the process of who, what and when undertakes the building information modelling to produce the building information model. The UK mandate is based upon an information management process.

BIMEET aims to broaden the BIM training agenda to support the European Union building energy efficiency agenda. This requires broad awareness and expertise in BIM practice across different asset types and across different roles in the industry.
In that respect, the current report study aims at identifying gaps and requirements and suggest skills, qualifications and capabilities that need to be improved for construction practitioners (from high professionals to blue collar workers) in order to increase market penetration and adoption of key technological development in BIM.
The research methodology utilises a mixed-method approach involving studies incorporating qualitative and quantitative methods to elicit construction industry stakeholders’ requirements, and skills training for industry professionals in the field of BIM for energy efficiency. The

methodology adopted provides a robust foundation for undertaking in-depth analysis of existing BIM best practice use-cases and to understand dependencies and linked processes of social and technological practices.
The combined consultations explored stakeholders' knowledge, understanding, attitudes, values and behaviours, and helped identify key barriers to BIM engagement in Europe. The identified barriers are discussed and debated from a variety of perspectives and presented in this report.

The remainder of this report is as follow: in Section 2 performs a review of BIM technologies and practices for energy efficiency. In Section 3 we present the methodology utilised to conduct our requirement capture process. Process framework is presented in Section 4. A description of the use-case to explain the process of use-case aggregation and associated analysis are presented in Section 5. Interview guide analyses and outcomes are presented in Section 6. A summary of main requirements for training in BIM for energy efficiency are presented in Section 7 and conclusions in Section 8.

3 Literature Review

In this section we explore related works from the field of BIM with particular emphasis on energy and training.

3.1 The role of BIM in Construction.

Building Information Modelling (BIM) is defined as the process of *generating, storing, managing, exchanging, and sharing building information in an interoperable and reusable way* (Vanlande et al. 2008). It requires the development and use of a computer generated model to simulate the planning, design, construction and operational phases of a project (Azhar et al. 2008). The BIM Industry Working Group shows that the UK Government believes that its use brings many efficiencies and benefits across the project lifecycle (Eadie et al. 2013).
However, to have a successful implementation of BIM processes, all members of the construction team need security of confidential data external and internal to the BIM model. The BIM model can be part of an extranet (Christensen et al. 2007) however, this may lead to legal issues. There is the need to deal with the legal issues through the construction contract in order to reduce this significant risk (Christensen et al. 2007; Martin 2009; K. Udom 2012).

The significance of the cost of implementing BIM in terms of resources and training has been seen to act as a substantial barrier within the construction industry(Thomsen and Wittchen 2008; Yan and Damian 2008; B et al. 2010; Azhar et al. 2011; Efficiency and Reform Group 2011; R. Crotty 2013). Despite the significant cost of implementation BIM will ultimately be driven by clients (Efficiency and Reform Group 2011). Hore et al. (Hore and Thomas 2011) suggest that if adoption becomes a requirement then training must be subsidised by the Government to facilitate implementation.

3.2 BIM for Energy Efficiency

The global construction market is forecast to grow by over 70% by 2025 (European Construction Technology Platform 2005). Several countries have already set-up the target to achieve sizeable objectives, such as the United Kingdom (UK) construction agenda: (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 (Cummings and Blanford 2013; Global Construction Perspectives and Oxford Economics 2015).
The construction industry hence presents a major opportunity to reduce energy demand, improve process efficiency and reduce carbon emissions; it is also traditionally highly fragmented and often portrayed as involving a culture of “adversarial relationships”, “risk avoidance”, exacerbated by a “linear workflow”, which often leads to low efficiency, delays and construction waste. The process of designing, re-purposing, constructing and operating a building or facility involves not only the traditional disciplines, but also many new professions in areas such as energy and the environment (Rezgui 2011).
In this context, building information modelling (BIM) can facilitate more effective energy modelling and multi-disciplinary collaborations with a total lifecycle and supply chain integration perspective. Building information modelling provides a digital representation of the building process, facilitating the exchange and interoperability of information in digital format; this modelling can greatly contribute to energy reduction. BIM has a number of socio-technological advantages not only at the technological level, but also the process level, and can complement the way that architectural design artefacts are created, but also can profoundly change the collaborative process associated with the act of building. As the construction industry is facing increased pressure from regulations calling for significant gains

in energy efficiency, increased economic pressure and competition, and a dramatic evolution of working culture and practices, BIM can represent a game-changing factor that would support the transition to more energy and cost-efficient practices (Boton et al. 2013a; Petri, Beach, et al. 2014; Petri, Li, et al. 2014; Yuce and Rezgui 2017).

BIM and information and communication technologies (ICT) can play this game-changing role, by enabling faster and more reliable design of decision-making and construction follow-up. Building information modelling (BIM), at first, has proven to provide for enhancement of design support (through 3D visualization, physical simulation, upstream assessment of design options) and construction planning and monitoring (construction phasing and continuous monitoring). Such advanced support from digital tools is likely to allow for significant improvements in the quality and energy performance of buildings, as well as time and cost-savings to preserve competiveness of European businesses. During these different phases (as presented in Figure 1), the building information model has to be enriched by large data, notably related to building components, or simulated and/or sensed usages in order to support the energy analyses and simulations.

There are several research attempts in the field of building information modelling and energy efficiency trying to determine a methodology for utilizing BIM for reducing energy consumption and emissions in buildings.

Building information modelling in construction projects can support collaboration between employers, designers, suppliers and facilities managers through a range of design and construction tasks (Barrett and Sexton 2006). BIM has also been validated in studies (Egan 1998; Bryde et al. 2013) as an efficacious instrument for addressing (a) project failure caused by lack of effective project team integration across supply chains (b) the emergence of challenging new forms of procurement incl. design–build–operate contracts (Dainty et al. 2006) and (c) decreasing the whole life cost of a building through the adoption of BIM in facilities management (Becerik-Gerber et al. 2012). BIM also facilitates information collected and stored in a BIM-compliant database which often could be beneficial for a variety of practices, such as energy management, maintenance and repair, and space management (Cerovsek 2011).

The implementation of BIM for energy efficiency will provide energy savings through the combination of accurate energy monitoring, real-time decision support systems, and actuators and identification of consumption patterns. Moreover, (a) the reliance on a semantic approach (i.e., BIM, real-time data analysis, behaviour modelling, etc.); (b) enhanced supervision of energy flows and use in buildings; and (c) new partnerships between energy managers, energy distributors, energy equipment suppliers, and technology (including smart software tools), will inform the optimal management on the evolution of energy use in buildings, and result in quantifiable energy consumption reduction. It will provide an analytic operating capacity, KPI (key performance indicator) control, annual consumption forecast progress, reports and personalized alerts (Petri et al. 2017).

A smart distribution of the (reduced) building energy consumption will imply economic savings that will be commensurate with the targeted energy reduction. Although according to some thermal regulations the energy consumption of a building is expected to not exceed a given limit, the real energy performance is usually lower. One means to reduce the gap between prediction and reality is to improve the entire process, from the early design phase to the operation phase (Petri, Li, et al. 2014; Yuce and Rezgui 2017).

3.3 BIM Training

In our European societies, as well as in most parts of the world, education is recognized as a key pillar of community life and a universal right(United Nations Human Rights Office of the High Commissioner 1976). As stated by Jah & Polidano (2016), “those without necessary skills and qualifications face diminished life prospects and risk alienation from mainstream society”. The literature also puts a particular emphasis on the clear relationship between education and social stability: “increasing access to postsecondary vocational education and training does significantly reduce property crime, drug crime and crime against the person”. In this report, analysis and consultations are undertaken to determine gaps in current BIM for energy practices and to emphasize new skill that need to be developed for industry professionals in order to increase BIM awareness and applicability.

Enhancing qualifications of workers is key in all economic sectors but it is particularly critical in the Construction sector. The European construction industry is actually facing a three-sided challenge:

- Construction is a key component of the Energy Union strategy and as such, faces huge pressure from EU and national regulations. Buildings represent 40% of primary energy consumption in the EU and between 30 and 40% of CO2 emissions depending on national energy mixes(Communication and from the Commission 2015). Improving the energy efficiency of European buildings is therefore a key step in achieving the 2020, 2030 and 2050 EU energy and CO2 emission targets. European Energy Directives, in particular the Energy-Efficiency Directive (EED) and Energy Performances of Building Directive (EPBD) and related national regulations, set very strict energy-efficiency targets on European buildings, with the aim to generalize Near-Zero Energy Buildings (NZEB) by 2020. NZEB are highly complex systems, which call for significant technical progress in several areas among which: building envelope performance, energy and comfort monitoring and integration of renewable energy production(THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE and EUROPEAN UNION 2010; European Commission 2013).
- The Construction sector is still facing the consequences of the economic crisis, which has reduced the investment capacities of its companies. The European sector is a strong economic sector (10% of the EU GDP) but it is also essentially made of small and very small companies, which have been particularly impacted by the economic downturn. This is one of the reasons why the financing of the required European building stock enhancement through deep renovation (up to 100 billion euros per year until 2020), is recognized as a challenge by the European Commission(European Commission 2015). Cost-effectiveness and productivity are therefore two overarching issues for European Construction businesses.
- The European Construction industry is experiencing its digital revolution, with an intensification of digital support in all stages of building design and construction. The Building Information Modelling (BIM) approaches and tools have in particular gained significant interest in the sector(Centre for Digital Built Britain 2016). They are recognized as key components of future construction practices, and their benefits on productivity and reliability are widely acknowledged(Petrullo et al. 2015). This evolution contrasts with the original culture and practices of the Construction sectors, which is widely perceived as a “low-tech” area with a significant proportion of “blue collar” workers. Training is therefore, even more than in other economic sectors, a critical challenge of our time (United Nations Human Rights Office of the High Commissioner 1976).

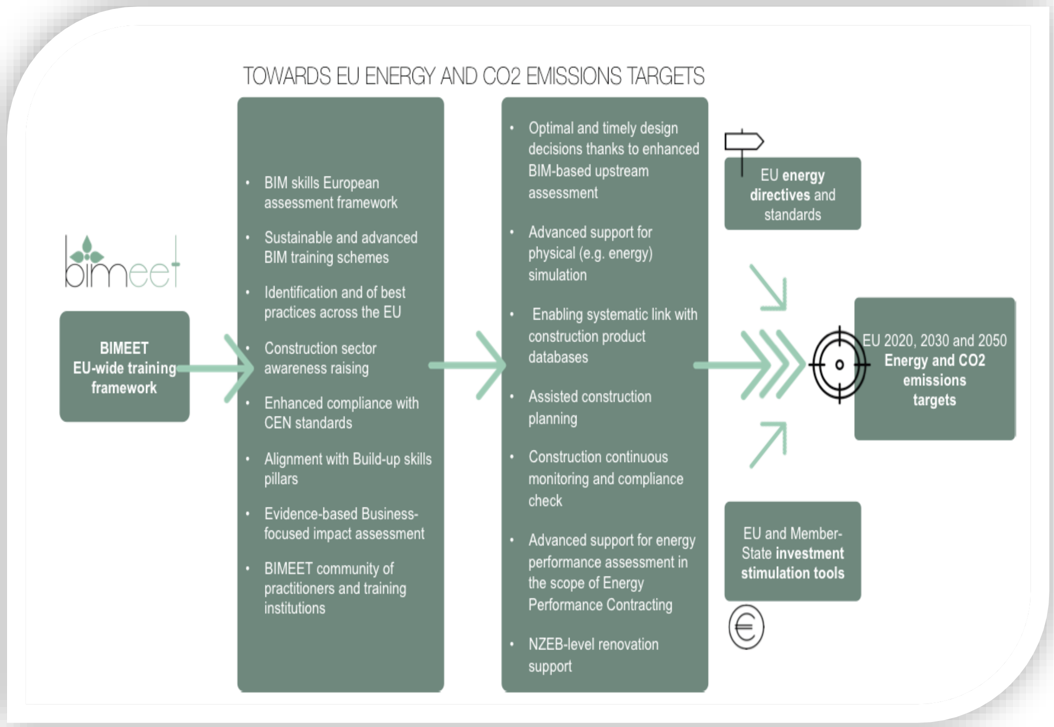

Figure 2: From BIMEET to EU energy targets - impact generation approach

Skills and competencies need to be developed to actively promote the widespread use of BIM-based transversal and multidisciplinary collaborative approaches and methods in the European (and beyond) construction industry, currently facing fragmentation and inadequate training resources. Training and education programs will raise awareness of stakeholders in the construction value chain about (a) environmental challenges, (b) current and future sustainability scenarios, and (c) energy efficiency targets and EC and governments agendas, with a view of delivering informed built environment interventions across lifecycle and supply chain underpinned by an effective BIM-based training Europe-wide agenda.

3.4 BIM training approach to EU-wide impact

The previous paragraph illustrates the intricacy of the challenges the Construction industry is facing: increased pressure from regulations calling for significant gains in energy efficiency; increased economic pressure and competition; dramatic evolution of working culture and practices. There is a clear need for a game-changing factor that would support the transition to more energy- and cost-efficient practices see Figure 2.
Information and Communication Technologies (ICT) can play this game-changing role, by enabling for faster and more reliable design decision-making and construction follow-up (Petri, Beach, et al. 2014). Building Information Modelling (BIM), at first, has proven to provide for enhancement of design support (through 3D visualization, physical simulation, upstream assessment of design options) and construction planning and monitoring (construction phasing and continuous monitoring)(Boton et al. 2013b). Such advanced support from digital tools is likely to allow for significant improvements of the quality and performance of buildings (Yuce and Rezgui 2017), as well as for time- and cost-savings to preserve competiveness of European businesses. Based on the rationale elaborated above, the main objectives for BIM engagement and training are to leverage the take-up of ICT and Building Information Modelling

technologies through a significant upgrade of the skills and capacities of the European Construction workforce, in order to dramatically improve the reliability and effectiveness of design and construction practices, with a view to achieve the objectives of the Energy Union. In the methodology applied for capturing requirements for developing BIM skills for energy efficiency, ICT methods are utilised to create a dynamic and open community of users that can share experiences and contribute to the process of training and education for BIM in energy efficiency.

4 Methodology

The research methodology proposed in this deliverable utilises a mixed-method approach involving studies incorporating qualitative and quantitative methods to elicit BIM training requirements for energy efficiency in the construction sector.

4.1 General methodology

The requirements gathering studies employed extensive consultations including:

1 A user engagement instrument in the form of an online 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) and

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 supported by **energy-bim.com** (platform presented in Section 3.2 and Appendix C and D).

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 behaviours, and helped identify key barriers to BIM applicability for energy efficiency. The identified barriers were discussed and debated from a variety of socio-technical perspectives. A total of **40** experts took part in the consultations (workshop), including: construction companies and practitioners, advisory groups, professional organisations, consultants, policy makers and education and training bodies.The results of the use-cases and interview analysis are presented in Section 5 and Section 6, respectively.

The detailed steps adopted in the methodology are as follows: (Figure 3)

- **Step 1:** Adapt an existing web portal to carry out the BIMEET WP2 consultation while maximising continuous engagement with our Expert panel and Community of Practice.
- **Step 2:** Develop a BIMEET Web Crawler that aggregated BIM related knowledge and stores it adequately to enable searches and authoritative URIs as input.
- **Step 3:** Invite partners, expert panel members, and community of practice members to register on BIMEET portal to provide authoritative sources of information.

Step 4: Provide an implicit validation of the BIMEET crawler by partners by ensuring that relevant projects have been identified.

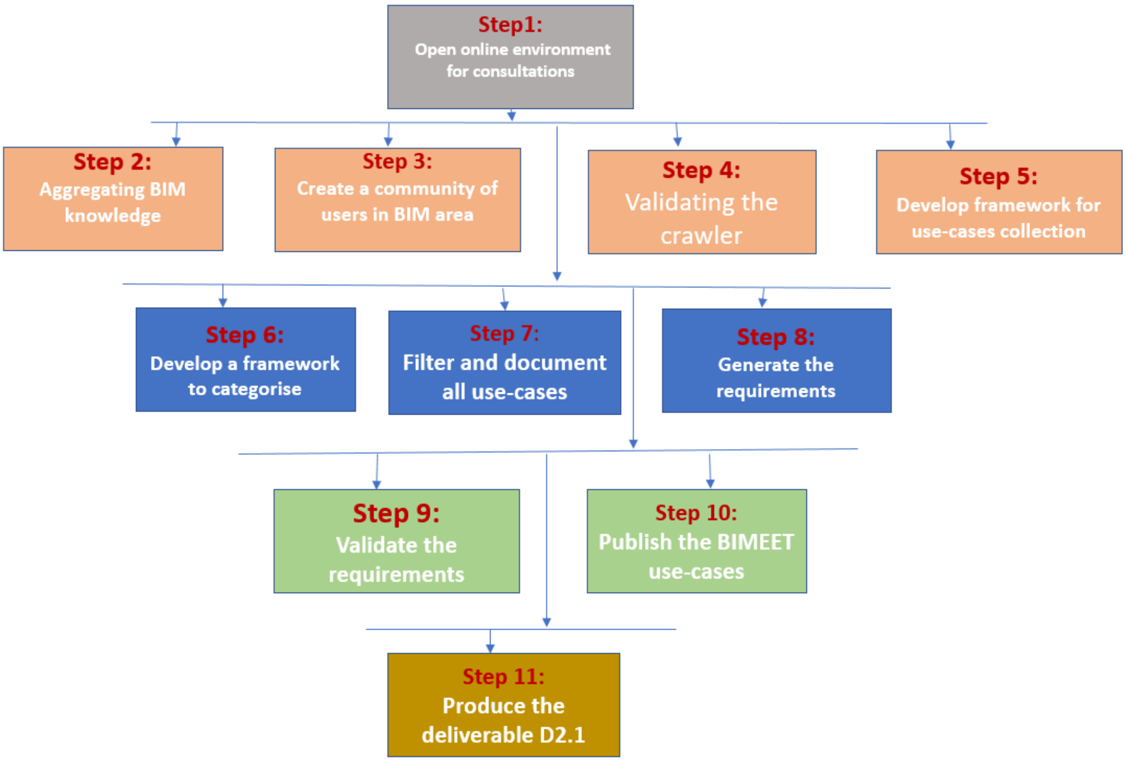

Figure 3: BIMEET requirements methodology (D2.1)

Step 5: 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).

Step 6: Develop a template to report selected use cases, implemented directly on the BIMEET portal. The template will involve a field to categorise the use case for further retrieval.

- **Step 7:** Filter and document all retained use cases on the BIMEET portal.
- **Step 8:** Generate the BIMEET requirements.
- **Step 9:** Validate the requirements using our Expert Panel.
- **Step 10:** Community exposure by publishing the BIMEET use cases widely inviting people to register if they want to access BIMEET materials.
- **Step 11:** Produce the resulting living deliverable D2.1.

4.2 Supportive 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-based platform solution that provides integrated access to building information modelling (BIM) resources. The platform is an open, scalable and polymorphic context-based solution with modules enabling serendipitous BIM information and knowledge discovery by utilizing a symbiosis of technologies such as semantic web, social network.

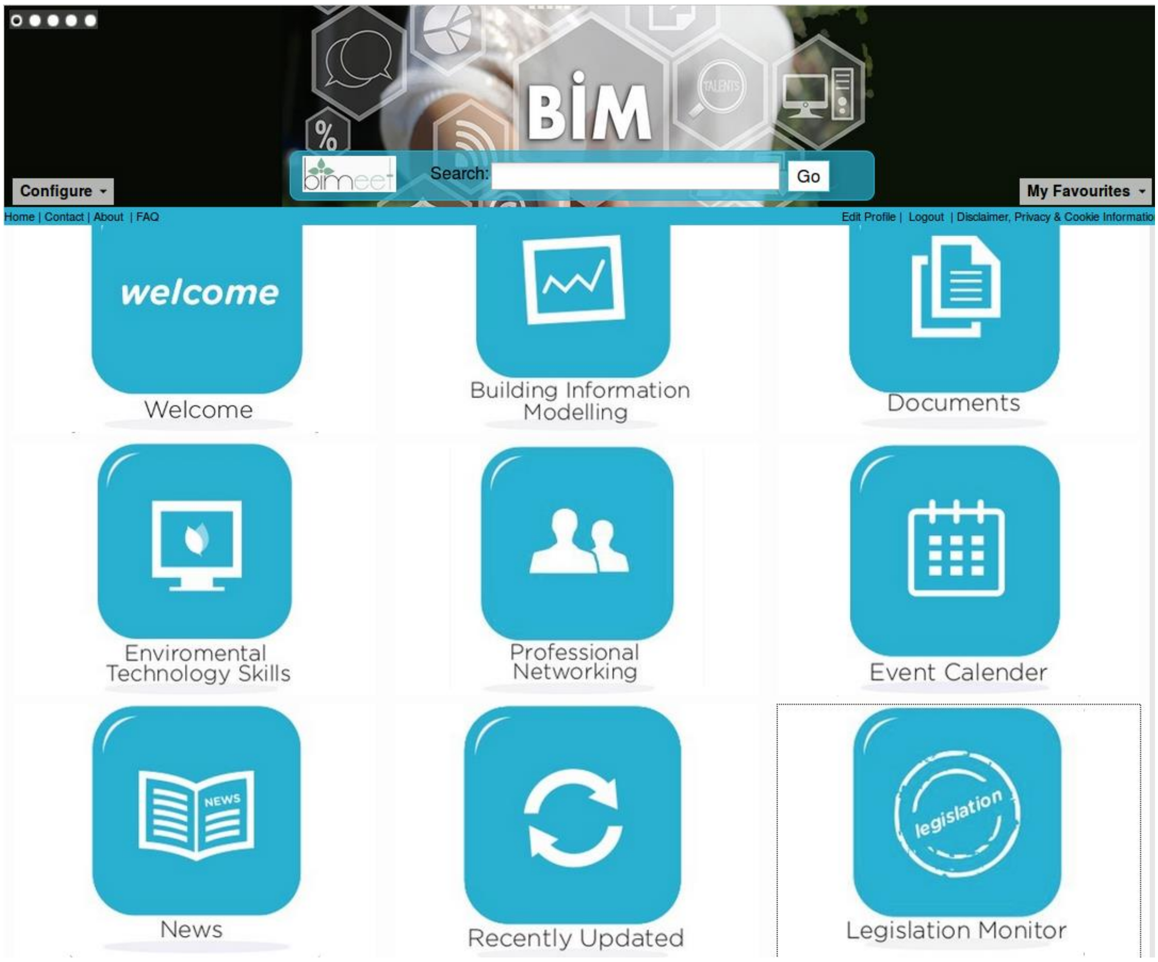

Figure 4: The community platform: [www.energy-bim.com]

This platform 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 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 also enabling them to utilise the latest best practice and regulations.

As part of the platform, we have implemented a search service that performs semantic searching on the platform BIM knowledge base from a set of authoritative URIs. The submitted BIM query has a set of associated ontological concepts for improving the precision and the recall of the returned results. The search service also provides an aggregation of data from a variety of trusted sources related to BIM via web-crawling. These sources can be proposed by users and validated by a group of experts according to their relevance to BIM for energy efficiency (see Figure 4).

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http://digitalbuilding.lu	Last updated:2017-11-17	0 pages Reset
http://www.list.lu	Last updated:2017-11-17	0 pages Reset
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http://construction21.org	Last updated:2017-11-17	0 pages Reset
http://bimcrunch.com	Last updated:2017-11-17	2109 pages Reset
http://mediaconstruct.org	Last updated:2017-11-17	0 pages Reset
http://bimblog.house	Last updated:2017-11-17	0 pages Reset
http://geometrygym.wordpress.com	Last updated:2017-11-17	0 pages Reset
http://cardiff.ac.uk	Last updated:2017-11-17	0 pages Reset
http://www.ines-solaire.org	Last updated:2017-11-17	44 pages Reset
http://eksergia.fi	Last updated:2017-11-17	307 pages Reset
http://buildingsmart.fi	Last updated:2017-11-17	0 pages Reset
Indexes Awaiting Approval:		
http://hwww.hitechcaddservices.com	Approve Index	Delete Index

Figure 5: Sources Aggregation

We have also implemented a Professional Networking Service that enables users to collaborate using social networks such as LinkedIn and Twitter aggregating associated data. This service also allows users to search for partners and colleagues and identify the corresponding networking profiles based on a set of BIM interests and disciplines. Other services for BIM training requirements and education identify: (i) an events calendar service is used a reminder of the important BIM events from the engineering community, (ii) a BIM tools service which will be implemented to expose a number of BIM-based tools addressing various aspects of energy such as carbon emissions, energy simulation, etc, and (iii) a BIM training service which will be implemented in the next stage of the project, enabling users to identify training and education programs related to BIM for energy efficiency in construction from various institutions such as universities, research organisations, governments agencies etc.

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. The procedure for searching and registration within the energy-bim.com are presented in Appendix C and Appendix D.

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.

4.3 Researching sampling techniques

The methodology has been focused on community knowledge extraction involving project consortia partners, expert panel members and skilled BIM experts. Such experts have been involved in validating the use-cases collection template and questionnaire elaboration. Based on the use-case collection template, the consortia partners have been asked to provide five relevant use-cases from their country of origin in order to cover a wider European BIM perspective. Use-cases have been collected from Greece, Finland, France and UK followed by analysis and requirements elicitation. Using this wide community of experts, interviews and consultations have been conducted as a mean to validate the findings in the assessment of the use-cases and leading to a more comprehensive BIM training set of requirements. One workshop for consulting the BIM community on the existing BIM practices, areas of improvement in BIM trainings and education for energy efficiency has been organised in Brussels. Brainstorming sessions with experts have been organised as part of the workshop, in order to understand existing gaps in the field of BIM for energy efficiency and to aggregate new best practices use-cases.

4.3.1 Searching authoritative URIs

To support in the process of use-case collection and BIM knowledge aggregation, partners and experts have been asked to contribute and register a list of authoritative URI sources. These have been registered within the energy-bim.com platform, indexed for crawling and BIM knowledge has been aggregated. Such sources have been integrated in the search service aiming at facilitating users of BIM to extract best practices, regulations and to support with requirements definition and training. As part of the energy-bim.com platform a specialised crawler service has been implemented to help with BIM knowledge harvesting from the provided URIs and to create a BIM knowledge repository for a community of users. A human based process has been utilised to validate these relevant sources and searching URIs based on specialised keywords. These have been validated by experts in the field of BIM and supported by the consortium partners. Such keywords include: BIM, energy efficiency, best practice, case study, training and education. The URIs registration and search functionality have been illustrated in Appendix C and D see Figure 5.

4.3.2 Searching education indexed engines

To support with the process of requirements elicitation, we have conducted searching in educational indexed engines such as Scopus and google scholar based on which requirements have been determined and additional use-cases practices have been identified and included in the BIMEET use-cases repository.

We undertook a broad critical review of the academic literature, international standards, legislation, and key economic and political events surrounding BIM, training and education, energy systems and their management. The body of literature was then broken down into chronological and thematic groupings. Following the observation of new challenges and opportunities arising imminently from a mismatch in these projections, key concepts were identified to address these from related fields and novel management paradigms. The rest of this section details the scope of the review and initial observations of the subject domain.

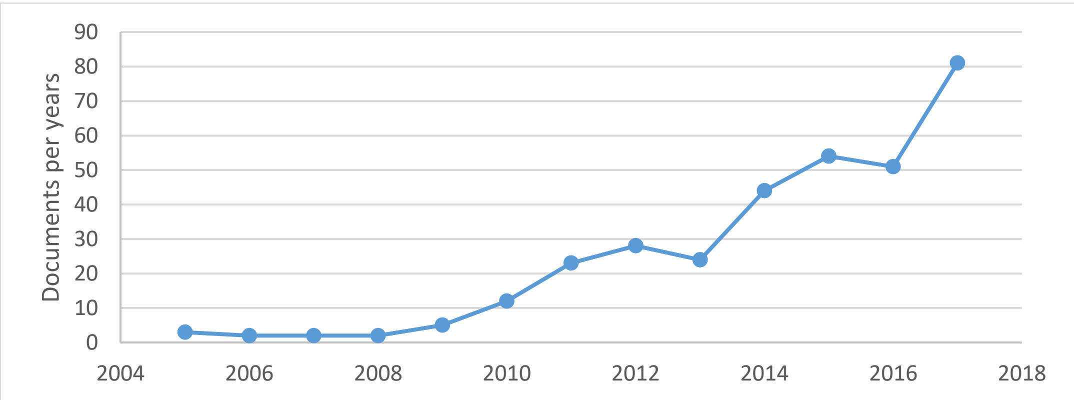


Figure 6: Popularity of BIM for Energy Efficiency research over time as number of relevant Scopus articles per year

Keyword: BIM for Energy Efficiency

Search Driver: Scopus

Period: 2005-2018

Number of documents: 331

Area: Engineering, Computer science, Energy, Environment science

It was apparent that as an emerging field, building information modelling for energy efficiency encompasses many other fields, mandating a well-considered scope. We therefore disregarded papers which only focused on national or building level energy management, or which only considered the design phase of energy systems. We also placed an emphasis on recent publications due to the accelerating change in technologies and focused on BIM training for energy efficiency. Based on this, a trend of increasing popularity in the field was observed since circa 2005, as depicted in Figure 6. The sources were filtered to those deemed most relevant and influential, to a final bibliography of circa 250 references.

5 BIM process framework

In recent years, have appeared a number of strategies and key methods that the construction industry has applied to improve its services. Such strategies have been comprehensively reviewed and explored by Cooper et al. (Cooper 2005) and a summary has been provided in this section. According to Hibberd & Djebarni (1996) the concept of procurement raises awareness of the issues involved in challenging generally accepted practices and establishing strategies, thus the need to consider new approaches to the design and construction process (Hibberd and Djebarni 1996, Masterman 1992). Latham (1994) argues that reducing variations in the project process will improve performance and make significant cost savings (Latham 1994). The fundamental benefit of such an improved design and construction project process should be to optimise predictability (Kagioglou 1999), (Cooper 2005). This can only be ensured when a truly co-operative project environment exists. The project process should look to facilitate team working and effective communication between participants (Kagioglou et al. 1998). Further, information technology (IT) can assist the attainment and maintenance of a new project process if its operation and the relationship between the parties is sufficiently prescribed and detailed (Latham 1994). The current perception is that flexibility is difficult within the process because the supply chain changes for every project and relationships are dynamic. Despite the lack of a `standard' project process there are several well recognised models of the construction process, such as the Royal Institute of British Architects (RIBA).

5.1 Basic process map of undertaking BIM

Building Information Modelling is defined within the British Standards documentation series 1192, and the first of these was BS 1192: 2007 *Collaborative production of architectural, engineering and construction information – Code of Practice*.
BS 1192: 2007 provides a practical process for the management of Building Information Models (Graphical) and Building Information (Non-Graphical) which enables collaborative working. It also gives a procedure that has the potential to eliminate the main problems associated with increased costs and increased time in the construction delivery because information is inaccurate, ambiguous and incomplete.

At the core of the 1192 series are a number of key requirements which include:

- Use of a Common Data Environment
- Defined roles and responsibilities
- Clash avoidance and volume strategy

The Common Data Environment (CDE) ensures that all information is checked, approved and authorized to eliminate abortive work in the total design process and rework at the site (see Figure 2). It ensures that information is fit for purpose, has the appropriate revision and status code and is correct for use. If information shared by the teams is incorrect, then all information derived from it will also be incorrect.

Building Information Modelling is the overall process of creating a collection of three-dimensional data sets to create the form of a model of information that pertains to the design of a building or built asset. Stakeholders involved can then use this information to generate and manage an asset's data over its life cycle using model-based technologies linked to a repository of reliable information. The three main components of the information model are: Graphical Model, Non-graphical Model and Documentation.

Figure 7 below shows the three components make up the Project Information Model (PIM) during the CAPEX (construction) stage of an asset life-cycle, or the Asset Information Model (AIM) during the OPEX (In-use) stage of an asset life-cycle. The BIM project delivery process is outlined below. Figure 8 overleaf shows the cost estimating process in BIM.

1. The Employers Information Requirements (EIR) is used for the tendering and assessment of teams that will be procured to complete the task
2. The Tenderers response to the EIR is compiled and returned to the Employer in the form of a BIM Execution Plan (BEP)
    i. Pre-contract
    ii. Post-contract
3. Lead design or contractor to define a delivery programme to complete tasks in discussion with supply chain and the employer, the Task Information Delivery Plan (TIDP)
4. Finalised Master Information Delivery Plan (MIDP) with clear confirmation of responsibilities and outputs.
5. Continuous exchange of information in the early design, concept and definition stages via the CDE
6. Handover at Opex stage with the construction record models and drawings; all associated documents; the model rendition; the LIDOR or other surveys; and the COBie (Construction Operations Building Information Exchange) file containing all of the requested asset information
7. Use Asset Information Model (AIM) to operate and maintain the asset
8. Asset & Project Portfolio information management for fit-outs and refurbishment - steps from 1-7 repeats during the life of the asset.

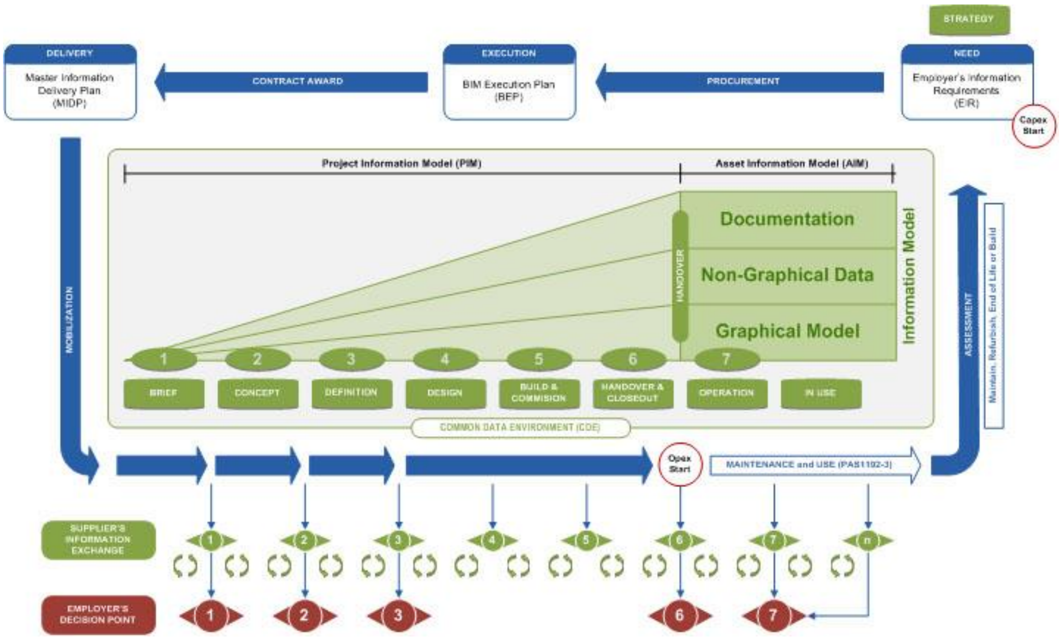


Figure 7: Information Model Delivery Cycle (PAS1192-2:2013)

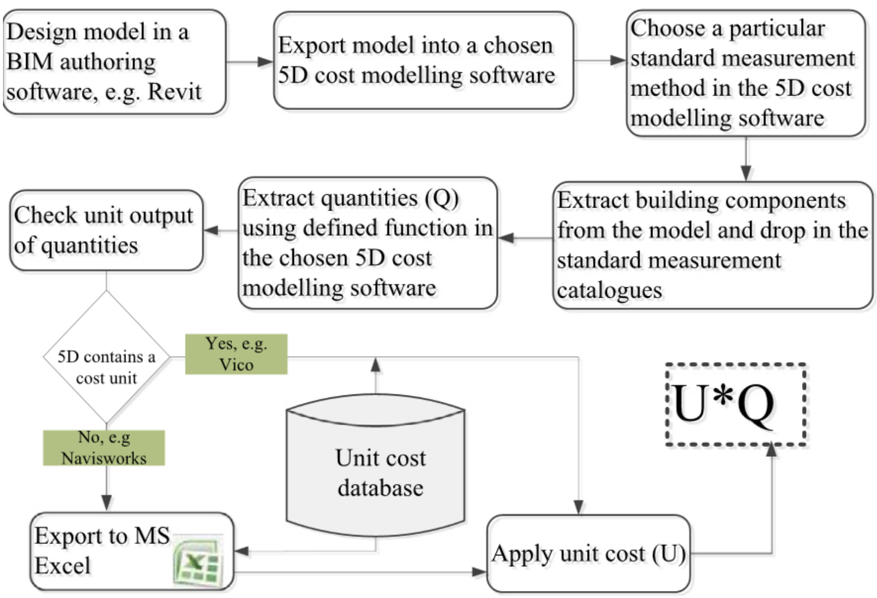


Figure 8 Cost estimating process in a BIM-based cost estimating software [1]

5.2 BIM Tools

Figure 9 shows a typical project. BIM is a collection of data and information generated for various strands of issues to be addressed in delivering a scheme. This information flow in each stage of an asset's lifecycle (see Figure 10) needs to be planned and managed as per the operational requirements of the building owner/client. The CDE is where all of this information continuously shared and its workflow is managed.

[1] Source: Abanda et al (2017) *BIM – New rules of measurement ontology for construction cost estimation*, Engineering Science and Technology Journal 20 (2017), 443-459

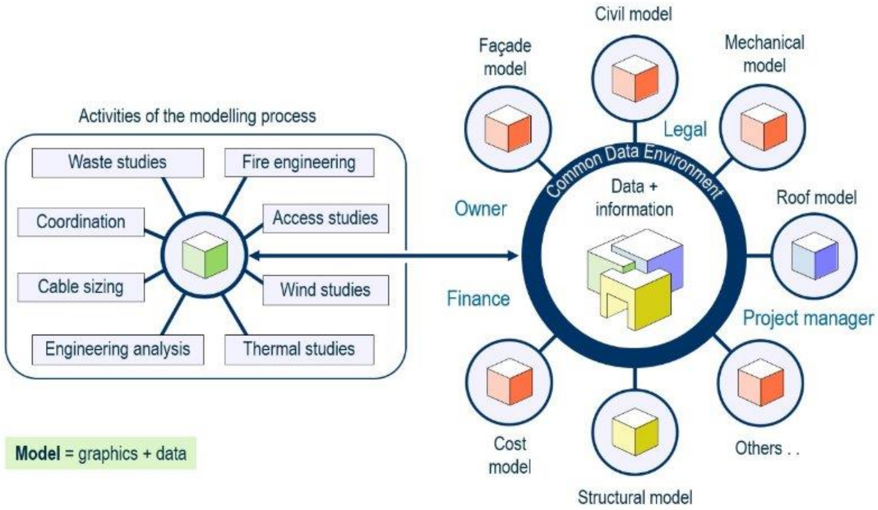


Figure 9: Organising different models in the Common Data Environment (https://www.linkedin.com/pulse/bim-can-big-beautiful-alim-bigger-well-sexy-paul-king

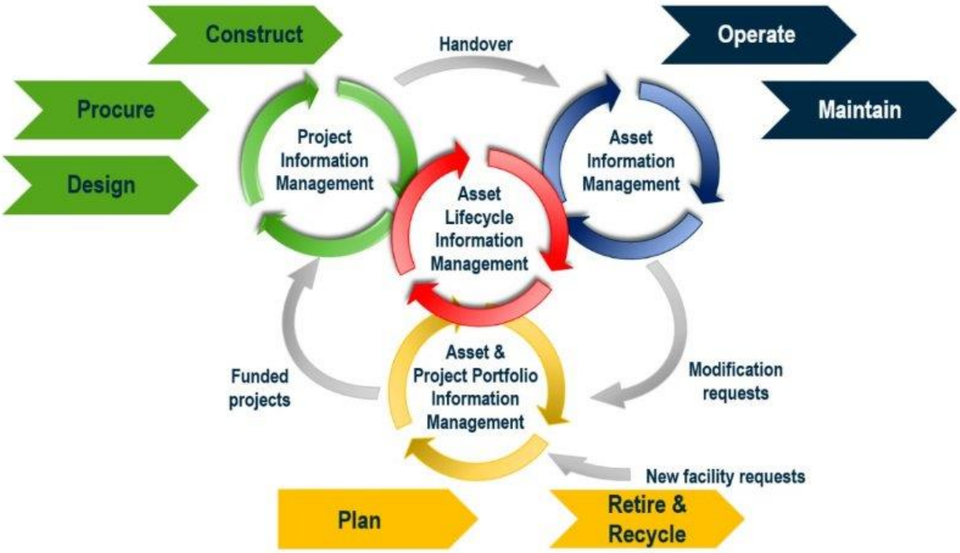


Figure 10: Information management

There are number of proprietary applications that are used in BIM projects for analysis and decision making (e.g. architectural, structural, mechanical and electrical, energy analysis, quantity-take off scheduling) in the process of designing, building and managing an asset (see Figure 11). Revit is one of them and can be considered as the most commonly used application. Navisworks brings building information models from various disciplines together in a single environment to see how they physically interact allowing designers to make necessary adjustments before construction begins.

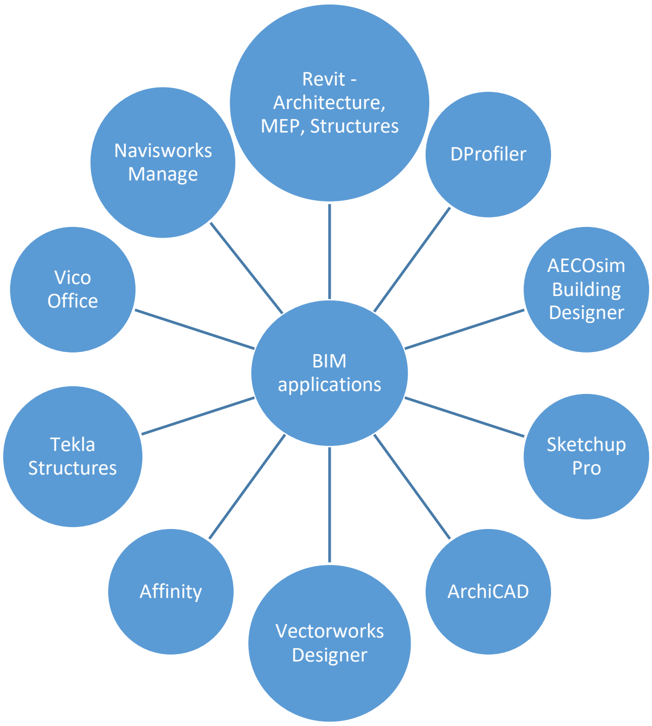


Figure 11: An extract of several proprietary BIM Tools

5.3 RIBA Plan of Work

The RIBA Plan of Work (RIBA 1997) was originally published in 1964 as a standard method of operation for the construction of buildings and it has become widely accepted as the operational model throughout the building industry (Kagioglou et al. 1998).
The RIBA Plan of Work from Figure 12 represents a logical sequence of events that should ensure that sound and timely decisions are made during the course of a construction project. It suggests that all the decisions, set out or implied, have to be taken or reviewed and it is anticipated that the model will only need adjustments depending upon the size and complexity of the project. The project progresses from inception to feedback, i.e. from stages A to M, in a linear fashion requiring the completion of one stage before proceeding to the next. However, the design and construction process is essentially not linear and cannot be viewed in such a functional fashion. Moreover, this sequential flow only aids the hard breaks between the organisational structure of the industry and contributes to the problems of fragmentation and poor co-ordination and communication between project team members (Sheath et al. 1996), as highlighted earlier by many governmental and institutional reports (Phillips 1950; Emmerson 1962; Banwell 1964; Gyles 1992; Latham 1994; Egan 1998).

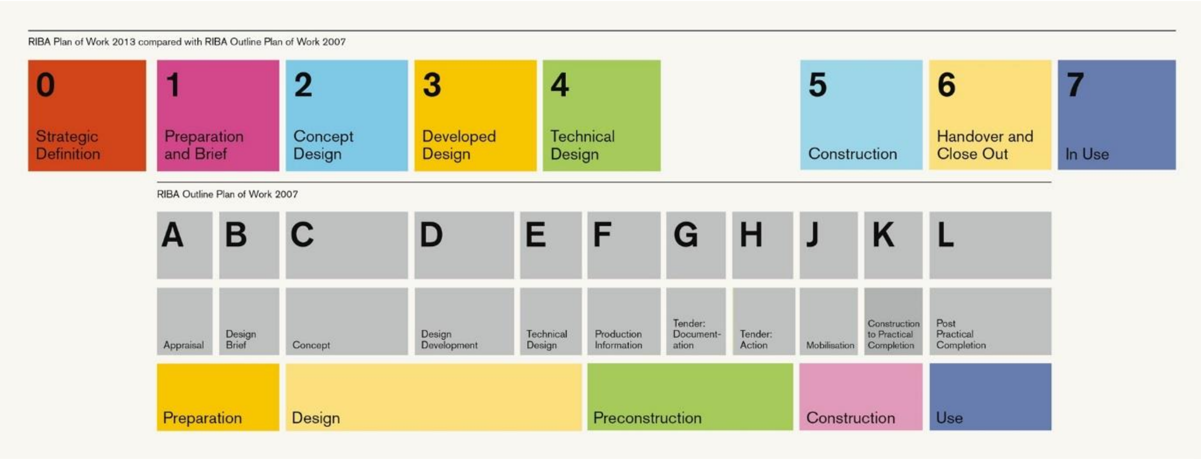


Figure 12: Plan of Work 2013 compared with RIBA Outline Plan of Work 2007

Split into a number of key project stages, RIBA provides a shared framework for design and construction that offers both a process map and a management tool. Whilst it has never been clear that architects actually follow the detail of the plan in their day to day activities, the work stages have been used to designate stage payments and identify team members' responsibilities when assessing insurance liabilities, and they often appear in contracts and appointment documents.

The Outline Plan of Work has evolved through its history to reflect the increasing complexity of projects, to incorporate increasing and changing regulatory requirements and to reflect the demands of industry and UK government reports on the industry. It has moved from a simple matrix representing just the traditional procurement route, to include multiple procurement routes, more diverse roles, multi-disciplinary teams, UK government gateways and to add stages before and after design and construction.

The latest version, published in 2013, has moved online and has undergone a radical overhaul. It is now more flexible, with stages such as planning permission and procurement being moveable, it reflects increasing requirements for sustainability and Building Information Modelling (BIM) and it allows simple, project-specific plans to be created. In addition, the work stages have been re-structured and re-named as follows: Strategic definition, Preparation and brief, Concept design, Developed design, Technical design, Construction, Handover and close out and In-use.

5.4 British Property Federation (BPF) model

The formation of the British Property Federation (BPF) model was a direct result of the growing concern at the increasing problems within the construction industry, notably poor design, inadequate choice of materials and poor supervision of the works combined with a lack of representation of the private sector client (Kagioglou et al. 1998). The model was intended for use by all those involved in a construction project, i.e. client, design consultants, contractors, subcontractors and suppliers, which was where the RIBA Plan of Work was lacking. It highlights the formal and informal relationships between these parties and aims to provide the client with value for money from the construction process by dividing the design and construction process into five stages (British Property Federation. 1983):

- Concept.
- Preparation of the brief.
- Design development.
- Tender documentation and tendering.
- Construction.

The model sets out to be flexible and allows the client to make a decision as to whether to continue with the project at the end of each stage. Furthermore, the model can determine the actual position of the dividing line between stages, outlining when to make that decision. Although the model has not been widely implemented, which may be due to its close link with repetitive house building projects, it has many advantages over the `normal' methods of design and construction such as (British Property Federation,1983):

- It produces better buildings more quickly and at lower cost.
- It removes the overlap of effort between design team members.
- Through more thought at the initial stages of the project fewer variations

are needed when on site, resulting in fewer delays, a lower cost and improved performance by the design team.

5.5 Mapping the design process during the conceptual phase of building projects

There are several process frameworks to manage a construction project such as : BAA Project Process (Airports 1995) , Salford Process Protocol (Kagioglou 1998), RIBA Plan of Work (RIBA 2013), MOD 'Working Document' (MOD 1997), CIRIA 113 (Potter 1995) , BS: 7000 (BSI 1989), Hubka(Hubka and Eder 1982), Pahl&Beitz (Pahl and Beitz 2007), VDI 2222 (VDI-Richtlinie 2222 1973), French (French 1971).
In an comparison of the models, the following general criticisms have been found (Sebastian et al. 2002):

- most describe a sequence of phases which, typically, imply iteration within phases but not between one phase and another;
- most imply starting with an analysis of requirements before the generation of possible solutions (although much design work involves the modification of existing solutions, not the invention of new ones);
- most set out only what should be undertaken, not why or how it should be performed;
- most do not define what is to be carried out separately by different team members and what needs to be performed in collaboration; and
- most limit their concerns to the problem requirements and their solution, and do not address the social aspects surrounding team-working, such as the selection and involvement of team members at various stages, the exchange of information, or the promotion of effective collaboration.
- In considering how these models deal with the conceptual design phase, we noted that:
- All the models start by an analysis of requirements – none starts by taking an existing concept and modifying it to suit new needs;
- Few of the models explicitly encourage the generation of alternative concepts for evaluation, thus most of them imply convergence to one solution quite early in the process;
- None of the models makes explicit reference to means for generating alternative solutions, or to formal measurement, evaluation or assessment methods.

From the evaluation of these tools we have concluded that apart from RIBA Plan of Work, none of the models succeeded in capturing ways to help a new design team overcome the intense requirements identified at start of a project when team members have conflicting aims, priorities and expectations, and need to find ways to construct consensus, develop common goals and share problem-ownership.
In the methodology process of this report, RIBA Plan of Work has been used due to existing integration with building information modelling standards and practices. Figure 13 explains integration between RIBA and BIM with the three inter-related issues of sustainable design,

BIM and procurement which can have a great deal of influence on the future shape of the European construction industry. In 2011 RIBA published the Green Overlay to the RIBA Outline Plan of Work and, in 2012, it published the BIM Overlay so as to provide straightforward guidance on the activities needed at each RIBA work stage to successfully design and manage construction projects in a BIM environment.

As well as setting out BIM activities at each work stage, key data drop points are identified within the overall project process. The aim is to assist design and construction teams in using BIM to provide a more efficient, intelligent and cost effective design process and to offer enhanced services to clients, particularly in relation to the whole life value of buildings.

RIBA Outline Plan of Work was found the most comprehensive process management framework especially with its particular application to BIM as well as sustainability and energy efficiency and is ideally suited to the objectives of the BIMEET project.

BIM Overlay to the RIBA Outline Plan of Work

		RIBA Work Stage	Description of Key Tasks	Core BIM Activities
Preparation	A	Appraisal	Identification of client's needs and objectives, business case, sustainability, life cycle and Facilities Management aspirations and possible constraints on development. Preparation of feasibility studies and assessment of options to enable the client to decide whether to proceed.	• Advise client on purpose of BIM including benefits and implications. Agree level and extent of BIM including 4D (time), 5D (cost) and 6D (FM) following software assessment. Advise client on Integrated Team scope of service in totality and for each designer including requirements for specialists and appointment of a BIM Model Manager. • Define long-term responsibilities, including ownership of model. • Define BIM Inputs and Outputs and scope of post-occupancy evaluation (Soft Landings). • Identify scope of and commission BIM surveys and investigation reports. • Data drop 1.
	B	Design Brief	Development of initial statement of requirements into the Design Brief by or on behalf of the client, confirming key requirements and constraints. Identification of procurement method, project sustainability and BIM procedures, building design lifetime and project organisational structure and range of consultants and others to be engaged for the project, including definition of responsibilities.	
Design	C	Concept	Implementation of Design Brief and preparation of additional data. Agreement of Project Quality Plan including BIM and Change Control protocols. Preparation of Concept Design including outline proposals for structural and environmental strategies and services systems, site landscape and ecology, outline specifications, preliminary cost and energy plans. Review of procurement route.	• BIM pre-start meeting. • Initial model sharing with Design Team for strategic analysis and options appraisal. • BIM data used for environmental performance and area analysis. • Identify key model elements (e.g. prefabricated component) and create concept level parametric objects for all major elements. • Enable design team access to BIM data. • Agree extent of performance specified work. • Data drop 2.
	D	Design Development	Development of concept design using project BIM data to include structural and environmental strategies and services systems, site landscape and ecology, updated outline specifications and cost and energy plans. Completion of Project Brief. *Application for detailed planning permission.*	• Data sharing and integration for design co-ordination and detailed analysis including data links between models. • Integration/development of generic/bespoke design components. • BIM data used for environmental performance and area analysis. • Data sharing for design co-ordination, technical analysis and addition of specification data. • Export data for Planning Application. • 4D and/or 5D assessment. • Data drop 3.
	E	Technical Design	Preparation of technical design(s) and specifications, sufficient to co-ordinate components and elements of the project, BIM data and *information for statutory standards, sustainability assessment and construction safety.*	
Pre-Construction	F	Production Information	F1 ~~Preparation of production information~~ Development of BIM data in sufficient detail to conclude co-ordination of design team inputs, to enable performance specified work to commence and enable a tender or tenders to be obtained. *Application for statutory approvals.* F2 ~~*Preparation of further information for construction required under the building contract.*~~ *Development of BIM data to integrate performance specified design work into model.* Review of BIM information provided by contractors and specialists, including integration into project BIM data.	• Export data for Building Control Analysis. • Data sharing for conclusion of design co-ordination and detailed analysis with subcontractors. • Detailed modelling, integration and analysis. • Create production level parametric objects for all major elements (where appropriate and information exists this may be based on tier 2 supplier's information). • Embed specification to model. • Final review and sign off of model. • Enable access to BIM model to contractor(s). • Integration of subcontractor performance specified work model information into BIM model data. • Review construction sequencing (4D) with contractor. • Data drop 4.
	G	Tender Documentation	Preparation and/or collation of tender documentation in sufficient detail to enable a tender or tenders to be obtained for the project.	
	H	Tender Action	Identification and evaluation of potential contractors and/or specialists for the project. Obtaining and appraising tenders; submission of recommendations to the client.	
Construction	J	Mobilisation	Letting the building contract, appointing the contractor. ~~Issuing of information to the contractor.~~ Arranging site handover to the contractor.	• Agree timing and scope of 'Soft Landings'. • Co-ordinate and release of 'End of Construction' BIM record model data. • Use of 4D/5D BIM data for contract administration purposes. • Data drop 5.
	K	Construction to Practical Completion	Administration of the building contract to Practical Completion. ~~Provision to the contractor of further Information as and when reasonably required.~~ Clarification and resolution of design queries as they arise. ~~Review of information provided by contractors and specialists.~~ Assist with preparation for commissioning, training, handover, future monitoring and maintenance.	
Use	L	Post Practical Completion	L1 Administration of the building contract after Practical Completion and making final inspections. L2 Assisting building user during initial occupation period.	• FM BIM model data issued as asset changes are made. • Study of parametric object information contained within BIM model data. • Data drop 6.
R&D	M	Model Maintenance & Development	L3 Review of project performance in use and comparison with BIM data. Analysis of BIM data for use on future projects, following feedback and research.	

Figure 13: BIM overlay to RIBA Plan of Work

6 Use-case analysis

We have created a requirement capture use-case template based on which we have aggregated a number of 38 best practice use-cases from the field of BIM for energy efficiency. In order to identify gaps and training requirements the analysis is presented below. The entire porfolio of use-cases can be accessed online and the status at the time this deliverable is submitted is presented in Appendix A.

6.1.1 Determining relevant indicators of variables in BIM project use-cases

6.1.2 Objective-based analysis

In this evaluation, we have performed a classification of the use-cases based on the 'objectives' being identified. Table 1 presents the distribution of the collected use-cases based on the objective variable.

Table 1: An objective-based analysis of use BIM for Energy Efficiency

No.	Objectives	Nb. of use-cases
1	Minimise capital and operation cost	7
2	Minimise energy consumption	9
3	Minimise carbon emission	4
4	Maximise energy comfort	4
5	Optimise energy performance- efficiency	5
6	Reduce energy demand (operation)	3
7	LEED	2
8	Reduce cost and water consumption	2
9	Reduce water demand	1
10	Water resource-efficient	1
11	Develop EU market for ICT	2
12	Low impact building	1
13	Improving use and control of energy	1
14	Healthy building	1
15	Enhancing the competitiveness of the energy distribution and control sector	1
16	Deal with energy profiles and consumption through the product lifecycle	1
17	Management lifecycle data sets of relevance to building energy management	1

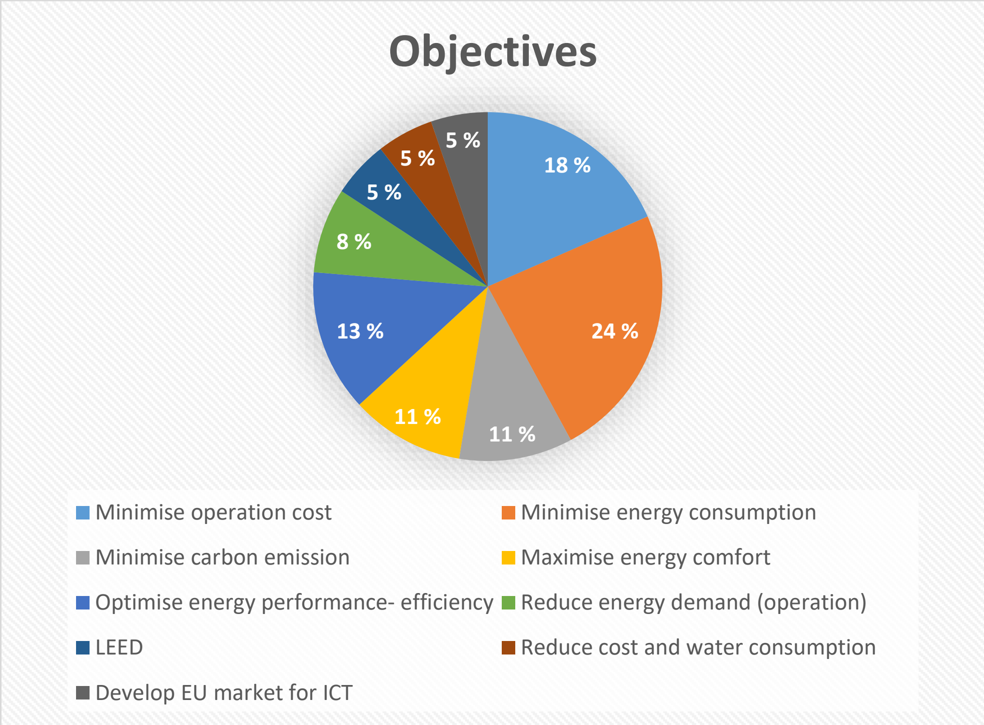


Figure 14: An objective based analysis of use BIM for Energy Efficiency

The use-cases have multiple objectives as shown in the Figure 14. Minimise energy consumption is the most common objective for the identified best-practices use-cases, with a total of nine use cases. Optimise energy performance- efficiency has been recorded as an objective for five use cases whereas other frequent objectives are related to minimising carbon emission, and maximising energy comfort.

6.1.3 Use-case type analysis

In this part we are interested in identifying what is the overall distribution of use-cases in relation to the use-case type as shown in Table 2.

Table 2: Use-case type analysis of use BIM for Energy Efficiency

No.	Use Case Type	Number of use cases
1	Research &Development	17
2	Real world application	13
3	BIM Guideline	1
4	Other	

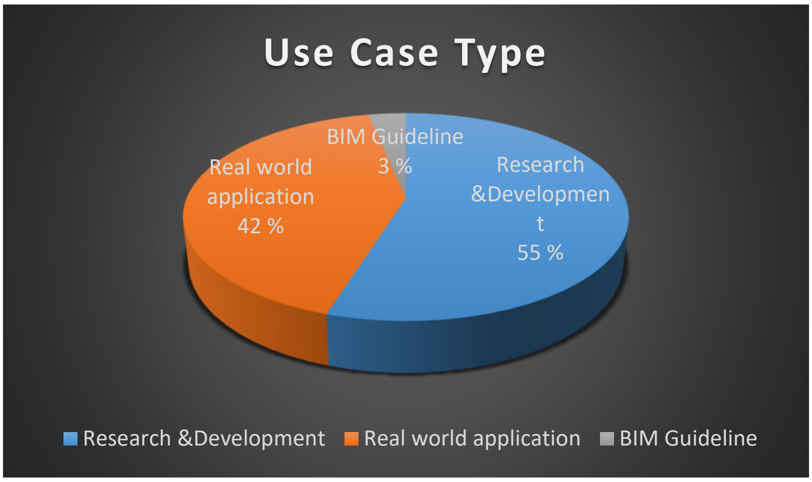


Figure 15: Use-case type analysis of use BIM for Energy Efficiency

There are three types of use cases in this evaluation which are Research &Development, Real world application and BIM Guideline.Figure 15 shows that Research &Development cover a number of 17 use cases, and Real-world application has 13 use cases and BIM guideline has only one use-case.

6.1.4 Building type analysis

In this part we assess the use-cases based on the type of building project where BIM has been utilised. As reported in Table 3, the majority of projects are for public buildings whereas domestic, commercial and industrial building seem less popular in adopting BIM.

Table 3: : Building type analysis of use BIM for Energy Efficiency

NO.	Building Type	Number of use cases
1	Public	26
2	Domestic	7
3	Commercial	4
4	Industrial	3

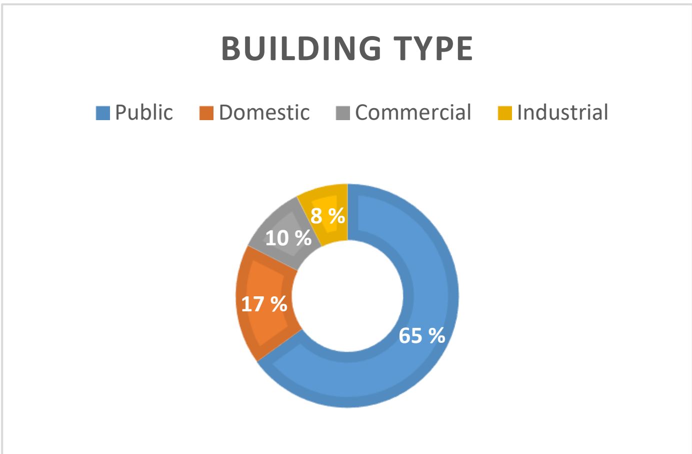


Figure 16: Building type analysis of use BIM for Energy Efficiency

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 16, 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.

6.1.5 Project type analysis

In this part we investigate how the set of use-cases that have adopted BIM, classifies in relation to the project type variable.

Table 4: Project type analysis of use BIM for Energy Efficiency:

No.	Project type	Number of use cases
1	Existing	15
2	New build	15
3	Renovation	4
4	Extension	2

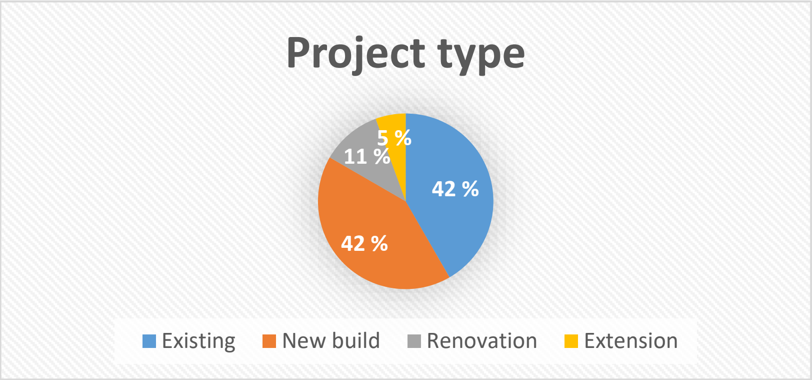


Figure 17: Project type analysis of use BIM for Energy Efficiency

From the analysis reported in Table 4 and Figure 17, it can be observed that a majority of use-cases use BIM for existing and new buildings, whereas extension and renovation projects tend to not adopt BIM. In percentage, 84% of project types are existing and new build projects and the rest of the project types are renovation and extension projects.

6.1.6 Target discipline analysis

In this part we structure the portfolio of use-cases based on the target discipline. Table 5 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.

Table 5: Target Discipline analysis of use BIM for Energy Efficiency

No.	Target Discipline	Number of use cases
1	Architecture design	20
2	Facility management	17
3	Structure engineer	11
4	Mechanical engineer	10
5	Other	11
6		

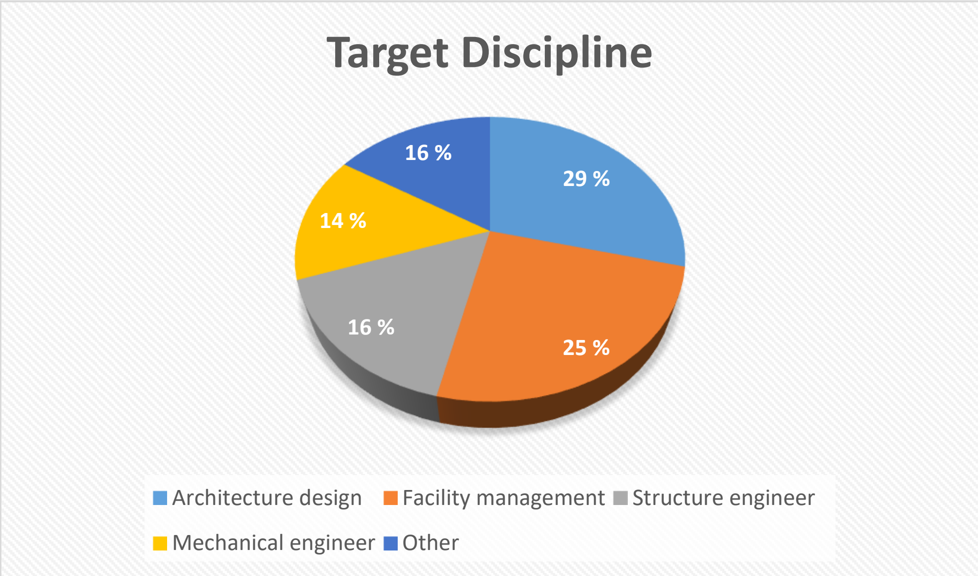


Figure 18: Target Discipline analysis of use BIM for Energy Efficiency

In the analysis we have used different target disciplines such as architecture design, facility management, structure engineer, mechanical engineer, and other. Architecture designers are targeted by 29%, facility management by 25% whereas the structure and mechanical engineers are targeted by 16% and 14%, respectively, see Figure 18.

6.1.7 Lifecycle stage 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 see Table 6.

Table 6: Lifecycle stages analysis of use BIM for Energy Efficiency

No.	Lifecycle stage (RIBA)	Number of use cases
0	Strategic Definition	4
1	Preparation and Brief	6
2	Concept Design	15
3	Developed Design	14
4	Technical Design	13
5	Construction	6

6	Handover and Closeout	4
7	In Use	13

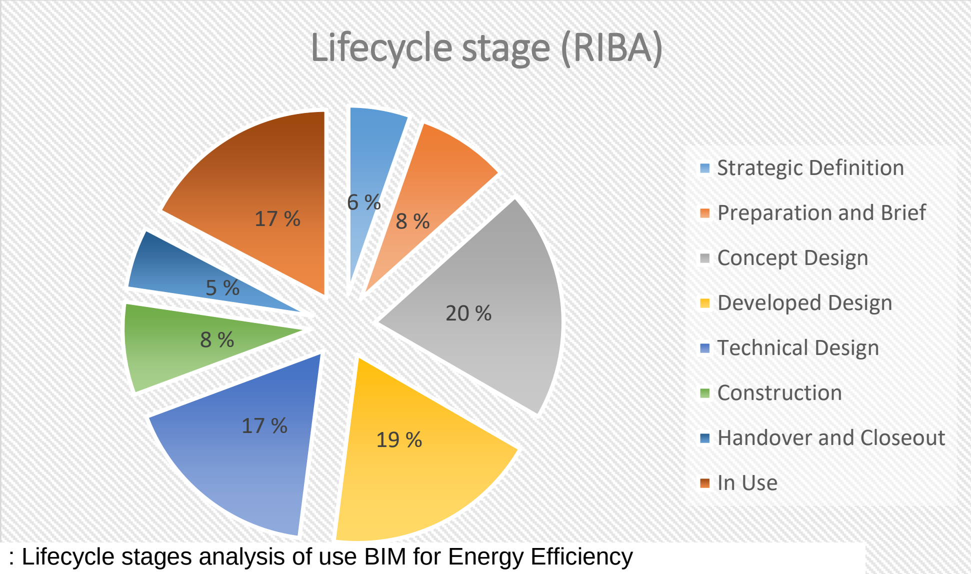


Figure 19: : Lifecycle stages analysis of use BIM for Energy Efficiency

Figure 19 shows that, 56% form 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.

6.1.8 Impact based analysis

Investigating the impact associated with each use-case can be useful exercise to understand what the benefits of BIM for energy efficiency are. The analysis below seek to determine what are the most common impact of utilising BIM for energy efficiency. Table 7 presents the distribution of use-cases based on corresponding impacts.

Table 7: An impact based analysis of use BIM for Energy Efficiency

No.	Impacts	Number of use cases
1	Reduction in carbon emission	7
2	Increasing energy Saving	10
3	Increasing comfort	5
4	Reduction energy consumption	8
5	Reduced energy running costs	1
6	Optimisation energy performance	11
7	Increase occupants awareness about BIM	3
8	Deliverable SMART building	1
9	Achieved energy efficiency certificate (LEED, PassivHaus, etc)	3
10	Saving in capital and operation cost	2
11	Save time	1
12	Achieved sustainable design	1
13	Saving water consumption	1

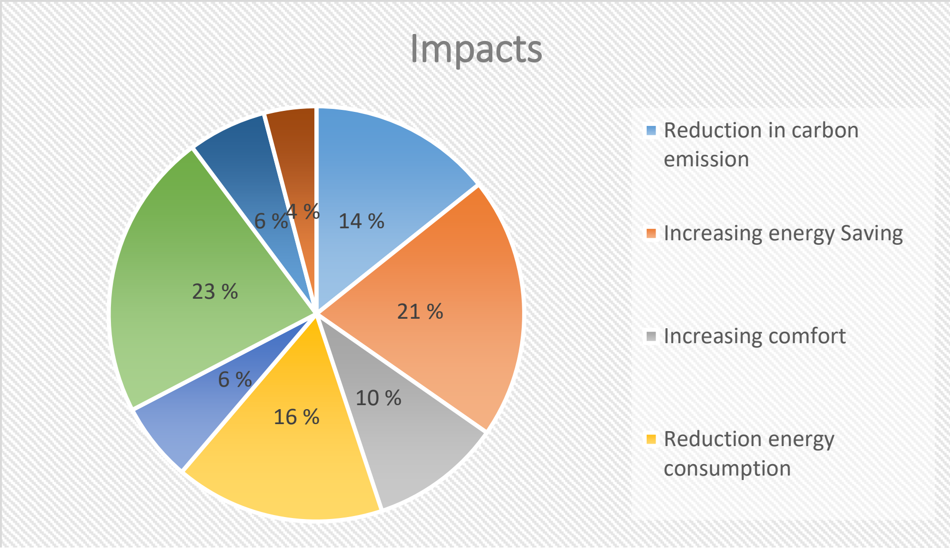


Figure 20: An impact based analysis of use BIM for Energy Efficiency

From the range of impacts, the optimisation of energy performance has the highest percentage of 23%, meaning that optimisation of energy efficiency represents a common impact for projects that use BIM for energy efficiency see Figure 20. The second impact, as resulted from the use-cases, is related to increasing energy saving of 21%, reduction energy consumption is 16%, and reduction in carbon emission is 14%. Also, increasing comfort has an associated proportion of 10%. In Figure 21, we provide an ontological representation illustrating dependencies between various parameters of the best practice use-cases template.

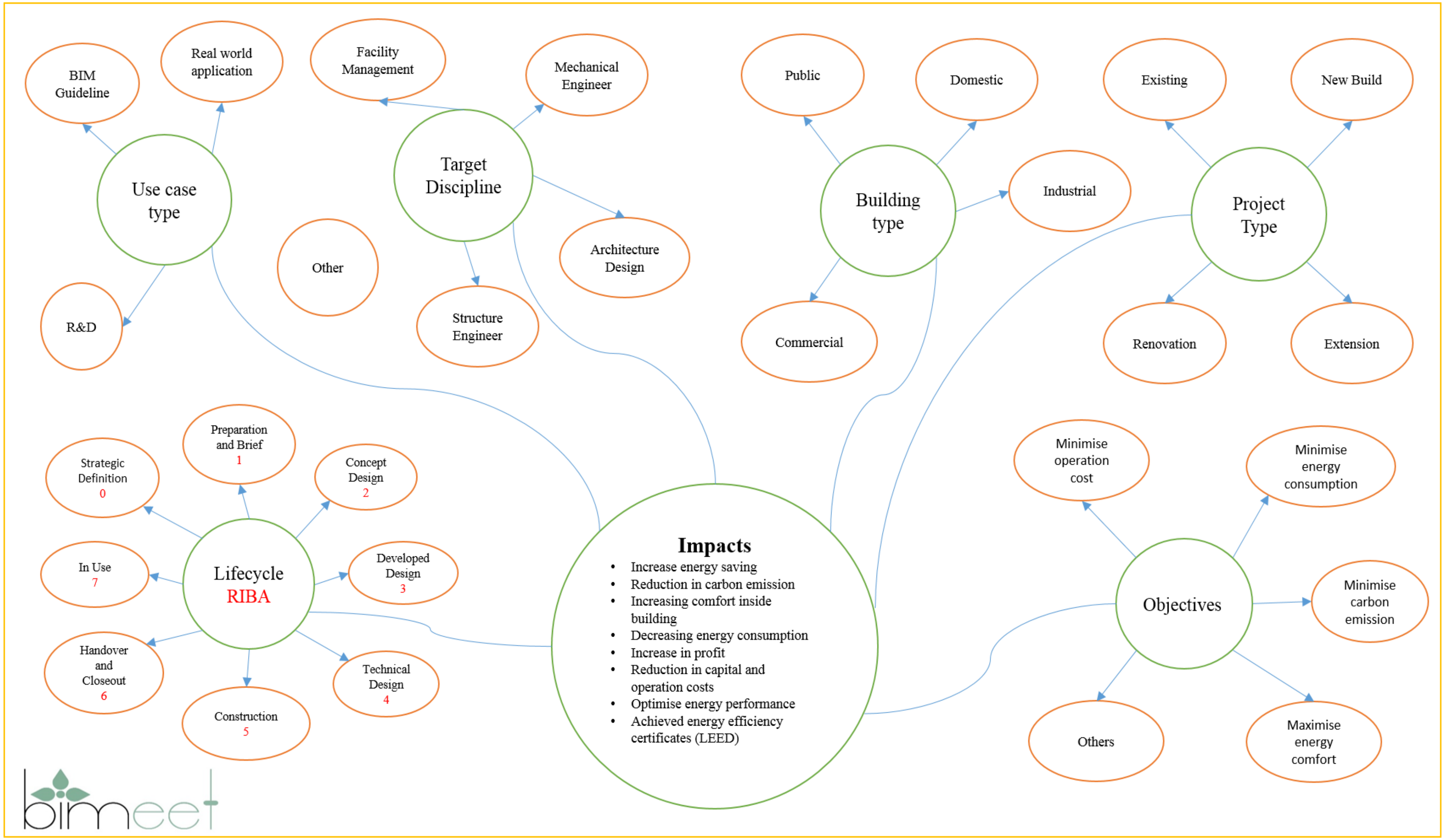


Figure 21: Ontology of use-cases of BIM for Energy Efficiency

6.2 Determining relevant relationships between the variables and the impacts

Assessing impact can have a particular relevance when conducting analysis where new gaps and limitations of current BIM for energy practices can be assessed and new links between various parameters can be observed. In this section, we analyse the use-cases from an impact perspective, where impact can be measured using specific criterions (i.e. energy saving, water saving, comfort).

6.2.1 Target discipline and Impacts

Table 8: Relevance between target discipline and impacts

N	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 CO_2 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.

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. Table 8 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

6.2.2 Building Type and Impacts

Building type is another variable used in our analysis and compared with the impacts it has provided great insights in identifying gaps. From Table 9, it can be concluded that BIM for energy efficiency has been applied in majority for public buildings.

Table 9: Relevant between building type and impacts

N	Use cases/Building Type	Public	Domestic	Commercial	Industrial	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 CO_2 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.

6.2.3 Project Type and Impacts

In this section, we try to determine dependencies between project type and impacts, where project types can be: existing project, new builds, renovation and extension. From Table 10, it can be concluded that greater impact is recorded when applying BIM for existing and new build projects. One use-case has been recorded as applying BIM for renovation project with a significant impact in energy and water savings.

Table 10: Dependencies between project type and the impacts

N	Use cases/Project type	Existing	New Build	Renovation	Extension	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.

6.2.4 Relation between the lifecycle of project and impact

This section explores the relation between project lifecycle and impacts. As reported in Table 11, the highest impact is recorded for projects that are ‘in-use’ (stage 7 from RIBA). However, the portfolio of project use-cases when BIM is applied at all stages cycle with great impact in energy and water savings (Case 10 and 11).

Table 11: Relevance between lifecycle and high impacts

N	Use cases/ Lifecycle	0	1	2	3	4	5	6	7	Impacts
		Lifecycle applicability (RIBA)								
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								■	Leading to a 32% increase in profit and 36% reduction in CO2 emissions.
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			■						Use of Optimization tool has the potential to save money and time while directing to more optimal energy efficiency solutions.

	efficiency before actual design									

6.2.5 The effectiveness of BIM

Table 12: Effectiveness of BIM in each case study

Use cases	BIM Effectiveness
Reduce the Gap Between Predicted and Actual Energy Consumption in Buildings	reduction of 25% energy compared to baseline figures.
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.
Innovative Information and Communication Technologies (ICT) platform able to support the optimization of water networks and to enable change in consumer behavior	made more efficient (in terms of both cost and water consumption)
Intelligent management and control of HVAC system	Up to 30% of Energy Saving Up to 30% Emission reduction
Rural Regeneration Centre, Hadlow College	achieve PassivHaus certification.
Sustainable Design and Building Information Modelling: Case study Energy Plus House, Hieron's Wood, Derbyshire UK	using integrated design technologies as well as simulation software.
Friendly and Affordable Sustainable Urban Districts Retrofitting (FASUDIR) - Heinrich-Lubke housing area, Frankfurt, Germany	GWP reduction of 60%. Operational energy consumption reduction of 35%
Friendly and Affordable Sustainable Urban Districts Retrofitting (FASUDIR) - Budapest Residential District	Operational energy reduced by 35% and energy running costs reduced by 35%
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 performanc
BIM-based Parametric Building Energy Performance Multi- Objective Optimization	understand trade-offs between daylighting and energy use.
Parametric design of a shelter roof in urban context	Early BIM for parametric optimization through simulations
Parametric modeling for architectural form finding	

Introducing the innovative tool of the Building Sector	placement techniques of clay products and on their life cycle.
Intelligent Services For Energy-Efficient Design and Life Cycle Simulation	The combination of energy profile models with product development STEP models and building and facility BIM models
Collaborative Holistic Design Laboratory and Methodology for Energy-Efficient EMBEDDED Building	integrated information management framework
Semantic Web for Information Modelling in Energy Efficient Buildings	building energy management.
Building As A Service	optimize energy performance in the application domain of non-residential buildings
Occupant Aware, Intelligent and Adaptive Enterprises	develop and validate a holistic energy performance evaluation framework
Robust decision making around building efficiency and occupant comfort	Delivery of SMART building to be established once it is completed
Delivering highly energy efficient hospital centre	41% reduction in fabric loss heat, 29% reduction in carbon emissions,15% reduction in overall energy usage
Design for future climate change - Developing an adaptation strategy	The project would have benefited from fully integrating BIM into IES
Shopping Center using around half the energy of a typical development	50 % energy savings , 50 % savings in water consumption
Use of BIM in design and construction phase to achieve sustainability goals of an office building	Holistically BIM-based project achieved LEED Core & Shell Platinum Certificate.
Design of energy-efficient library with high architectural goals	Energy optimization results impacted for the building and HVAC design
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.
Improving Energy Performance of Office Buildings Based on Light Building Information Model (BIM)	Minimal information requirements for energy simulation is highlighted in the study.
Retrofit alternatives based on energy simulations	BIM model used for sensitivity analysis simulations as well as AHU groups, room specific internal loads and ventilation rates need were model based input.

Collaborative optimisation of building performance during concept design phase	results help all participants to understand and and assess the energy specific results
De Lacy Row	benefit from its social agenda for providing local jobs to is workforce and good quality affordable housing at a price that is no greater than what it would cast to get external contractors to build.
Energy properties of solar shading devices and their impact on the visual comfort of occupants	Integration of multidisciplinary approach for the choice of solar shading
Use of BIM for ESD Analysis of BCA Academic Tower	achieving energy efficiency by leveraging the BIM model and performing several types of energy analysis and simulations.

7 Questionnaire analysis

As it was not trivial to get access to use cases in BIM and Energy Efficiency in all of the consortium's countries, it was obvious that this trending topic was not mature enough in a lot of European country. So, we have conducted interviews with 15 BIM industry experts[2] from Europe in order to have a more global understanding of the maturity associated with BIM applied for Energy Efficiency, and to determine gaps and requirements in this field. The results of these interviews are reported below and a full repository of the interviews is provided in Appendix B see Figure 26.

7.1 Section 1: Experience

We have interviewed 15 experts from different fields of BIM expertise. Table 13 presents the distribution of experts with associated fields of expertise.

Q1: What is your field of expertise?

Table 13: Field of expertise

No.	Experts consultation	Experts
1	Research in BIM assessment	4
2	Architecture service	3
3	Design and construction	3
4	Training of EE and durability of construction	3
5	Applied technology for design and engineering project delivery	2
6	Sustainable design	2
7	Physics of building	1

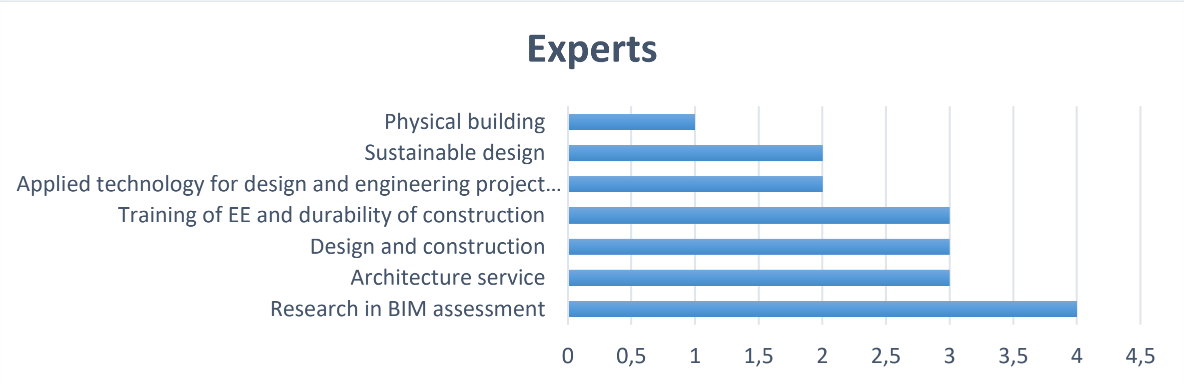


Figure 22: Field of expertise answers

Figure 22 shows the BIM expertise of the experts such as: research in BIM assessment, architecture service, design and construction and training of energy efficiency and durability of construction. Also we have managed to interview experts with fields of expertise in applied technology for design and engineering project delivery, sustainable design, and physical building.

Q2: Could you please give a brief of your historic experience of using BIM?

[2] Note for the understanding of the following data tables: Amongst these 15 experts, several of them mentioned multiple fields of expertise.

Table 14: Experience with BIM

No.	Experts consultation	Times
1	Used BIM in multiple ways and its software	15
2	Use BIM for EE	3
3	Energy designer	3
4	Developing BIM training course	2

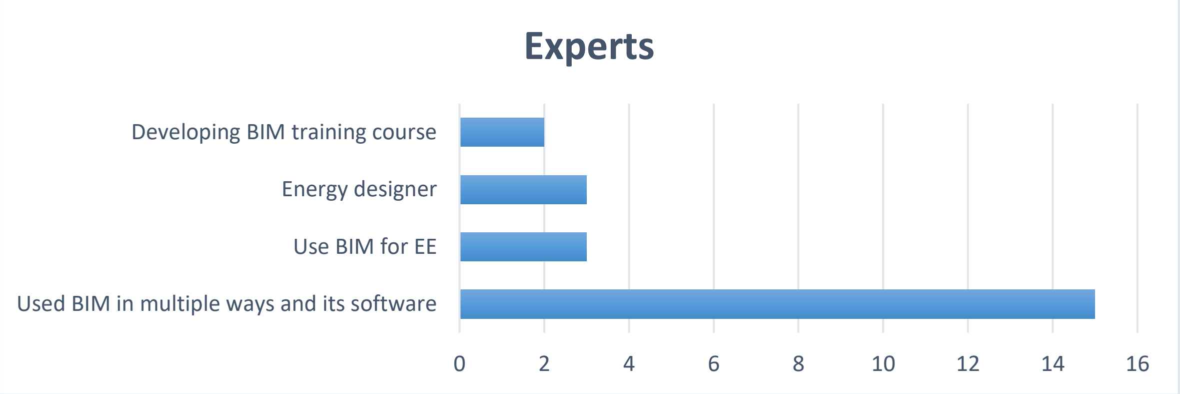


Figure 23: BIM experience with experts

The main objective of the interviews was to target experts who have experience in a wide range BIM activity so the aggregated feedback can be comprehensive and inspired from industrial experience. Figure 23 and Table 14 presents the experts' historical experience where two-thirds of the experts have experience of using BIM in multiple ways and they have good experience also with BIM software.

Q3: What aspects of BIM are (were) used in the activity and how is the activity related to energy?

Table 15: Aspects of BIM in daily activity

No.	Experts consultation	Times
1	Design Phase	13
2	List of materials	2
3	Research of BIM implementation	1
4	Use of sun (optimisation: windows, orientation, PV)	1
5	Dimensioning of isolation	1
6	Update the models and keep the BIM link operation	1
7	Less printed plans	1

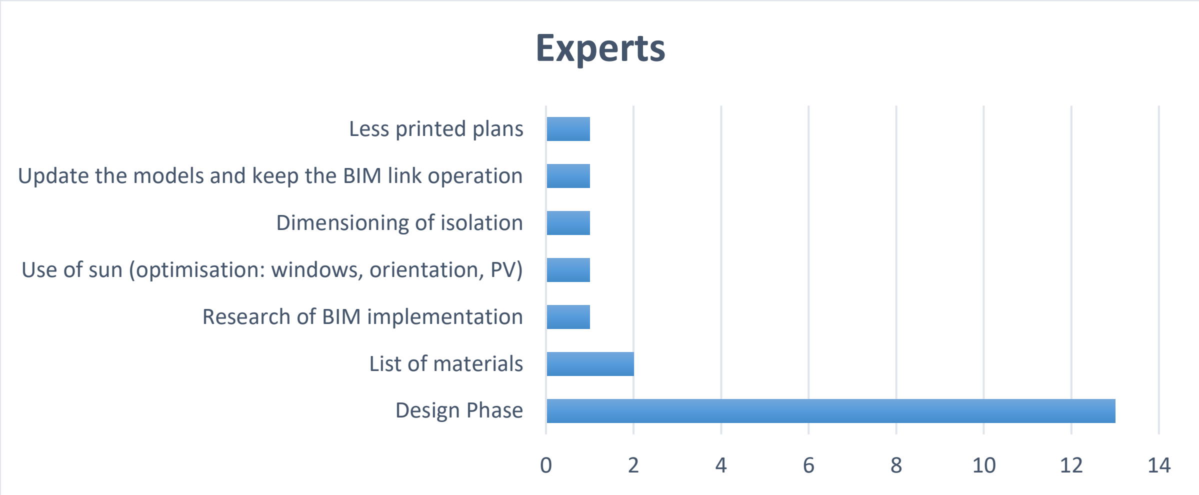


Figure 24:Aspects of BIM in daily activity

Table 15 and Figure 24 illustrate what aspects of BIM are the experts using in their activity related to energy.

Q4: What is (was) your role discipline in construction projects?

Table 16: Expert discipline role in projects

No.	Experts consultation	Times
1	Project manager	6
2	Architects	5
3	Training for stakeholders about EE in buildings	3
4	Planning and consulting of EE in buildings	4
5	Researcher and teacher in university	2
6	Real-estate maintenance data management consult	1
7	Structure	1

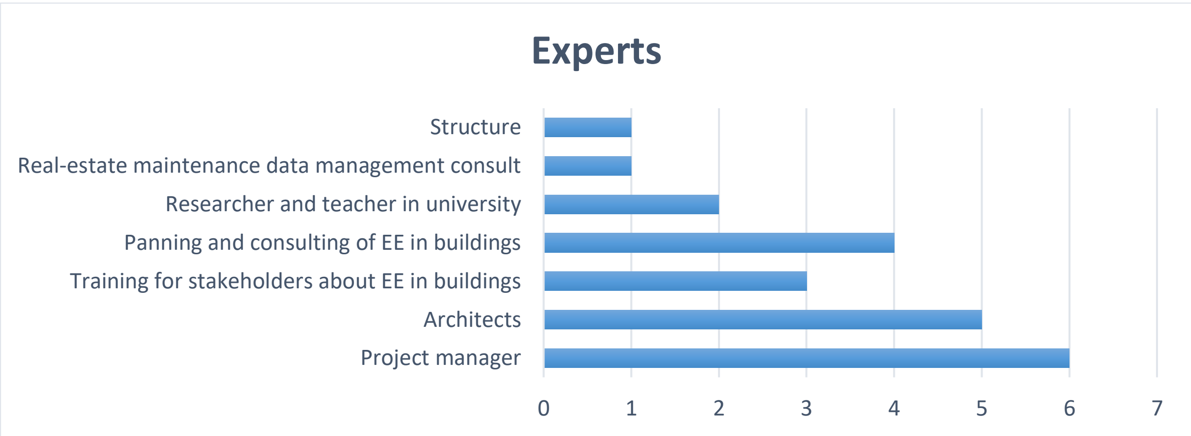


Figure 25: Expert disciplines

Figure 25 and Table 16 show the disciplines of the experts used in the consultation process.

Q5: Is there any use case that you have been used BIM for Energy Efficiency?

Table 17: Number of use cases

No.	Experts consultation	Experts
1	yes	10
2	No	5

Section 1: Experience

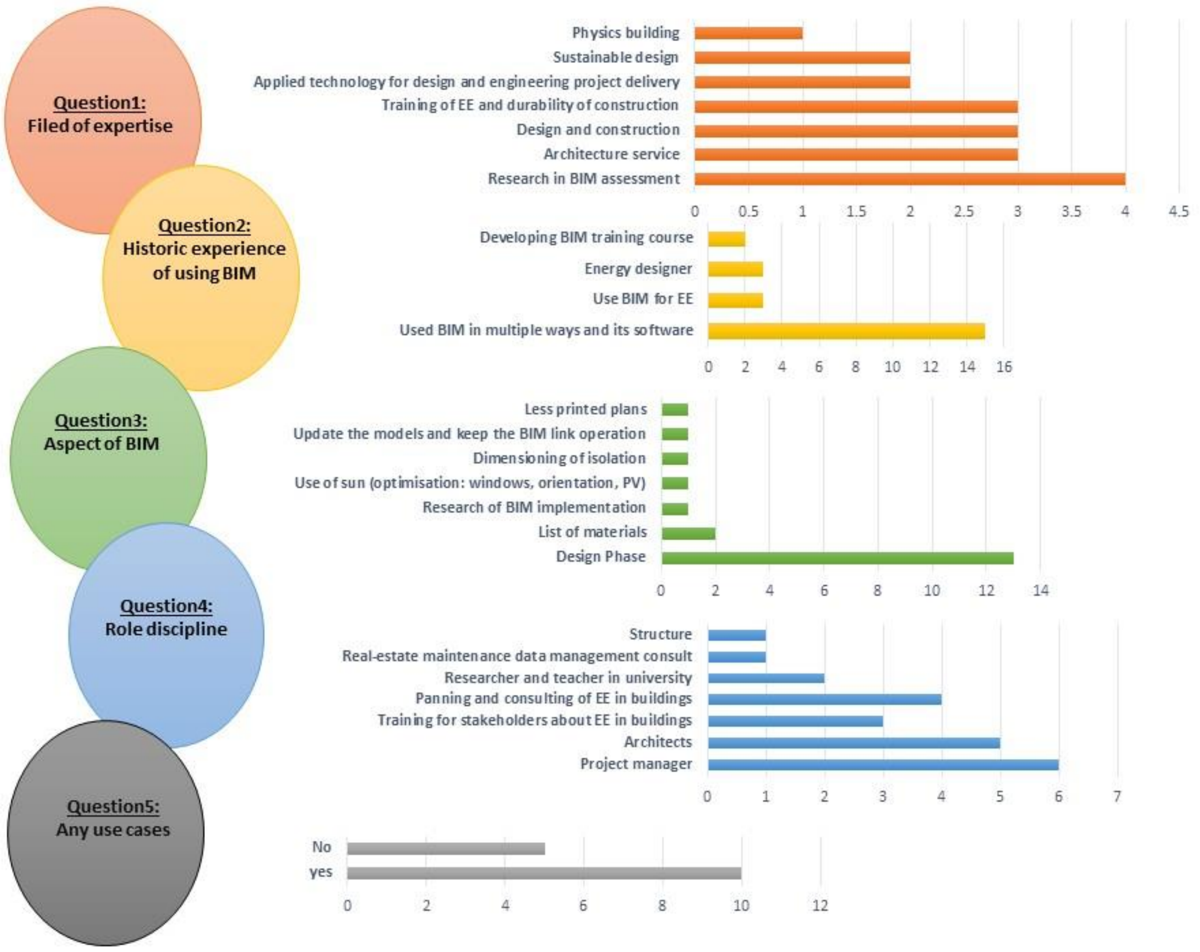


Figure 26: Experts background summary

7.2 Section 2: Skills and Training

In this section, experts are asked to specify required skills to improve BIM management with particular emphasis on energy efficiency see Figure 37.

Q6: Could you please identify for each discipline involved (designers, contractors, ranging from site superintendent to blue collar workers) the skills they require to handle BIM data for the purpose of energy efficiency?

Table 18: Required skills to handle BIM data for the purpose of energy efficiency

NO.	Designer	Answer	Contractors	Answer	Blue collar worker	Answer
1	Capability to use CAD programs and other EE software	8	Skills to separate the information needed	4	Knowledge of reading the plans and separate the information needed	3
2	Knowledge about the principle of EE & sustainable	5	Knowledge how to use BIM	3	Accurate implementation of BIM plans and construction specs	1
3	Maintaining data of different variation and solutions	3	BIM training ability to implement BIM construction with energy space	3	Understanding of the functioning of the building utilities	2
4	Formulating the model with EE simulation programs	2	Collaborate with designer to manage the information from the model	3		
5	Good communication between designers, client, supplier	2				

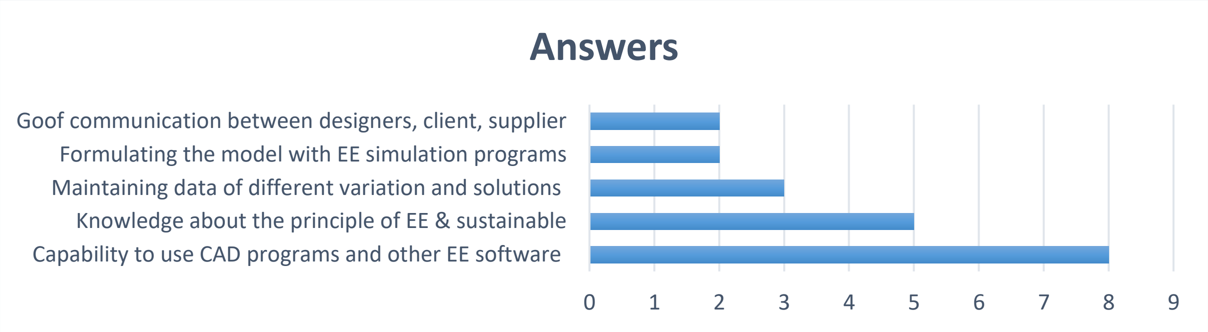


Figure 27: The required skills for designers

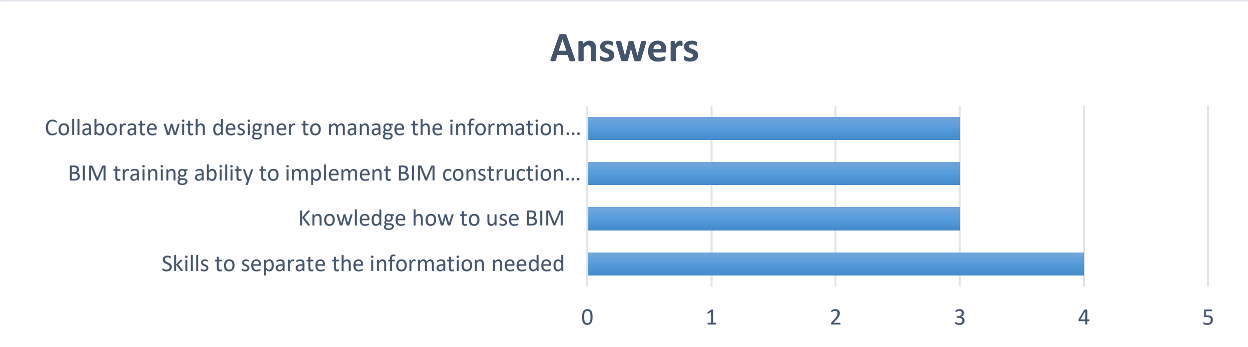


Figure 28: The required skills for contractors

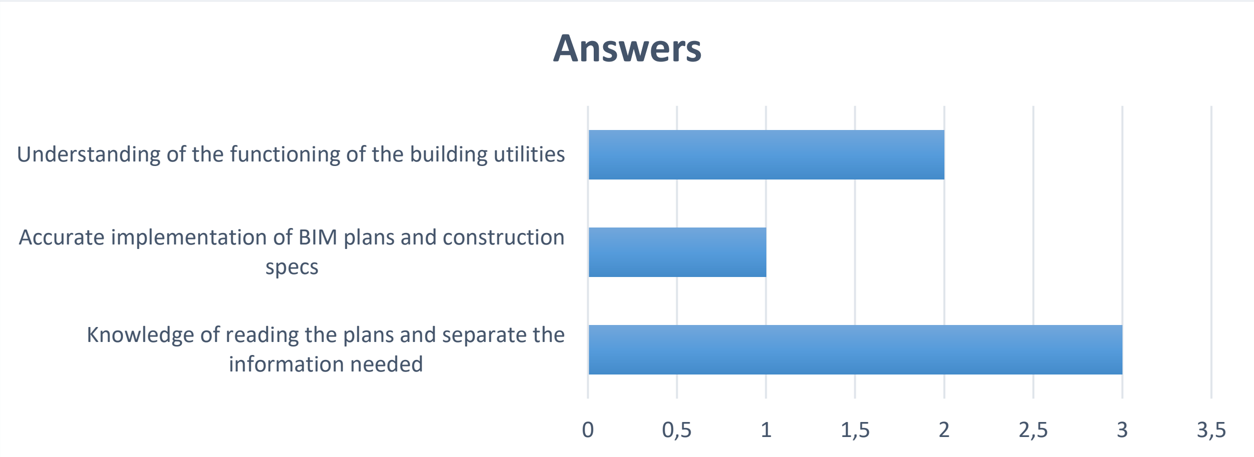


Figure 29: The required skills for blue collar worker

Table 18 presents the set of skills that have been identified by the experts as important for handling BIM data for energy efficiency associated with role of designers, contractors, and blue-collar worker. There are several skills highlighted by experts for designers and presented in Figure 27: (1) Capability to use CAD programs and other EE software, (2) Knowledge about the principle of EE & sustainable, (3) Maintaining data of different variation and solutions, (4) Formulating the model with EE simulation programs, and (5) Good communication between designers, client, supplier. A high percentage of answers identify that an important skill for managing BIM for energy efficiency is the capability to use CAD programs and other EE software and knowledge about the principle of EE & sustainable.

The identified contractor skills (see Figure 28) in BIM for energy efficiency are: (1) Skills to separate the information needed, (2) Knowledge how to use BIM, (3) BIM training ability to implement BIM construction with energy space, and (4) Collaborate with designer to manage the information from the model. The four skills have almost the same degree of importance as recorded from the interviews, therefore these skills should be considered for a further training course for improving BIM competencies in the field of energy efficiency.

One of the main disciplines in the industrial construction activity is the blue-collar workers and as presented in Figure 29 the identified skills are: (1) Knowledge of reading the plans and separate (*i.e extract*) the information needed, (2) Understanding of the functioning of the building utilities, and (3) Accurate implementation of BIM plans and construction specifications.

In addition, from Table 18, it can be observed a set of common gaps that are identified for improving BIM for energy efficiency. Such common skills are related to knowledge about principles of BIM and energy efficiency, skills to separate the information needed and good communication between the disciplines in projects.

Q7: Based on experience, what skills are lacking at the moment for using BIM for Energy Efficiency in the construction field?

Table 19: Skills are lacking for using BIM for Energy Efficiency

NO.	Experts consultation	Answers
1	Link between different software-tools	5
2	Understanding to find good solutions to get to fine level of EE	5
3	Understanding what the impacts of using BIM for EE	4
4	Architects BIM-model are not compatible with energy simulation programs	3
5	Energy designer must construct an own model for conducting the simulations	3
6	BIM EU legislative framework/ standards	2
7	Complicated to find training sessions	2

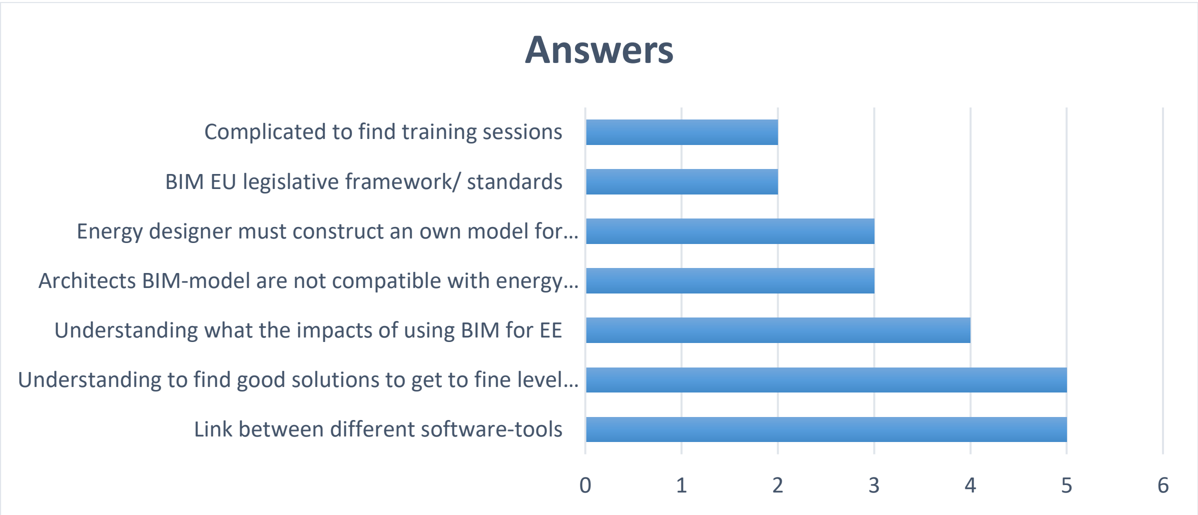


Figure 30: Skills lacking for using BIM for Energy Efficiency

Based on the experience of the interviewed experts, Figure 30 shows what skills are lacking at the moment for using BIM for energy efficiency in the construction field. As in Table 19, a high degree of importance has been given by the experts for shortage of skills related to the link between different software-tools, understanding and finding good solutions to get to a fine level of energy efficiency, and understanding what the impacts of using BIM for EE.

Furthermore, almost 40% of the experts highlighted that other gaps necessary for using BIM in energy efficiency are related to: architects BIM-model are not compatible with energy simulation programs, energy designer must construct their own model for conducting the simulations, BIM EU legislative framework/ standards, and complicated to find training sessions. Such limitation and lack of skills need to be addressed by developing appropriate training programs for using BIM for energy efficiency.

Q8: What are or could be the particular ways to enhance the stakeholders' skills for using the BIM for Energy Efficiency in the project? According to:

I. Blue collar workers: workers, technicians:

Table 20: The particular ways to enhance the blue-collar workers' skills

No.	Experts consultation	Answers
1	Training and field meetings to explain the specific plans	3
2	Know –how of how to order proper models	1
3	Best practice modelling guidance	1
4	Change the old attitude to add value gained from use BIM.	1
5	They should not be held responsible with this sort	1

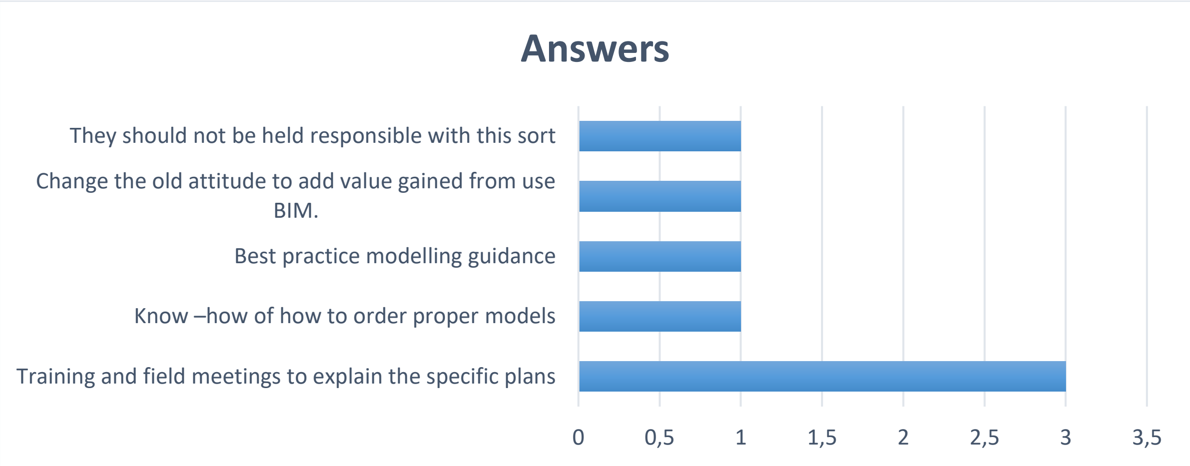


Figure 31: The particular ways to enhance the blue-collar workers' skills

II. Designers/Engineers

Table 21: The particular ways to enhance the designers/engineers' skills

No.	Experts consultation	Answers
1	Energy, BIM and data management training and educating	7
2	Understand the essence of simulation and to apply the result in practice	5
3	Awareness of BIM for EE	4
4	Adopt a BIM energy workflow for early decision making	4

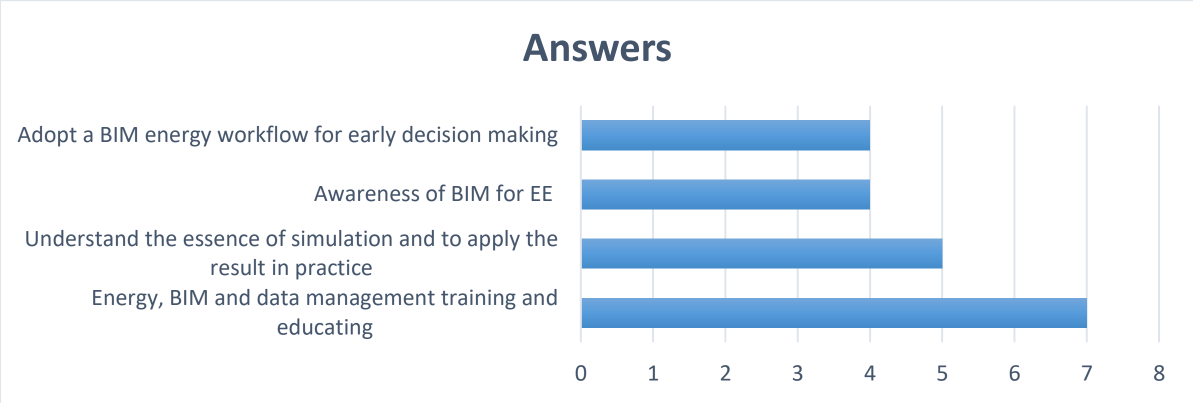


Figure 32: The particular ways to enhance the designers/engineers' skills

III. Contractors

Table 22: The particular ways to enhance the contractors' skills

No.	Experts consultation	Answers
1	Educating and training understand the needs	3
2	Work (consultants/designers/workers) to use BIM for EE	2
3	Ability to maintain and update information from the BIM model	2
4	Visualizing model	1
5	Use BIM platforms to manage product data	1

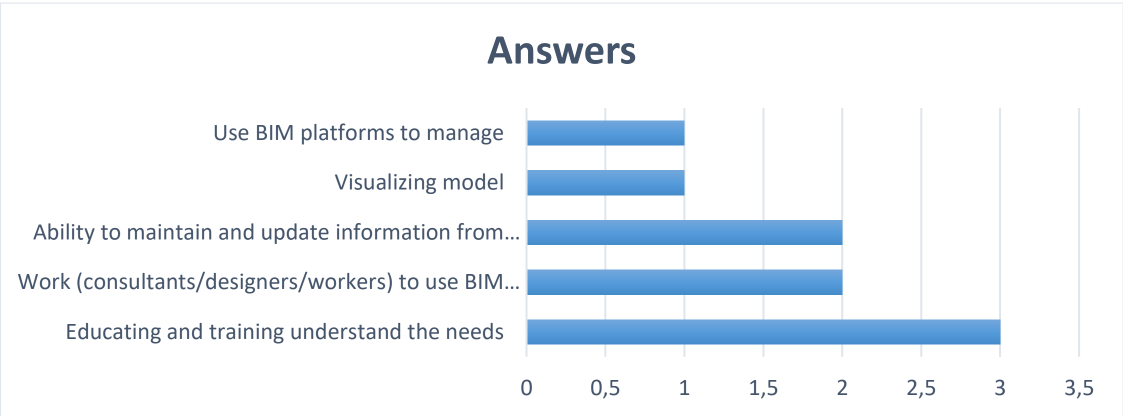


Figure 33: The particular ways to enhance the contractors' skills

IV. Facility management teams

Table 23: The particular ways to enhance the facility management teams' skills

No.	Experts consultation	Answers
1	Ability to extract and update information from BIM model	4
2	BIM for EE training	2
3	A guiding handbook	2
4	Work with BIM manager and energy consultant	1

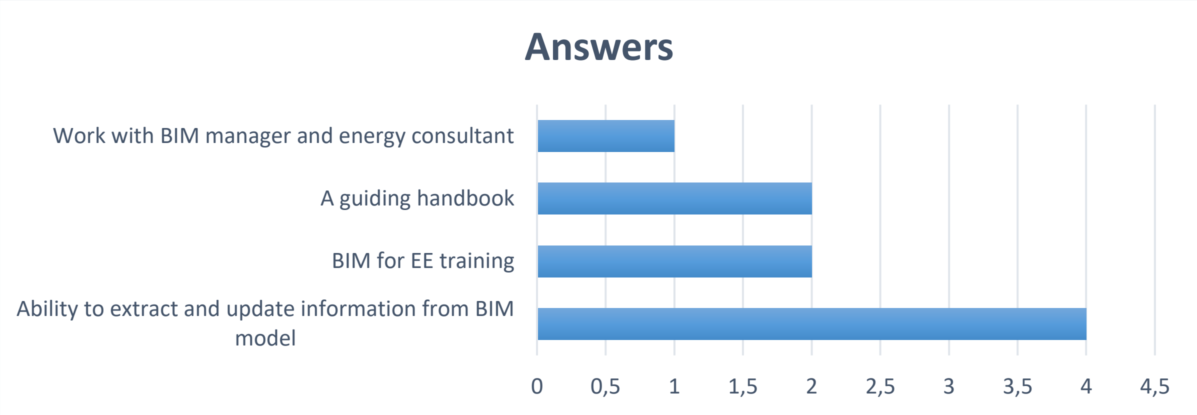


Figure 34: The particular ways to enhance the facility management teams' skills

To enhance the stakeholders' skills for using BIM for energy efficiency in the project (see Table 20, Table 21, Table 22, and Table 23), the experts highlighted several methods to enhance these skills according to:

1- Blue collar workers: workers, technicians

2- Designers/Engineers

3- Contractors

4- Facility management teams

For blue-collar workers, the experts mentioned that training and field meetings to explain the specific plans represents an efficient method for improving the BIM skills (see Figure 31). Experts have also reported as important skills the "Know–how" of how to order proper models, find best practice modelling guidance, change the old attitude to add value gained from using BIM. On the hand, one of the experts highlighted that blue-collar worker should not be held responsible for this sort of work and this is beyond their job description and knowledge.

Similarly, the particular methods to enhance the designers'/engineers skill are BIM data management training and educating, understand the essence of simulation and to apply the result in practice, increase the awareness of BIM for EE, and adopt a BIM energy workflow for early decision making (see Figure 32).

Moreover, based on experts' consultations in Figure 33, there are several ways to enhance the contractors' skills as third of the experts have listed educating and training as a requirement to understand BIM and increase practices. Other experts have highlighted novel methods to improve skills such as: encourage (consultants/designers/workers) to use BIM for EE, ability to maintain and update information from the BIM model, visualizing model, and use BIM platforms to manage product data.

Furthermore, the facility management teams need different ways to develop their skills for using BIM for energy efficiency. Based on the experts, recommendation some solutions report as important the ability to extract and update information from BIM model. One of the experts reported as necessary condition to increase BIM practices the work with BIM manager and energy consultant to enhance facility management teams see Figure 34.

According to experts' consultation, these methods have been suggested to enhance the stakeholders' skills and corresponding training is required for using BIM for energy efficiency.

Q12: Is your organisation support the training BIM for Energy Efficiency?

Table 24: The role of organisations to support BIM for Energy Efficiency

NO.	Yes, brief description	Experts	No, why	Experts
1	Training; utilizing BIM in energy design	8	Hand of experience is the best training	3
2	Teaching software programs; BIM for EE	3	Have no time to make energy simulation	2
3	Continuous learning: issue with standardization	1	Currently working on integration BIM training.	1
4	Skills of BIM coordinators and BIM manager should be defined	1	Not important	1
5			University is not company	1

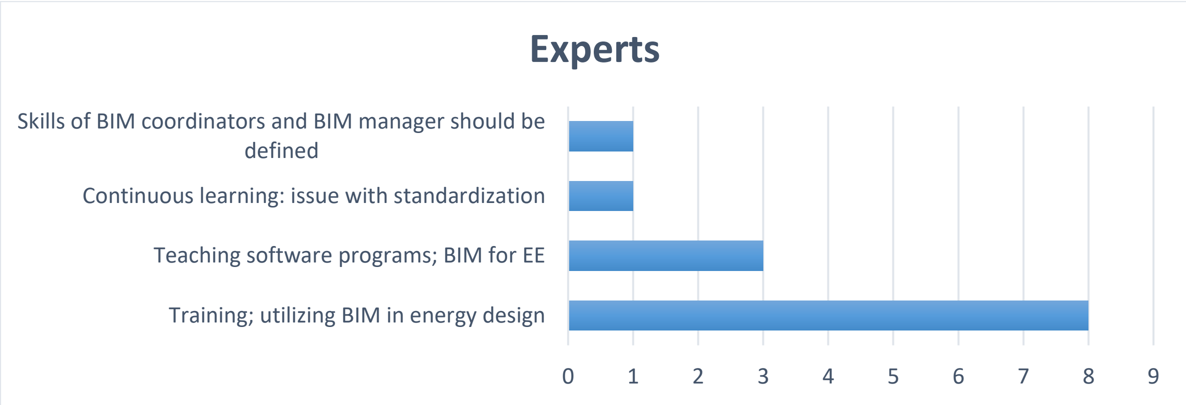


Figure 35: The role of organisations to support BIM for Energy Efficiency

Figure 36: The reasons for organisations to not support BIM for Energy Efficiency

To understand the role of the organisations to support the training BIM for energy efficiency, experts have provided several insights on what aspects need to be addressed, see Table 24 . As in Figure 35, experts have reported that organisations should support the training BIM for energy efficiency. More than 60% of experts highlighted that their organisations undertake training programmes on utilizing BIM in energy design. Also more than 20% of the experts consider that teaching software programs for using BIM for EE, is important alongside continuous learning: issue with standardization and skills of BIM coordinators.

On another hand, as reported in Figure 36, some of the organisations have no training programs to their staff and as reported in the interviews using hand of experience is the best training for the members of staff. Other organisations seem not to have time to make energy simulation training and other organisations do not support the training considering that the training is not important, whereas other institutions are reported to be working on integrating BIM training.

Figure 37: The skills and trainings summary

7.3 Section 3: BIM for Energy Efficiency

In this section, experts are asked to determine which are the advantages of using BIM for energy efficiency in relation to the project lifecycle see Figure 41.

Q9: What are the benefits of using BIM for Energy Efficiency during the lifecycle of the project?

Table 25: the benefits of using BIM for Energy Efficiency

NO.	Expert consultation	Answers
1	Design phase: BIM is constantly updated, energy performance can be controlled	8
2	Linking monitoring O&M measurements to BIM	4
3	Managing banks of material and analysis them	3
4	Giving better information as result and less mistakes	3
5	All participate work on the same version	2
6	Building system and upcoming users behaviour has been taken	1
7	In BIM project, energy simulation are more realistic about the design	1

Figure 38: Benefits of using BIM for Energy Efficiency

According to the experts' consultation see Table 25, there are a lot of benefits of using BIM for energy efficiency during the lifecycle of the project. Figure 38, demonstrate that several benefits are in the design phase: BIM is constantly updated, energy performance can be controlled. Also, many advantages are managing banks of material and analysis them and giving better information as result and fewer mistakes. In addition, linking monitoring operation and maintenance measurements to BIM has been mentioned by four of the experts as significant benefits. Other highlighted other benefits, for instance, all participate work on the same version, building system and upcoming users behaviour has been taken, and in BIM project, energy simulation is more realistic about the design. All these benefits confirm our previous findings that stable BIM training courses are required.

Q 10: What are the common barriers to use BIM for Energy Efficiency in the industry?

Table 26: The common barriers to use BIM for Energy Efficiency

NO.	Expert consultation	Responses
1	Lack of understanding the use and potential of BIM	5
2	Different software-tools.	3
3	Lake of expertise that able to use these difficult programs	3
4	Tight schedules	2
5	The cost of programs is very high	2
6	Internet issues	2
7	Achieving a proper BIM model	2
8	Lack of fundamental skills	2
9	Lack of information management standards	1
10	Lack of real case studies where BIM and energy are successful implement	1

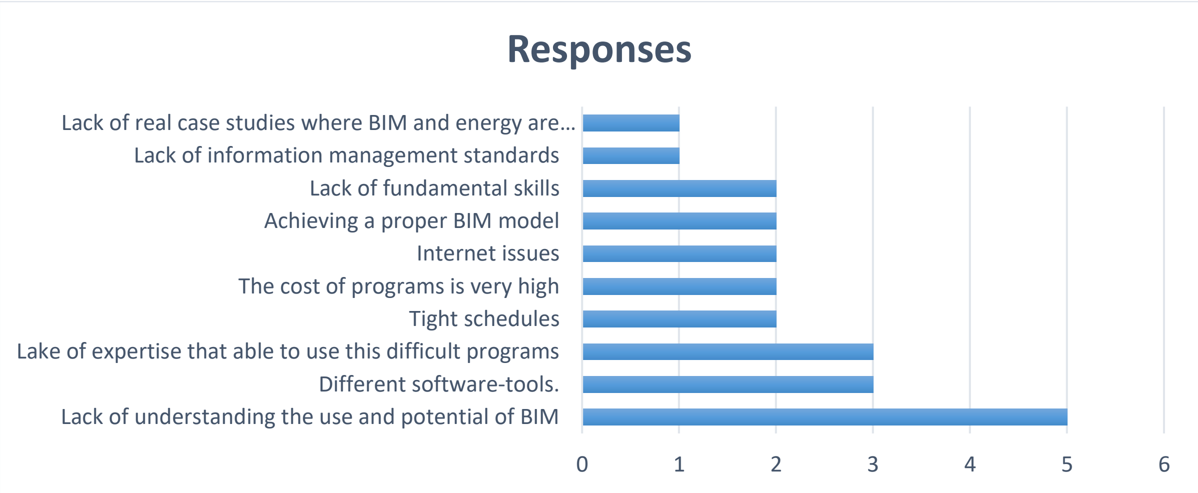


Figure 39: The common barriers to use BIM for Energy Efficiency

Table 26 shows many benefits of using BIM for energy efficiency, however, there are several barriers with using BIM for energy efficiency in real industrial applications. Figure 39 illustrates that an important barrier is the lack of understanding of the use and potential of BIM, followed by diversity of software-tools, and a lake of expertise in using these difficult programs. Some barriers are listed twice such as tight schedules, the cost of programs is very high, Internet issues, achieving a proper BIM model, and lack of fundamental skills. Other experts mentioned other barriers such as the lack of information management standards and the lack of real case studies where BIM and energy are successful implemented.

Q 11: What are your recommendations to enhance using the BIM for Energy Efficiency in the construction industry?

Table 27: The experts' recommendations to enhance using the BIM for Energy Efficiency

NO.	Expert consultation	**Responses**
1	Assessment performance evaluation and appropriate training mechanisms	6
2	The useful tools should be utilized as early stage of the project	4
3	Incentivise the adoption of BIM for EE	4
4	Use professional BIM-coordinator	1
5	Do not accept excuse but instead demand investigation why energy target are not actualized	1

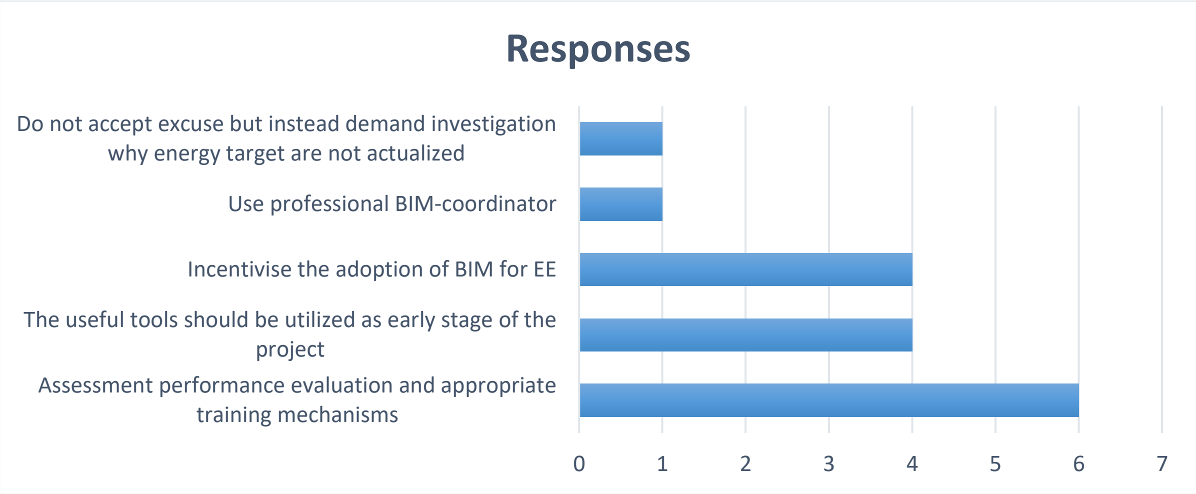


Figure 40: The experts' recommendations to enhance using the BIM for Energy Efficiency

Table 27 highlights that the majority of experts identify the need to do assessment performance evaluation and appropriate training mechanisms for BIM. BIM tools should be utilized as an early stage of the project, and incentives on the adoption of BIM for EE are determined as important recommendations. These recommendations will feed into the implementation phase on the BIMEET project and will be considered when developing the training programs for using BIM for energy efficiency see Figure 40.

Figure 41: BIM for Energy Efficiency summary

8 Requirements for training in BIM for energy efficiency

This section identifies a set of general and specific requirements for developing BIM skills, competencies and training with particular emphasis on energy efficiency as informed by the use-cases analysis, interview analysis and feedback acquired during the consultation workshop.

8.1 General requirements

There is a growing trend towards the adoption of BIM in the construction industry, because of its significant role in addressing several issues related to collaboration during construction projects, in addition to increasing stringent regulatory enforcements. However, this adoption of BIM requires the construction team to accept new collaborative methods.

The key findings reveal that construction industry still faces many issues and barriers with respect to socio-organisational, e.g. ‘people resistance to change’; legal, e.g. ‘lack of defined liability for wrong or incomplete information input’; financial, e.g. ‘training cost’; and technical, e.g. ‘lack of technical training’ that leads to negative impacts on team collaboration during the project. Although ICT and collaboration practices exist to a significant extent in construction projects, the current level of ICT and collaboration practices used in the industry does not support the adoption of collaborative BIM. Moreover, the use of inadequate data management solutions results in data errors, inconsistency, and poorly produced documents, which might have negative effects on the progress of construction projects. Further, there are more specific data-related issues including data inconstancy, compatibility, accessibility, security, and data storage problems.

In this report we have critically reviewed and investigated the current BIM practices landscape and gathered the requirements for developing a BIM training scheme to address current industry collaboration problems on projects. The aim of this solution is to facilitate and to govern the collaboration processes of construction teams taking into account construction practitioners’ requirements. Further, a number of requirements for developing a training scheme have been identified and classified into two main categories: (a) socio-organisational and legal requirements and (b) technical requirements. In addition to contributing to the growing body of BIM adoption and collaboration knowledge, this report underlines the importance of BIM training laying out as the foundation for future research and development in this area.

8.2 Specific requirements

This subsection provides the list of gaps as identified by the use-case analysis and validated by the interviews conducted. Table 28 presents the gaps that have been identified in the analysis of the use-case whereas Table 29 provides a list of requirements determined from the process of interviews.

Table 28: Use cases analysis identified gaps

No.	Parameters	Requirements and training
1	***Use case type***	Users need training in understanding and applying BIM Guideline (See Table 2)
2	***Building type***	Training is required for enhancing skills and competencies for using BIM for industrial and commercial buildings (See Table 3)
3	***Project type***	Training is required for expanding BIM applicability for renovation and extension projects (See Table 4)

4	***Target discipline***	Training is required for education on BIM methodology towards mechanical and structure engineers (See Table 5)
5	***Lifecycle stages***	Training is needed to address other RIBA stages lifecycles such as Strategic Definition, Preparation and Brief, Construction, and Handover and Closeout (See Table 6)
6	***Impacts on discipline***	Increase BIM applicability and impact for architecture and design, structural engineers, mechanical engineers (See **Error! Reference source not found.**)
7	***Impacts on building type***	Increase BIM applicability and impact for domestic, commercial and industrial projects (See **Error! Reference source not found.**)
8	***Impacts on project types***	Increase BIM applicability and impact for renovation and extension projects (See **Error! Reference source not found.**)
9	***Impact of project lifecycles***	Increase BIM applicability and impact for all RIBA stages (See **Error! Reference source not found.**)

Table 29 presents a summary of findings and associated requirements as recorded in the interviews. The experts have specific inputs for BIM training for industrial roles such as designers, blue collar workers and contractors. A particular emphasis was on the BIM software tools and the necessity to approach specialised training programs which can help actors to understand and utilise such tools. At the organisational level the experts have presented several strategies that can be adopted to improve staff BIM skills and practices.

Table 29: Questionnaire identified gaps

NO.	Parameters	Requirements
1	***The skills they require to handle BIM data for energy efficiency***	**Designer:** Formulating the model with energy efficiency simulation programs, maintaining data of different varieties and solutions. Good communication between designers, clients, and suppliers. **Blue-collar worker:** Basic understanding of use cases at design time, communication with clients and contractors to ensure best practice. **Contractors:** Knowledge on how to use BIM and training ability to implement BIM for energy efficiency, collaborate with the designer to manage the information from the model (See Table 18)
2	***The skills are lacking at the moment for using BIM for Energy Efficiency***	The link between different software-tools, finding suitable solutions to promote BIM in EE, understanding the impacts of using BIM for EE (See Table 19)
3	***The particular ways to enhance the stakeholders' skills for using the BIM for Energy Efficiency***	**Blue-collar workers:** Training and field meetings to explain the specific plans.

		Designers/Engineers: Energy, BIM and data management training and educating, understand the essence of simulation and to apply the results in practice (See Table 20, Table 21, Table 22, and Table 23)
4	***The training in BIM for Energy Efficiency by organisation***	Teaching software programs; BIM for EE, Continuous learning: issue with standardisation, skills of BIM coordinators and BIM managers should be defined. **Contractors:** Educating and training should be adapted based on specific requirements **Facility management teams:** Ability to extract and update information from BIM models (See Table 24)
5	***The common barriers to use BIM for Energy Efficiency***	Lack of understanding the use of BIM, limitation in using different software-tools, lack of expertise in using BIM programs (See Table 26)
6	***Recommendations to enhance using the BIM for Energy Efficiency***	Assessing the performance and appropriateness of the training mechanisms, tools should be utilised in the early stage of the project, incentivise the adoption of BIM for EE (See Table 27)

8.3 Community engagement requirements

As construction projects involve multi-discipline, multi-actor collaboration during the project lifecycle results from the survey also explored the current ICT and collaboration practices among the team on typical BIM construction industry projects.

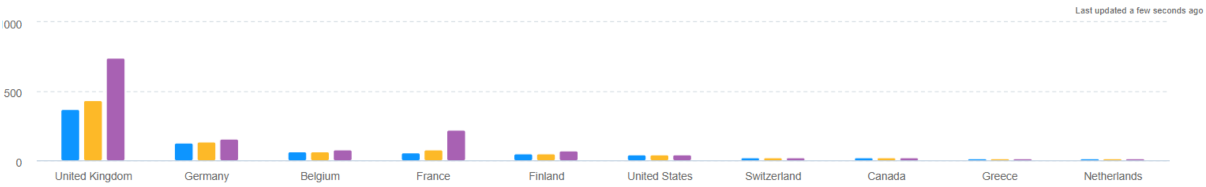
Setting up, maintaining a team collaboration environment is a very important task on collaborative construction projects. From the analysis most respondents agreed that project managers are responsible for preparing the construction project's collaborative environment and agreed that the responsibility of this varies from one project to another.

The establishment of online communities requires a robust mechanism for controlling interactions between end-users and their access to resources. With the proposed platform, we intend to contribute to the establishment of online engineering communities which assumes the existence of trust between users within such a system, thereby overcoming some of the restrictions to sharing and information exchange which is a major problem in the online engineering communities. For instance, in the context of such a community, clients and providers from construction industry can contribute with their own resources in addition to making use of resources provided by others (at different times and for access to differing services).

This symbiosis of technologies, knowledge representation and artificial intelligence concerned with sustainability in constructing and maintaining (potentially complex) models of the world can enable new business models such as online communities, online market places and advertising supported site and can offer facilities for using user profiles (including personal data) with a view of achieving a higher order of BIM knowledge integration.

Many consultation participants have appreciated professional networking services as key to addressing their perceived barriers to BIM knowledge elicitation and sharing, and also to aid in training issues. The bi-directional nature of such technologies would address the perceived requirement for flexibility, allowing others to add their knowledge. It was noted, however, that provision of enabling initiatives in this way would not guarantee sharing; as one participant stated: “People who ‘get it’ share; those who don’t, won’t.”

We have exposed the energy-bim.com platform as an online location for creating a community of users in the filed on BIM training for energy efficiency. From the monitoring interval between December 2017-February 2018 we have attracted new users and identified an increase number of visits. Using the Woopra analytics bellow we provide several statistics on the platform web activity. Figure 42, illustrates the total amount of visits of the **energy-bim.com** platform over a trial period of 3 months.

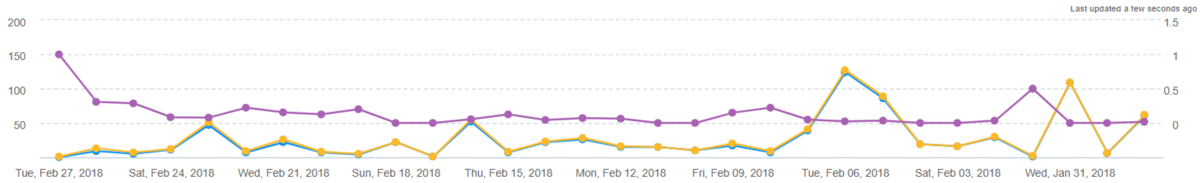


Countries	People	Visits	Actions
United Kingdom	372	439	740
Germany	131	134	160
Belgium	61	64	81
France	57	79	224
Finland	47	48	70
United States	44	44	44
Switzerland	22	22	24
Canada	20	20	20
Greece	17	17	17

Figure 42: Statistics for energy-bim.com web activity

Analysing the visitors’ geographical provenience from Figure 42, it has been identified that the platform presents interest not only of UK visitors but also for US or other EU countries.

From the initial statics presented in Figure 43, it can be concluded that the proposed web portal (a) has the potential to engage further practitioners in delivering BIM interventions as inferred through our portal validation work, and (b) contributes to the ongoing debate and BIM integration in the energy efficiency domain. In addition, the diversity of technologies can contribute to the emergence of new business models and contribute to the development of online market places for the construction industry. A new release of the energy-bim.com platform search capabilities is scheduled as well as the online support and interface features in order to develop an effective and easy-to-use BIM training dedicated platform for the energy sector.



Return Rate	New Visitors	All Visitors	Return Rate
Tue, Feb 27, 2018	**0**	**1**	**100%**
Mon, Feb 26, 2018	**9**	**13**	**31%**
Sun, Feb 25, 2018	**5**	**7**	**29%**
Sat, Feb 24, 2018	**11**	**12**	**8%**
Fri, Feb 23, 2018	**47**	**51**	**8%**
Thu, Feb 22, 2018	**7**	**9**	**22%**
Wed, Feb 21, 2018	**22**	**26**	**15%**
Tue, Feb 20, 2018	**7**	**8**	**12%**
Mon, Feb 19, 2018	**4**	**5**	**20%**
30 Result(s)	796	801	1%

Figure 43: Returning visitors and visits for energy-bim.com

Thus, the provision of BIM training and facilities is viewed as highly important for such a community. Combined with this is the need for information and knowledge regarding legislation and also facilities to enable procurement. Whilst the proposed platform is being developed initially for BIM training, it also emerges that participants view it as having the potential to provide necessary BIM education to the general public and thereby aid in the promotion of behavioural change.

9 Conclusions

In this report we address 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 involves the BIMEET expert panel with a view to reach key stakeholder communities with a view 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 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 BIMEET 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.
As part of this report, the main objective was to identify the gap between the demand of skills and the learning for BIM application in energy efficiency. We have used a consultation driven methodology and use-cases aggregation techniques supported by a semantic searching engine to facilitate submission of BIM queries with sets of associated ontological concepts for recording “live” BIM knowledge and to search for best practices. The consultation process has helped both in defining skills related to BIM technology and associated application for energy efficiency in buildings and, in identifying the BIM training requirements across the value chain (from blue collar workers to middle/senior level workers).

Therefore, in this report we have addressed two major objectives:

1. Identify critical gaps in terms of BIM skills and related training offer based on an assessment of the current situation and,
2. Deliver a set of requirements as derived from the consultations, interviews and use-cases analysis.

Our approach has started from the consultations process that identified, analysed, and assessed construction sector stakeholders’ requirements for BIM training to ensure engagement with energy management in construction. This research revealed a set of perceived barriers to engagement at individual, organisational, and wider industry levels. Based on the research results it was found that an online training repository that provides integrated access to BIM resources (knowledge, expertise, best practice, and software tools and applications) in the form of interactive, dynamic, and user-oriented services may address these barriers.

From the analysis of the consultation results, and the associated literature review, the initial specification of such BIM training and education for energy environment, including the general service requirements, skills to address and organisational policies have been ascertained and described.

We have also identified the need to establish an open BIM community of end-users with access to resources and facilitating training and education programs in order to overcome some of the restrictions to sharing and BIM information exchange which is a major problem in the field.

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Appendix A:

Repository of best practice use-cases

CU

Use Case: 1

Use Cases Title	RESILIENT
Use Case type	Research & Development
Funding source	The European Commission under FP7
Project Title	Resilient
Web Link (URL)	http://www.resilient-project.eu/
Targeted Discipline	Facility Management
Targeted Building type	Public
Project type	New Build
Lifecycle applicability	Operation
Brief description of the case study	This study takes a black box approach to efficient management during the operational phase of district energy systems, using generic algorithms to solve a multi-objective optimisation problem. This study approaches the problem from the supply side, applying optimisation methods through scenarios to an analytic model for a 24 hour period, with the aim of helping decision making. This method takes into account both heat and electricity demand profiles in Ebbw Vale district, in Wales. The model helps compute and analyse optimisation methods and strategies using the generic algorithm for the generation mix. The results convey an increase in profit by 32% in heat production and reduction in CO_2 emissions by 36% in the 24 hour period.
Key Highlights	Multi-objective district management considering emissions, costs and energy efficiency
	Optimisation performed well when algorithm is flexible with both power output and production strategy
	Solution considers all constraints and factors, and can be more beneficial in complicated districts
Supporting best practice case study	The case study is a mixed use site in Ebbw Vale, Wales, consisting of a school, leisure centre, energy cnetre, MSCP, learning zone, and general offices. The validation work involves minimizing operational costs and carbon emissions through matching supply with demand of heat and electricity production.

Scenario Definitions	Holistic Solution
Scenario Definition	This scenario provides two sets of results, one in which the GA is flexible with just the power output of heat and electricity supply, the other where the GA is flexible with both output and production strategy
Control Variables	CHP - Lower Bound: 375kW, Upper Bound: 401kW, Biomass Biolers - Lower Bound: 124kW, Upper Bound: 495kW, Gas Boilers - Lower Bound: 0kW, Upper Bound: 1600kW
Objectives	Minimise operational costs, minimise carbon emissions

<table>
<tr><td></td><td><table>
<tr><td>Effective Environmental Variables</td><td>Carbon emissions</td></tr>
<tr><td>Control Rules</td><td>Thermal energy supplied must exceed the sum of thermal demand, CHP, gas boilers and biomass boilers have respective upper and lower bounds of power capacities, maximum generations set at 100</td></tr>
<tr><td>Actors</td><td>CHP, Biomass Boilers, Gas Boilers, National Grid</td></tr>
<tr><td>When Applicable</td><td>This scenario is applicable in optimising energy supply for a district area</td></tr>
</table></td></tr>
<tr><td>Learning Outcomes:</td><td>The black box approach using a generic algorithm can be used to define an optimum strategy behind heat production leading to a 32% increase in profit and 36% reduction in CO2 emissions.</td></tr>
<tr><td>Supporting resources</td><td>http://www.ijmo.org/vol6/521-SC006.pdf</td></tr>
</table>

Use Case: 2

Use Cases Title	Innovative Information and Communication Technologies (ICT) platform able to support the optimization of water networks and to enable change in consumer behaviour
Use Case type	Research & Development
Funding source	The European Commission under FP7
Project Title	Water analytics and Intelligent Sensing for Demand Optimised Management (WISDOM)
Web Link (URL)	http://www.wisdom-project.eu/home
Targeted Discipline	Facility Management
Targeted Building type	Domestic
Project type	Existing
Lifecycle applicability	In Use
Brief description of the case study	The WISDOM (Water analytics and Intelligent Sensing for Demand Optimised Management) project aims at developing and testing an intelligent ICT system that enables "just in time" actuation and monitoring of the water value chain from water abstraction to discharge, in order to optimise the management of water resources. The WISDOM project's unique selling point is the combined use of three key elements: the adoption of a semantic approach that captures and conceptualizes holistic water management processes, including the associated socio-technical dimensions (social networks interactions with physical systems).
Key Highlights	To collect real-time data about water consumption at domestic, corporate and city level.
	To deliver an ICT framework for real-time and predictive water management at domestic, corporate and city level.
	To provide a Water Decision Support Environment to enable professionals within the water industry to visualise, manage and optimise the water system.
Supporting best practice case study	The analysis of the processes within the Cardiff pilot it has become apparent that the interaction between control room staff, the water network itself and local controllers are the key interactions. The use case analysis for the Welsh Water control facilities.

<table>
<tr><td></td><td>
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>In Wales there are a number of pilots addressing a variety of scenarios:
• Firstly, we have studied WISDOM’s applicability to the problem of optimizing clean water networks by attempting to optimize, in real time, pumping schedules and service reservoir levels so as to reduce energy consumption.
• Secondly, we have examined how WISDOM can enable the application of data driven modelling techniques to water network data, specific focus in our trial was predicting the occurrence of combined sewer overflows (CSOs) in waste water networks.
• Finally, along with conducting the largest roll out of smart meters in Wales we are also researching consumer behaviour, and developing a range of innovative feedback mechanisms designed to improve on the six monthly feedback UK water users currently receive. This will enable us to determine how water consumers in the UK respond to feedback regarding their water usage and how feedback can be used to motivate them to achieve water savings.</td></tr>
<tr><td>Control Variables</td><td>Water demand, Users behaviours</td></tr>
<tr><td>Objectives</td><td>Demand Improvement: In this scenario we propose that the current trend of ever increasing demand on water networks can be reduced.
Better Understanding of the State of the Water Network: In this scenario we propose that the operations of water suppliers can be made more efficient (in terms of both cost and water consumption).
More Efficient Resource Management: In this scenario we propose that water suppliers can be more resource efficient (in terms of water and energy).</td></tr>
<tr><td>Effective Environmental Variables</td><td>Water resource</td></tr>
<tr><td>Control Rules</td><td>The interaction between control room staff, the water network itself and local controllers are the key interactions.</td></tr>
<tr><td>Actors</td><td>Water consumers, water network operators, local authorities, water management, water products, ICT.</td></tr>
<tr><td>When Applicable</td><td></td></tr>
</table>
</td></tr>
<tr><td>Learning Outcomes:</td><td>The following interactive displays of the technologies developed in WISDOM will be available during breaks and at lunch:
• The WISDOM User interfaces for household water consumers and water network operators.
• Demonstration of the sensing and data collection technologies deployed on the water network and in homes.
• Internet of Things for Water Networks</td></tr>
<tr><td>Supporting resources</td><td>http://www.wisdom-project.eu/documents/84944/90565/WDSA+July+2014+Bari/b827fe2c-5c43-4b98-89cc-662270ab99bc</td></tr>
</table>

Use Case: 3

<table>
<tr><td>Use Cases Title</td><td>Intelligent management and control of HVAC system</td></tr>
<tr><td>Use Case type</td><td>R&D</td></tr>
<tr><td>Funding source</td><td>EU-FP7 funded project</td></tr>
<tr><td>Project Title</td><td>SPORTE2</td></tr>
<tr><td>Web Link (URL)</td><td>http://www.sporte2.eu/</td></tr>
<tr><td>Targeted Discipline</td><td>Facility Management</td></tr>
<tr><td>Targeted Building type</td><td>Public</td></tr>
<tr><td>Project type</td><td>Existing</td></tr>
<tr><td>Lifecycle applicability</td><td>Not In Use</td></tr>
<tr><td>Brief description of the case study</td><td>The European Sport and Recreation Building Stock accounts for approximately 1.5 Million buildings or 8% of the overall building stock. These facilities are unique by their physical nature, their energy consumption profiles, the usage patterns of people inside, ownership, and comfort requirements. SPORTE2 aims to manage and optimize the triple dimensions of energy flows (generation, grid exchange, and consumption) in Sport and Recreation Buildings by developing a new scalable and modular BMS based on smart metering, integrated control, optimal decision making, and multi-facility management.</td></tr>
<tr><td rowspan="4">Key Highlights</td><td>• To increase the knowledge base of sport facilities with respect to energy and energy efficiency</td></tr>
<tr><td>• To develop 4 scalable energy savings modules specific Objectives 3 to Sport Facilities</td></tr>
<tr><td>To validate the system at three pilots</td></tr>
<tr><td>To promote energy efficiency at sport facilities • 30% Energy and CO2 reduction</td></tr>
<tr><td>Supporting best practice case study</td><td>Fidia swimming pool consumes a lot of energy – almost 50% of electricity consumption, and 44% of thermal energy in the site. Swimming pools loose energy in many different ways. Out of these evaporation is one of the largest sources of energy loss.
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>This scenario proposes air treatment in the zone which aims to provide sufficient indoor ventilation to control indoor humidity levels caused by large amount of evaporation. By controlling the room temperature set point and supplied air flow, the scenario aims to maintain comfort requirements whilst reducing energy usage</td></tr>
<tr><td>Control Variables</td><td>Air temp. inlet Supplied air flow into room</td></tr>
<tr><td>Objectives</td><td>Minimization of energy consumption; maximize of the comfort</td></tr>
<tr><td>Effective Environmental Variables</td><td>Occupancy, Indoor relative humidity Indoor room temperature, Water temperature.</td></tr>
<tr><td>Control Rules</td><td>Relative humidity < 70%
24 ◦C < water temp. < 30 ◦C</td></tr>
</table></td></tr>
</table>

<table>
<tr><td></td><td><table>
<tr><td></td><td>24 ◦C < room temp. < 27 ◦C
CL in air >3.4 ppm</td></tr>
<tr><td>Actors</td><td>BMS, automation server, facility technician, sensor, actuator</td></tr>
<tr><td>When Applicable</td><td></td></tr>
</table></td></tr>
<tr><td>Learning Outcomes:</td><td>Up to 30% of Energy Saving
Up to 30% Emission reduction</td></tr>
<tr><td>Supporting resources</td><td>http://www.sciencedirect.com/science/article/pii/S0378778814003788</td></tr>
</table>

Use Case: 4

Use Cases Title	An innovative integrated concept for monitoring and evaluating building energy performance (Addressing the gap between predicted and actual building energy performance).
Use Case type	R&D
Funding source	7th Framework Programme (FP7)
Project Title	Portable, Exhaustive, Reliable, Flexible and Optimized approach to Monitoring and Evaluation of building energy performance (PERFORMER).
Web Link (URL)	http://performerproject.eu
Targeted Discipline	Facility Management
Targeted Building type	Public
Project type	Existing
Lifecycle applicability	In Use
Brief description of the case study	The aim of the PERFORMER project is to devise a holistic (total lifecycle, multi-aspects, context-based) building energy monitoring methodology that factors in appropriate energy performance indicators, information models, and simulation tools, to achieve building energy performance targets.
Key Highlights	To devise a holistic building energy monitoring methodology that factors in appropriate energy performance indicators, information models, and simulation tools, to achieve building energy performance targets
	The project will devise a building-oriented and "large scale" energy performance strategy aimed at large clients with extensive building stocks with a view of achieving economies of scale leading to sizeable retrofitting cost savings and reduced pay-back periods.
	To deliver knowledge transfer and embedding related activities, via the elaboration of a PERFORMER replication guide, to ensure results uptake by industry across Europe.
Supporting best practice case study	As a new building the UK pilot site already had a large number of sensors connected to its Siemens BMS over a KNS network. It also had some existing equipment that was not functioning correctly and had to be replaced. (*Llanedeyrn Road, Cardiff CF23 9DT, United Kingdom, Internal floor area: About 3500 sqm)*

Scenario Definitions	Holistic Solution
Scenario Definition	In March 2014 thermal envelope testing was carried out in a small section of the school while it was unoccupied for a week. St Teilo's Church in Wales High School. To improve the potential of building to automatically manage itself.
Control Variables	occupation of rooms, lighting, temperature, ventilation and energy generation from the solar PV and biomass boiler systems

<table>
<tr><td rowspan="5"></td><td>Objectives</td><td>Improve the potential of building to automatically manage itself with a view to:
Improving use and control of energy in new or renovated buildings.

Enhancing competitiveness of the Energy distribution and control sector.

Development of a European market for ICT-based energy performance systems for energy and control management.</td></tr>
<tr><td>Effective Environmental Variables</td><td>Solar- temperature</td></tr>
<tr><td>Control Rules</td><td>The school makes an excellent test facility as almost every room has temperature sensors installed and the data is collected through the BMS. Further monitoring will be undertaken during the deployment phase of the PERFORMER hardware/software through this monitoring will be carried out in the background while the school is operational.</td></tr>
<tr><td>Actors</td><td>Unoccupied rooms, rooms have occasional use, staff/pupils, sensors, lighting, temperature, energy generation and solar PV. Awareness.</td></tr>
<tr><td>When Applicable</td><td>The scenario is applicable</td></tr>
<tr><td>Learning Outcomes:</td><td colspan="2">The UK Pilot Site is in final stages of deployment, as PERFORMER solution comes online thanks to “Advantic Systems & Services” technologies. The wireless metering solution to pick up data from Heat Meters and the Electricity sub metering at St Teilo’s was installed. As a result, the energy savings and comfort in a school building will be maximized.</td></tr>
<tr><td>Supporting resources</td><td colspan="2">http://www.sustainableplaces.eu/wp-content/uploads/2017/07/posterA0PERFORMER_final.pdf</td></tr>
</table>

Use Case: 5

Use Cases Title	Hadlow College
Use Case type	Real world application
Funding source	Hadlow College
Project Title	Rural Regeneration Centre, Hadlow College
Web Link (URL)	
Targeted Discipline	Architectural Design
Targeted Building type	Public
Project type	Renovation
Lifecycle applicability	Design
Brief description of the case study	This case study explores the use of sustainable architecture to develop designs taking into consideration of energy consumption, carbon emissions and operational costs. The design was successful in meeting PassivHaus standards through the use of ArchiCAD together with its integrated thermal performer, EcoDesigner to evaluate energy consumption. Numerous sustainable technologies were implemented in the design of this project through intricate modelling and simulations.
Key Highlights	Designed using ArchiCAD, UK's first certified PassivHaus educational building
	Uses 10% of the typical energy consumption of a modern building
	Structure is airtight to a very high standard of 0.34h^(-1)
	Uses +/- 50% less heating and more than 50% less electricity compared to the best performing schools in a survey of 834 schools built in the last 10 years

<table>
<tr><td>Supporting best practice case study</td><td>This case study is an extension to an existing building with the aim of meeting PassivHaus requirements.
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>This scenario provides a solution that is PassivHaus certified through various sustainable design choices for the Rural Regeneration Centre</td></tr>
<tr><td>Control Variables</td><td>Window opening/closing set point</td></tr>
<tr><td>Objectives</td><td>Reduction in energy consumption, carbon emissions and operational costs</td></tr>
<tr><td>Effective Environmental Variables</td><td>Solar gain, fresh air rates</td></tr>
<tr><td>Control Rules</td><td>Temperature to be maintained between 19 - 22°C</td></tr>
<tr><td>Actors</td><td>Mechanical ventillation systems, triple glazed windows, ground source heat pump, waterless urinals, timed water savers, low energy T5 lighting, sustainable resources, automatic clerestory windows, integral heat exchanger</td></tr>
<tr><td>When Applicable</td><td>The scenario is applicable for use of the Rural Regeneration Centre in Hadlow College</td></tr>
</table></td></tr>
<tr><td>Learning Outcomes</td><td>BIM technologies used predominantly for integrated building design at the design phase to achieve PassivHaus certification.</td></tr>
<tr><td>Supporting resources</td><td>http://www.graphisoft.com/ftp/marketing/case_studies/Hadlow_GRAPHISOFT_CaseStudy.pdf</td></tr>
</table>

Use Case 6:

Use Cases Title	Sustainable Design and Building Information Modelling: Case study Energy Plus House, Hieron's Wood, Derbyshire UK
Use Case type	Real world application
Funding source	Derek Latham (Home Owner)
Project Title	Hieron's Wood, Derbyshire
Web Link (URL)	
Targeted Discipline	Architectural Design
Targeted Building type	Domestic
Project type	New Build
Lifecycle applicability	Design
Brief description of the case study	This case study explores the use of sustainable architecture to develop designs taking into consideration of energy consumption, carbon emissions and operational costs. The design was successful in meeting PassivHaus standards through the use of ArchiCAD together with its integrated thermal performer, EcoDesigner to evaluate energy consumption. Numerous sustainable technologies were implemented in the design of this project through intricate modelling and simulations.
Key Highlights	Integration of BIM and sustainable design analysis
	Case study considers various environmental variables such as wind, topology, orientation,air rates and many more
	Case study utlises various modelling and simulation technologies to achieve accurate analysis
	Innovative use of structural and construction material

<table>
<tr><td>Supporting best practice case study</td><td>This case study is a new 4 bed house located in Hieron's Wood. The design concept was to produce a low impact house due to the physical, historical and visual context of the location.
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>This scenario provides a low impact solution tailored to Hieron's Wood due to the physical, historical and visual context of the location through the use of integrated building design and energy analysis.</td></tr>
<tr><td>Control Variables</td><td>passive stack and earth tube ventilation</td></tr>
<tr><td>Objectives</td><td>Low impact building</td></tr>
<tr><td>Effective Environmental Variables</td><td>Energy consumption, water usage, solar gain and carbon emissions</td></tr>
<tr><td>Control Rules</td><td>Predetermined specifications such as estimated energy use and emissions</td></tr>
<tr><td>Actors</td><td>sycamore, passive stack and earth tube ventilation</td></tr>
<tr><td>When Applicable</td><td>The scenario is applicable for use of the Rural Regeneration Centre in Hadlow College</td></tr>
</table></td></tr>
<tr><td>Learning Outcomes:</td><td>Successful integration of sustainable design analysis with building information modelling using integrated design technologies as well as simulation software.</td></tr>
<tr><td>Supporting resources</td><td>https://ac.els-cdn.com/S1876610215028283/1-s2.0-S1876610215028283-main.pdf?_tid=f5c0889e-d392-11e7-a528-00000aacb362&acdnat=1511801560_7d8476ee574b2c69126c26a54b53faa2</td></tr>
</table>

Use Case 7:

Use Cases Title	Friendly and Affordable Sustainable Urban Districts Retrofitting (FASUDIR) - Heinrich-Lubke housing area, Frankfurt, Germany
Use Case type	Research & Development
Funding source	EU / FP7
Project Title	FASUDIR
Web Link (URL)	http://cordis.europa.eu/project/rcn/110304_en.html
Targeted Discipline	Facility Management
Targeted Building type	Public
Project type	Existing
Lifecycle applicability	Operational & Maintenance Stage
Brief description of the case study	This project is mainly concerned with the traditional approach taken with building retrofitting seeing that this approach ranks poorly with respect to sustainability and economic returns. The presence of the FASUDIR Integrated Decision Support Tool (IDST) along with a supporting software provides a new methodology that addresses the issue in order to increase the sustainability of the whole building/district with specified targeted energy reduction goals through considering the Global Warming Potential (GWP). In the Frankfurt case study, three steps are established to follow; firstly, creating an energy model, followed by an IDST demonstration and evaluation, and lastly the results and how they could be achieved through 2 approaches, a realistic and an ideal one.
Key Highlights	Initially a data model was set-up in order to implement the FASUDIR model. Geometric generation was established through OpenStreetMap (OSM) and the German National Institute of Geography
	Results show a good score with respect to the KPI Global Warming Potential, 70 Kg CO2 e/m2. year. Operative energy demand is also average. Renewable energy scored 0 because none is present
	Real Variant was introduced considering real measures implemented during the renovation phase. Ideal Variant proposes a further reduction in CO2 emissions through introducing a biomass plant, and the area of solar panels increased.

<table>
<tr><td>Supporting best practice case study</td><td>Real variant provided a reduction of only 20% in operational energy used and 25% in Global Warming Potential. Ideal Variant provided 35% reduction in operational energy use in as well as 60% reduction in GWP.
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>This scenario provide an alternative approach to the traditional one considered for building retrofitting through the use of BIM system (FASUDIR IDST) in order to achieve higher goals in reducing energy demand and CO2 emission.</td></tr>
<tr><td>Control Variables</td><td>* Global Warming Potential (GWP)
* Operational Energy Demand</td></tr>
<tr><td>Objectives</td><td>To reduce GWP from 70kgCO2e/m2.year to 50 kgCO2e/m2.year …. 30% reduction.
To reduce operational energy demand from 310 kgCO2e/m2.year to 210 kgCO2e/m2.year … 33% reduction</td></tr>
<tr><td>Effective Environmental Variables</td><td>Introduction of a biomass plant.</td></tr>
<tr><td>Control Rules</td><td>Real Package:
Wall outer insulation 160mm
Doors insulated + seals
Windows triple glaze (U=0.8w/m2k)
Insulate hot water pipes, Insulate hot water tanks, Insulate heating pipes 5m2 solar thermal.
PV 160kw (garages building only)
Ideal Package:
Wall outer insulation 160mm
Doors insulated + seals
Windows triple glaze (U=0.8w/m2k)
Insulate hot water pipes, Insulate hot water tanks, Insulate heating pipes 5m2 solar thermal.
Very reflective solar glazing (G=0.10)
Brise soleil 1000mm (above window)
Condensing boiler CoP 0.95 Biomass LED best (120lm/w) Roof insula on 300mm
Exposed floor insula on 200mm
Very tight passivehaus 0.5 ACH50 BEMs
Zone & thermostatic control</td></tr>
<tr><td>Actors</td><td>users, owners, investors, building solution suppliers, urban managers and grants management</td></tr>
<tr><td>When Applicable</td><td>The scenario is applicable to optimise energy and increase sustainability</td></tr>
</table></td></tr>
<tr><td>Learning Outcomes:</td><td>GWP reduction of 60%. Operational energy consumption reduction of 35%</td></tr>
<tr><td>Supporting resources</td><td>http://fasudir.eu/documents/FASUDIR_CaseStudies_booklet.pdf</td></tr>
</table>

Use Case 8:

Use Cases Title	Friendly and Affordable Sustainable Urban Districts Retrofitting (FASUDIR) - Budapest Residential District
Use Case type	Research & Development
Funding source	EU / FP7
Project Title	FASUDIR
Web Link (URL)	http://cordis.europa.eu/project/rcn/110304_en.html
Targeted Discipline	Facility Management
Targeted Building type	Public
Project type	Existing
Lifecycle applicability	Operational Stage
Brief description of the case study	This project is mainly concerned with the traditional approach taken with building retrofitting seeing that this approach ranks poorly with respect to sustainability and economic returns. The presence of the FASUDIR Integrated Decision Support Tool (IDST) along with a supporting software provides a new methodology that addresses the issue in order to increase the sustainability of the whole building/district with specified targeted energy reduction goals through considering the Global Warming Potential (GWP). In the Frankfurt case study, three steps are established to follow; firstly, creating an energy model, followed by an IDST demonstration and evaluation, and lastly the results and how they could be achieved through 2 approaches, a realistic and an ideal one.
Key Highlights	Initially a data model was set-up in order to implement the FASUDIR model
	Several BIM software such as *AutoCAD* and *Feasibility of Heat Networks* were used to establish data for the district
	Energy demand is slightly above average. Renewable energy scored worst as none is present. Operational energy running costs are significantly high. (75% of energy is used for heating and water purposes. 50% of electricity is used for lighting
	Real Variant was introduced considering real measures implemented during the renovation phase. Ideal Variant proposes a further reduction in operational energy use as well as introducing renewable energy measures

<table>
<tr><td>Supporting best practice case study</td><td>Real variant provided a reduction of only 7.5% in operational energy used and 4.5% in operational energy running costs. Ideal Variant provided 35% reduction in operational energy use in as well as 35% reduction in energy running costs.
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>This scenario provide an alternative approach to the traditional one considered for building retrofitting through the use of BIM system (FASUDIR IDST) in order to achieve higher goals for sustainability and economic purposes.</td></tr>
<tr><td>Control Variables</td><td>* Operation Energy Running Costs
* Operational Energy Demand</td></tr>
<tr><td>Objectives</td><td>To reduce operational energy running costs from 22 EUR/m2.year to 11 EUR/m2.year.
To reduce operational energy demand from 270 kWh/m2.year to 200 kWh/m2.year</td></tr>
<tr><td>Effective Environmental Variables</td><td>Introduction of renewable energy to the district</td></tr>
<tr><td>Control Rules</td><td>Real Package:
Wall outer insula 160/200mm
Roof insula on 200/300 mm
Windows double glazed (U=1.4 w/m2.k)
Ideal Package:
Wall outer insula 160/200mm
Roof insula on 200/300 mm
Windows double glazed (U=1.4 w/m2.k)
LED best (120 lm/w)
Insulate hot water pipes
Insulate hot water tanks
Insulate heat pipes
Tight 0.3 ACH50
Zone & thermostat controls
Standalone occupancy switching (-15%)
PV4 kw (medium domes c)</td></tr>
<tr><td>Actors</td><td>users, owners, investors, building solution suppliers, urban managers and grants management</td></tr>
<tr><td>When Applicable</td><td>The scenario is applicable to optimise energy and increase sustainability</td></tr>
</table>
</td></tr>
<tr><td>Learning Outcomes:</td><td>Operational energy reduced by 35% and energy running costs reduced by 35%</td></tr>
<tr><td>Supporting resources</td><td>http://fasudir.eu/documents/FASUDIR_CaseStudies_booklet.pdf</td></tr>
</table>

Use Case 9:

Use Cases Title	Reduce the Gap Between Predicted and Actual Energy Consumption in Buildings
Use Case type	Research & Development
Funding source	EU / FP7 KnoholEM project
Project Title	Knowledge-based energy management for public buildings through holistic information modeling and 3D visualization
Web Link (URL)	http://www.knoholem.eu/page.jsp?id=2
Targeted Discipline	Facility Management
Targeted Building type	Public
Project type	Existing
Lifecycle applicability	In Use
Brief description of the case study	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. Due to the absence of historical energy consumption data, a theoretical simulation approach is used that takes into account a wide range of factors, including building fabric, occupancy patterns, and environmental conditions. Energy sensitive variables are then identified as well as available control variables (set points) to train and learn energy consumption patterns and behavior within the considered building. The resulting model is then used as a cost function engine (predictor) for an optimization process to generate energy saving rules that can be applied to the operating BMS.
Key Highlights	The Building BIM model is used to generate a calibrated energy model.
	An enhanced BIM model is then developed in the form of a knowledge base augmented with energy saving rules.
	The rules are regularly adapted to changing environmental conditions through a training capability.

<table>
<tr><td>Supporting best practice case study</td><td>The case study is a carehome building located in the Netherlands. The validation work involves minimising energy consumption while maintaining acceptable comfort conditions for the elderly occupants.
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>This scenario provides a negotiation based energy management solution to the FORUM building. The ATRIUM zone, by minimising energy</td></tr>
<tr><td>Control Variables</td><td>Heating temperature set point: [16-24], (incremental size=1)</td></tr>
<tr><td>Objectives</td><td>* Desired amount of minimisation for energy consumption.
- Heating energy minimisation
- Atrium roof window set point (state): {Off=0, On=1}
- Lighting set point (state): {Off=0, On=1}
- Shading set point (state): {Off=0, On=1}
* Comfort (Predicted Mean Vote(PMV)) optimisation</td></tr>
<tr><td>Effective Environmental Variables</td><td>The most effective variables will be determined after sensitivity analysis.</td></tr>
<tr><td>Control Rules</td><td>Legislation regarding required internal temperature will need to be adhered to all times regardless of radiator optimization scheme implement.</td></tr>
<tr><td>Actors</td><td>BC5, Occupancy sensor, light automation system, automation system, facility manager, technician, TRV, actuators, temperature sensors, weather station, window actuator, shade actuator.</td></tr>
<tr><td>When Applicable</td><td>The scenario is applicable to optimise energy and comfort in the Atrium Zone of the FORUM building.</td></tr>
</table></td></tr>
<tr><td>Learning Outcomes:</td><td>The use of BIM has helped achieve a reduction of 25% energy compared to baseline figures.</td></tr>
<tr><td>Supporting resources</td><td>http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7317804&tag=1</td></tr>
</table>

Use Case 10:

Use Cases Title	eeEmbedded Pilot Demonstrators
Use Case type	Real world application
Funding source	The European Commission under FP7
Project Title	eeEmbedded
Web Link (URL)	http://eeembedded.eu/
Targeted Discipline	Architectural Design
Targeted Building type	Public
Project type	Existing
Lifecycle applicability	Design
Brief description of the case study	The pilot project models were used to test and evaluate the eeEmbedded virtual lab platform, which comprises many end-user applications and service components that support the design methodology in different ways. The platform was tested for three targetting design phases of Urban Design, Early Design and Detailed Design, with the most comprehensive tests performed for the Urban Design phase to verify the holistic design goal of combining architectural and energy system design, life cycle analysis and simulations.
Key Highlights	Key Point based design method supporting the control of the collaborative design
	Open ICT Platform incorporating various applications from process management to simulation and analysis
	Project collaboration through consistent use of the BIM collaboration format, where the successor in the process is informed about the finalisation of previous tasks with relevant links to necessary data.

<table>
<tr><td>Supporting best practice case study</td><td>Pilor demonstrators for this project are W2 Building in the Netherlands, and the Z3 Building in Germany, both office buildings with different surroundings, work spaces, and energy demands.
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>This scenario provides analysis performed in 3 separate design phases through the virtual lab platform</td></tr>
<tr><td>Control Variables</td><td>Varies with each design phase (Material U-values, building shape and orientation, materials of construction, weather conditions)</td></tr>
<tr><td>Objectives</td><td>Evaluate the capabilities of the virtual lab platform in various stages of design</td></tr>
<tr><td>Effective Environmental Variables</td><td>Wind, Temperature, Solar gains</td></tr>
<tr><td>Control Rules</td><td>Varies with design stage</td></tr>
<tr><td>Actors</td><td>Building geometries and relevant components of construction</td></tr>
<tr><td>When Applicable</td><td>This is applicable for the design phase of a project.</td></tr>
</table>
</td></tr>
<tr><td>Learning Outcomes:</td><td>The eeEmbedded design methodlogy features a BIM-based approach using Key Points to drive the design and templates to faciliate and accelerate the process. KPs are measurable target requirements from clients, regulations, site and designers and templates contain valuable information to streamline the design processes.</td></tr>
<tr><td>Supporting resources</td><td>http://eeembedded.eu/wp-content/uploads/2017/09/20170917_eeE_Final_Report_V2.0.pdf</td></tr>
</table>

Use case 11:

Use Cases Title	EFFESUS Glasgow Case Study
Use Case type	Real world application
Funding source	The European Commission under FP7
Project Title	EFFESUS
Web Link (URL)	http://www.effesus.eu/about-effesus/case-studies/glasgow
Targeted Discipline	Construction Eningeering
Targeted Building type	Public
Project type	Renovation
Lifecycle applicability	In Use
Brief description of the case study	The project aims to investigate energy efficiency and sustainability of European historic urban districts and measures and tools to make significant improvements whilst protecting their heritage value. The Glasgow case study is located in the historic district of Govanhill, with prevalent use of tradition sandstone tenements. The case study demonstrates the use of adapted aerogel insulation solutions providing a cost effective solution for with minimised disruption to both occupiers and building fabric
Key Highlights	Minimal disruption to interior and exterior walls of the building
	Fast and cost effective solution
	Mininal disruption to occupiers
Supporting best practice case study	This case study comprises of a four storey tenement with traditional stone masonry and plasterboard interior finishes. The building was constructed between 1910 and 1920 and refurbished during 1980s.

Scenario Definitions	Holistic Solution
Scenario Definition	This scenario provides an energy efficient solution buildings in the specific district of Govanhill
Control Variables	Insulation installed into the internal cavities at window breasts.
Objectives	Evaluate the capabilities of the virtual lab platform in various stages of design
Effective Environmental Variables	historical heritage, maritime climate conditions: precipitation, wind, solar gains and humidity
Control Rules	2 separate rooms monitored over a 10 month period for comparison
Actors	Aerogel fibre insulation
When Applicable	This scenario is applicable for historic buildings with similar relevant climate limitations

Learning Outcomes:	Not Applicable
Supporting resources	http://www.effesus.eu/wp-content/uploads/2016/02/EWCHP-2013-Effesus-final.pdf

Use Case 12:

Use Cases Title	HESMOS Pilot Projects
Use Case type	Real world application
Funding source	The European Commission under FP7
Project Title	HESMOS
Web Link (URL)	http://hesmos.eu/
Targeted Discipline	Design
Targeted Building type	Public
Project type	Existing
Lifecycle applicability	Design
Brief description of the case study	This case study is one of two pilot projects for the HESMOS project for the system development of the Integrated Virtual Energy Laboratory. Building Information Models were created of the school building Alfons-Kern-School Pforzheim for operation and optimisation, a SQL data server was installed to record sensor data and web access was provided to use sensor data for FM monitoring.
Key Highlights	Connection to BIM and uses structured requirements from design phase
	Comparison of requirements with measured data for thermal comfort, alongside visualisations of deviations
	Connection to Building Automation System performance data and the processing of data to performance metrix for easy analysis
	Annual energy need, purchased, CO_2 emissions, energy costs can be simulated and estimated with new primary energy library development
Supporting best practice case study	This case study consists of a number of school buildings, each categorised into sections: A - butchers, bakery, hairdresser, beauty; B - administration and cafeteria; C - sanitation, metal structure, motor engine; D - carpenters, craft professions.

Scenario Definitions	Holistic Solution
Scenario Definition	This scenario provides a platform to monitor and simulate energy performance using the Integrated Virtual Energy Lab
Control Variables	Maximum and minimum set points for relevant environmental variables
Objectives	Evaluate the capabilities of the virtual lab platform in various stages of design
Effective Environmental Variables	Outdoor and indoor temperature, room and outdoor seasonal humidity and CO_2 concentrations
Control Rules	Geometry of existing BIM model
Actors	HVAC systems, building components and materials, sensors for monitoring
When Applicable	This scenario is applicable for historic buildings with similar relevant climate limitations

Learning Outcomes:	Use BIM data and requirements from design phase for simulations
Supporting resources	http://hesmos.eu/downloads/hesmos_wp09_d09_3_final.pdf

Use Case 13:

<table>
<tr><td>Use Cases Title</td><td>Towards the development of a virtual city model, using a 3D mode of Dundalk city</td></tr>
<tr><td>Use Case type</td><td>Real world application</td></tr>
<tr><td>Funding source</td><td>The European Commission under FP7</td></tr>
<tr><td>Project Title</td><td>INDICATE</td></tr>
<tr><td>Web Link (URL)</td><td>http://indicate-smartcities.eu/</td></tr>
<tr><td>Targeted Discipline</td><td>Design</td></tr>
<tr><td>Targeted Building type</td><td>Public</td></tr>
<tr><td>Project type</td><td>Existing</td></tr>
<tr><td>Lifecycle applicability</td><td>Design</td></tr>
<tr><td>Brief description of the case study</td><td>The project explores the role of smart technologies in improving the efficiency and effectiveness of urban systems that can contribute to the sustainability of the city and its occupants. This case study examines the early stage analysis of the 3D dynamic simulation urban model of one of the test sites in Dundalk, Ireland. The model will analyse the impact of refurbishment for a select number of buildings.</td></tr>
<tr><td rowspan="4">Key Highlights</td><td>Results demonstrate the potential impact of energy consumption within the modelled buildings along with the implemented retrofits.</td></tr>
<tr><td>Shows an effective measure of the positive impacts of modelling and simulating at the early stage of analysis</td></tr>
<tr><td>Annual energy need, purchased, CO2 emissions, energy costs can be simulated and estimated with new primary energy library development</td></tr>
<tr><td></td></tr>
<tr><td>Supporting best practice case study</td><td>
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>This scenario provides a method of modelling and simulating at the early stage of analysis for urban systems</td></tr>
<tr><td>Control Variables</td><td>Not Applicable.</td></tr>
<tr><td>Objectives</td><td>Improving the efficiency and effectiveness of urban system</td></tr>
<tr><td>Effective Environmental Variables</td><td>Temperature, solar gain</td></tr>
<tr><td>Control Rules</td><td>Geometry of existing BIM model</td></tr>
<tr><td>Actors</td><td>HVAC systems, building components and materials</td></tr>
<tr><td>When Applicable</td><td>This scenario is applicable for urban systems</td></tr>
</table>
</td></tr>
<tr><td>Learning Outcomes:</td><td>Building Information Models developed of select buildings and subsequently used to simulate retrofits.</td></tr>
<tr><td>Supporting resources</td><td>https://infoscience.epfl.ch/record/213431/files/9_MELIA.pdf</td></tr>
</table>

Use Case 14:

Use Cases Title	Modelling, assessment and Sankey diagrams of integrated electricity-heat-gas networks in multi-vector district energy systems
Use Case type	Real world application
Funding source	The European Commission under FP7
Project Title	DIMMER
Web Link (URL)	www.dimmerproject.eu/
Targeted Discipline	Facilities Management
Targeted Building type	Public
Project type	Existing
Lifecycle applicability	Operation
Brief description of the case study	This case study explores the potential of advances in 3D modelling, visualisation, and interactive technologies enabling user profiling and real-time feedback in energy efficiency. A multi-temporal simulation model is used to carry out an integrated analysis of electricity, heat and gas distribution networks. The network linkages have been modelled through a multi-vector efficiency matrix specifically designed to map the transformation of final demands into network energy flows.
Key Highlights	Models successfully analysed 6 scenarios with varying components of district and building level supply, and identified the most efficient scenarios.
	Model can be flexibly adapted to generic network topologies and multi-energy supply technologies.
	Network linkages developed to map the transformation of final demands into network energy flows while taking into account inter-network locations of the individual supply technologies.

<table>
<tr><td>Supporting best practice case study</td><td>This case study takes place in the campus of the University of Manchester.
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>This investigation explores 6 scenarios of varying supply technologies and levels of a district multi-energy system</td></tr>
<tr><td>Control Variables</td><td>6 scenarios of various conversion components at different levels</td></tr>
<tr><td>Objectives</td><td>Minimise carbon emissions and operational costs</td></tr>
<tr><td>Effective Environmental Variables</td><td>Carbon emissions</td></tr>
<tr><td>Control Rules</td><td>Energy Prices: Grid electricity (50/6£/MWh),
Electrcity (export) (80% of grid price),
Natural gas (23.6£/MWh)
Carbon content: Natural gas (0.204 kgCO2/kWh),
Grid electricity (0.027-0.45 kgCO2/kWh)</td></tr>
<tr><td>Actors</td><td>District level and building level: gas boilers, CHP, heat pumps</td></tr>
<tr><td>When Applicable</td><td>The scenario is applicable for district multi-energy systems</td></tr>
</table></td></tr>
<tr><td>Learning Outcomes:</td><td>Integration of Building Information Modelling with real-time data and feedback, successfully extending to district level, leading to District Information Models</td></tr>
<tr><td>Supporting resources</td><td>https://ac.els-cdn.com/S0306261915010259/1-s2.0-S0306261915010259-main.pdf?_tid=5f3f7896-0838-11e8-b007-00000aacb361&acdnat=1517590065_aa53cc639ad2d0fa08d89605a4fadc91</td></tr>
</table>

Use Case 15:

Use Cases Title	Eebers ICT Clusters
Use Case type	Real world application
Funding source	The European Commission under H2020
Project Title	Eebers
Web Link (URL)	http://www.fabiodisconzi.com/open-h2020/projects/193414/index.html
Targeted Discipline	Facilities Management
Targeted Building type	Other
Project type	Existing
Lifecycle applicability	Operation
Brief description of the case study	The project focus is on identifying opportunities for synergies in Information and Communications Technologies related Research in Technical Developments in the energy efficient buildings domain. The aim is to engage stakeholders in networking activities for future research and technology development and exploitation of results.
Key Highlights	Through fitting different projects under one or more of the sub-topics of the taxonomy, a mapping matrix is produced, which can then be statistically analysed.
	Delivered the project clustering model to the stakeholder community and developed a literature review of technological developments and consolidation of best practices
	Identified project results and links with innovation and technology transfer initiatives, analysed Technology Readiness Levels.
Supporting best practice case study	Not Applicable.
Learning Outcomes:	Not Applicable.
Supporting resources	http://eebers.eu/static/img/Eebers_d1%201%20projects%20mapping_public%20deliverable.pdf

Scenario Definitions	Holistic Solution
Scenario Definition	Not Applicable.
Control Variables	Not Applicable.
Objectives	Not Applicable.
Effective Environmental Variables	Not Applicable.
Control Rules	Not Applicable.
Actors	Not Applicable.
When Applicable	Not Applicable.

LIST

Use Case 16

Use Cases Title	BIM-based Parametric Building Energy Performance Multi- Objective Optimization
Use Case type	R&D
Funding source	Autodesk Research
Project Title	BIM-based Parametric Building Energy Performance Multi- Objective Optimization
Web Link (URL)	https://autodeskresearch.com/publications/bimparametric
Targeted Discipline	Architectural Design
Targeted Building type	Domestic
Project type	New Build
Lifecycle applicability	C, D
Brief description of the case study	An integrated system is developed for enabling designers to optimize multiple objectives in the early design process. 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. The aim is to maximize the number of rooms of the residential unit that satisfy the requirements of the LEED IEQ Credit 8.1 for Daylighting while minimizing the expected energy use. The geographic location of the home is in the city of Indianapolis, Indiana, USA.
Key Highlights	The system enables designers to explore design alternatives and at the same time assess the building performance to search for the most appropriate design.

<table>
<tr><td>Supporting best practice case study</td><td>
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>The residential home has six rooms at level one and two rooms at the second level that are included as part of the daylighting calculation and energy use for the entire building. The light admitted to the building can enter via two fixed curtain walls that are not included as free parameters in the design space optimization. These two curtain systems light the main living space in the first floor and the balcony in second floor. The rooms separated from the main living space by interior partitions are lit naturally by fixed windows with a visual transmission coefficient of 0.9.</td></tr>
<tr><td>Control Variables</td><td>Size and height of windows
Angle of building orientation
Overall building footprint
Form of the roof
Interior layout</td></tr>
<tr><td>Objectives</td><td>In this study the "LEED Daylighting" node is created as a package of nodes to calculate the LEED daylight values based on LEED Reference Guide for Green Building Design and Construction (USGBC, 2009) as an objective function.</td></tr>
<tr><td>Effective Environmental Variables</td><td>The width and height of the windows are identified within the Dynamo interface as free parameters. The domains of the width and height of the glazing area are set independently from 0.5' to 7.0' with an increment of 0.1'.</td></tr>
<tr><td>Control Rules</td><td>Multiple Dynamo nodes contain essential functions for creating parametric BIM models in Revit and run parametric simulations in GBS. A MOO algorithm (Non-dominated Sorting Genetic Algorithm-II or NSGA-II, Deb et al., 2002) is created in Dynamo as a package of nodes that can help designers optimize multiple conflicting objectives and approach to a set of optimal solutions.</td></tr>
<tr><td>Actors</td><td>Designers</td></tr>
<tr><td>When Applicable</td><td></td></tr>
</table>
</td></tr>
<tr><td>Learning Outcomes:</td><td>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.</td></tr>
<tr><td>Supporting resources</td><td></td></tr>
</table>

Use case 17:

Use Cases Title	Parametric design of a shelter roof in urban context
Use Case type	Real-world application
Funding source	Private (Swire Properties)
Project Title	Climate Ribbon, Miami
Web Link (URL)	
Targeted Discipline	Architectural Design, Structural Design, Mechanical Engineering, Steel contractor
Targeted Building type	
Project type	New Build
Lifecycle applicability	C, D
Brief description of the case study	Brickell City Centre comprises a retail plinth on several distinct city blocks in downtown Miami's Brickell district, topped with several towers for condominium apartments, offices, and a hotel. The CLIMATE RIBBON TM ties these blocks together, forming a shelter to improve the microclimate for the public in the pedestrian circulation streets using purely passive energy design strategies. A symbol of sustainability: Beyond this functional performance, CLIMATE RIBBON TM is a unique sculptural icon for the Brickell City Centre that expresses Swire Properties' commitment to sustainable development.
Key Highlights	The project consist in the design of a roof shelter aiming at providing sun shade, breeze path as well as collect rainwater.

<table>
<tr><td>Supporting best practice case study</td><td>Using models for computer simulation: wind simulation, sun & daylight simulation, rain simulation, structural simulation and material and steel fabric
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>The CLIMATE RIBBON TM began as an architectural feature of the new Brickell City Centre development in Miami by Swire Properties by architects Arquitectonica. It shelters a pedestrian street at the heart of the development and improves the micro-climate of the public spaces through shading and natural ventilation. A 100 000 sq. ft. facetted canopy of steel and glass above the pedestrian street undulates between the hotel, office and residential towers with a fluid ceiling beneath of sinuous blades of architectural fabric shading.</td></tr>
<tr><td>Control Variables</td><td>Inclination of blades
Topography of roof surface
Dimensioning of support columns</td></tr>
<tr><td>Objectives</td><td>Airflow comfort
Wind effect on structure
Reduce solar radiation on public areas
Shading for comfort with indirect light
Anticipate quantity of rain water at each collection point
Manage structural behaviour, resist to hurricane wind loads</td></tr>
<tr><td>Effective Environmental Variables</td><td></td></tr>
<tr><td>Control Rules</td><td>Wind forces on the whole surface
Glass surfaces are calculated to withstand the maximal winds and tested for flying debris</td></tr>
<tr><td>Actors</td><td>Architect, Designer, Engineers, Steel contractor</td></tr>
<tr><td>When Applicable</td><td></td></tr>
</table></td></tr>
<tr><td>Learning Outcomes:</td><td>Early BIM for parametric optimization through simulations</td></tr>
<tr><td>Supporting resources</td><td></td></tr>
</table>

<u>**GR**</u>

Use Case 18:

Use Cases Title	Introducing the innovative tool of the Building Sector
Use Case type	BIM guideline
Funding source	
Project Title	BIMclay
Web Link (URL)	https://ied.eu/bimclay-project-introducing-innovative/
Targeted Discipline	workers in ceramic sector
Targeted Building type	Other
Project type	Existing
Lifecycle applicability	
Brief description of the case study	The project aims to the enhancement of the technical knowledge related to the Building Information Modelling and to the Life Cycle Analysis of a building, product or process.
Key Highlights	1) interactive platform
	2) courses and tools
Supporting best practice case study	

Scenario Definitions	Holistic Solution
Scenario Definition	Train and educate professionals of the ceramic sector on BIM
Control Variables	An online BIM tool that the users will be able to test and use as practice in order to familiarize themselves with this technology.
Objectives	
Effective Environmental Variables	
Control Rules	
Actors	1) APICER, the Portuguese Association for Ceramic and Domestic Glass Industry 2) Institute of Entrepreneurship Development (iED).
When Applicable	2017-2019

Learning Outcomes:	Placement techniques of clay products and on their life cycle.
Supporting resources	

Use Case 19:

Use Cases Title	Intelligent Services For Energy-Efficient Design and Life Cycle Simulation
Use Case type	R&D
Funding source	EU - 7TH FRAMEWORK PROGRAMME
Project Title	ISES
Web Link (URL)	http://ises.eu-project.info/about.php
Targeted Discipline	All
Targeted Building type	buildings and facilities
Project type	existing
Lifecycle applicability	In Use
Brief description of the case study	ISES is developing ICT building blocks to integrate and complement existing tools (STEP and BIM) for design and operation management into a Virtual Energy Lab capable of evaluating, simulating and optimizing the energy efficiency of products and facilities, in particular components for buildings and facilities, before their realization and taking into account their stochastic life-cycle nature.
Key Highlights	The targeted application domain is buildings and facilities. However, ISES is not only directed to construction and product development for construction. ISES developed products are generic, so that they can be also used in other domains or can serve as templates and best-practice cases.

<table>
<tr><td rowspan="2">Supporting best practice case study</td><td>The objective of ISES is to develop a missing framework of components for beneficially applying existing ICT tools (CAD modellers, FM systems, different simulations and analysis tools, cost calculation tools, Building Automation Data Management Systems (BAS), and product models – STEP/BIM)</td></tr>
<tr><td><table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>A holistic approach has been applied to enable efficient use of today's loosely connected numerical analysis tools, modellers and graphical presentation tools and new stochastic methods have been developed to deal with the random nature of energy profiles and consumption through the product life-cycle.</td></tr>
<tr><td>Control Variables</td><td>Interoperability between energy analysis tools and product and building design tools
Interoperability between product design tools (STEP) and building and facility design tools (BIM)
Multi-model concurrent engineering design for which only light-weight prototypes are currently available with regard to managing, filtering, navigation and evaluation services
Intelligent and adaptable access and management methods for heterogeneous distributed information resources and services
Intelligent and flexible interoperability methods for model and system interoperability based on ontology methods.</td></tr>
<tr><td>Objectives</td><td></td></tr>
<tr><td>Effective Environmental Variables</td><td>Energy profiles and consumption patterns for building facilities and components that are not yet adequately represented for stochastic treatments and are not generic enough.
Configurators and evaluators for combination of energy profiles for stochastic life-cycle consideration.</td></tr>
<tr><td>Control Rules</td><td></td></tr>
<tr><td>Actors</td><td>University of Cyprus, Russian Academy of Sciences – Institute for System Programming, Trimo d.d., Leonhardt, Andrä und Partner, National Observatory of Athens, Group Energy Conversation, Nyskopunarmidstod Islands, SOFiSTiK Hellas S.A., University of Ljubljana, Granlund Oy, Technische Universität Dresden,</td></tr>
<tr><td>When Applicable</td><td>2011-2014</td></tr>
</table></td></tr>
<tr><td>Learning Outcomes:</td><td>The combination of energy profile models with product development STEP models and building and facility BIM models</td></tr>
<tr><td>Supporting resources</td><td></td></tr>
</table>

Use Case 20:

Use Cases Title	Collaborative Holistic Design Laboratory and Methodology for Energy-Efficient EMBEDDED Building
Use Case type	R&D
Funding source	EU - 7TH FRAMEWORK PROGRAMME
Project Title	EEEMBEDDED
Web Link (URL)	http://eeembedded.eu/
Targeted Discipline	Engineering
Targeted Building type	Buildings of different types, for instance residential, office or hospital buildings
Project type	Simulation platform
Lifecycle applicability	Not applicable
Brief description of the case study	Develop an open BIM-based holistic collaborative design and simulation platform, a related holistic design methodology, an energy system information model and an integrated information management framework for designing energy-efficient buildings and their optimal energetic embedding in the neighbourhood of surrounding buildings and energy systems.
Key Highlights	Virtual design lab, platform, holistic design methodology, integrated information management framework

<table>
<tr><td>Supporting best practice case study</td><td>The project develops a platform which is composed of several simulators covering multiple physical and mathematical models as well as information models.
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>An integrated BIM –based management framework facilitates the interoperability among the whole variety of experts and multi-models (physical and information ones) of the different domains, such as architectural, HVAC, BAS, simulation or lifecycle costs among others, during all the design phases, since the very early urban design up to the very final detailed one.</td></tr>
<tr><td>Control Variables</td><td>To validate the eeEmbedded technologies, two real buildings of different types and its embedding into the neighbourhood were used as a test bench.</td></tr>
<tr><td>Objectives</td><td>Not applicable</td></tr>
<tr><td>Effective Environmental Variables</td><td>Not applicable</td></tr>
<tr><td>Control Rules</td><td>Not applicable</td></tr>
<tr><td>Actors</td><td>Technische Universität Dresden – Institute of Contruction Informatics/ Technische Universität Dresden – Institute of Power Engineering/ Fraunhofer Gesellschaft e.V., Institute IIS/EAS, Germany/ NEMETSCHEK ALLPLAN SLOVENSKO SRO, Slovakia/ Data Design System ASA, Norway/ RIB Information Technologies AG, Germany/ Jotne EPM Technology AS, Oslo, Norway/ Granlund Oy, Finland/ SOFiSTiK Hellas AE, Greece/ iabi – Institute for Applied Building Informatics, Germany/ Fr. Sauter AG, Switzerland/ Obermeyer Planen + Beraten GmbH, Germany/ Centro de Estudios de Materiales y control de Obra S.A., Spain/ STRABAG AG, Austria/ Koninklijke BAM Groep nv, Netherlands/</td></tr>
<tr><td>When Applicable</td><td>2013 - 17</td></tr>
</table>
</td></tr>
<tr><td>Learning Outcomes:</td><td></td></tr>
<tr><td>Supporting resources</td><td>http://eeembedded.eu/wp-content/uploads/2017/09/20170917_eeE_Final_Report_V2.0.pdf</td></tr>
</table>

Use Case 21:

Use Cases Title	Semantic Web for Information Modelling in Energy Efficient Buildings
Use Case type	R&D
Funding source	Horizon 2020
Project Title	The SWIMing Project
Web Link (URL)	http://swiming-project.eu/
Targeted Discipline	All
Targeted Building type	All
Project type	Not Applicable
Lifecycle applicability	The Data Management Plan (DMP) describes the full data management life cycle for all data sets that are collected, processed or generated over and beyond the duration of the SWIMing project.
Brief description of the case study	The aim of SWIMing is to address the challenge of managing the huge amounts of data generated across the building life cycle of relevance to building energy management. SWIMing will support EeB projects to enhance the impact of their results by making their data models open and accessible. It will develop a data modelling cluster where projects can share their use cases, data modelling requirements and get access to expertise in the area of open data models. The cluster will be structured by stages of the building life cycle (BLC) the projects results are applied, its particular domain, and the differing data requirements. By making project outcomes open and accessible to multiple stakeholders across the BLC, SWIMing will impact on the ease and efficiency with which these outcomes will be exploited across BLC energy management processes.
Key Highlights	1) Provide the basis for the creation of a Building Information Modelling cloud that can support Building Life Cycle Energy Management Services and Applications.
	2) Increase the ease and efficiency with which Linked Data will be exploited in Building Life Cycle Energy Management.

<table>
<tr><td>Supporting best practice case study</td><td>
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>SWIMing will generate data in the form of business use cases, guidelines and best practices. This data should be publicly available, comparable, correct, up-to date, complete and compelling and ideally maintained by an active and neutral EeB community.</td></tr>
<tr><td>Control Variables</td><td>Not Applicable</td></tr>
<tr><td>Objectives</td><td>Not Applicable</td></tr>
<tr><td>Effective Environmental Variables</td><td>Not Applicable</td></tr>
<tr><td>Control Rules</td><td>Not Applicable</td></tr>
<tr><td>Actors</td><td>Trinity College Dublin - KIT (Karlsruhe institute of technology)- AEC3 - CERTH (Information of Technologies Institute- GR)- Tyndall</td></tr>
<tr><td>When Applicable</td><td>2015-17</td></tr>
</table>
</td></tr>
<tr><td>Learning Outcomes:</td><td>Not Applicable</td></tr>
<tr><td>Supporting resources</td><td>Not Applicable</td></tr>
</table>

Use Cases 22:

Use Cases Title	Building As A Service
Use Case type	R&D
Funding source	EU - 7TH FRAMEWORK PROGRAMME
Project Title	BaaS Project
Web Link (URL)	www.baas-project.eu
Targeted Discipline	Engineering
Targeted Building type	non-residential buildings
Project type	platform
Lifecycle applicability	
Brief description of the case study	The BaaS system aims to optimize energy performance in the application domain of non-residential buildings in operational stage. In the building operational life-cycle three significant tasks have to be continuously performed: collect information and assess the buildings current state; predict the effect that various decisions will have to Key Performance Indicators (KPIs) optimization. A generic ICT-enabled system will be developed to provide integrated assess, predict, optimize services that guarantee harmonious and parsimonious use of available resources.
Key Highlights	Development of building modelling and simulation for energy performance estimation and control design.
	Development of integrated Automation and Control Services.
	Development of data Management: Working on existing initiatives and ongoing projects results, integrating State of the Art of extended BIM, EEB Ontologies and Standards.
	Development of middleware Platform: System Integration, Interoperability And Standards

<table>
<tr><td>Supporting best practice case study</td><td>The BaaS system comprises four components: 1) A data management component to collect, organize, store and aggregate data from various in- and out-of-building sources. An (IFC-based) BIM will act as a central repository for all static building data, and a data warehouse will be used for dynamic data. 2) A service middleware platform to abstract the building physical devices, support high level services on the cloud and facilitate secure two-way communication between the physical and ICT layers (building) with high level services (cloud). 3) Energy models for performance estimation and for control services, looking for a trade-off between prediction accuracy (performance estimation) and computational complexity (fast-model for control design). 4) Assessment, Prediction and Optimization Service such as: a. Assessment and prediction services: simulation models, acting as surrogates of the real building, incorporating sensor dynamic data, will be used to assess performance and comprehensively estimate the values of relevant KPIs as well as help perform sensitivity analyses; b. Optimization service, automatically will generate holistic nearly-optimal control strategies with the goal of achieving operational efficiencies as measured through relevant KPIs and will be imbued with adaptive and re-configurability properties to respond to faults and atypical scenarios.
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td></td></tr>
<tr><td>Control Variables</td><td>Upon verification of component interoperability, and development of a measurement and verification plan, the BaaS system will be demonstrated in two buildings and will be validated as an Energy Conservation Measure with Energy-Services Companies as the end-user.</td></tr>
<tr><td>Objectives</td><td></td></tr>
<tr><td>Effective Environmental Variables</td><td></td></tr>
<tr><td>Control Rules</td><td>End-user acceptance will be accomplished by analysing the replication potential in tandem with the results of a sensibility study.</td></tr>
<tr><td>Actors</td><td>Fundacion CARTIF - Technology Centre, Dalkia Energía y Servicios, Fraunhofer IBP, Honeywell Prague Laboratory, NEC Laboratories Europe, Technical University of Crete, University College of Cork - IRUSE</td></tr>
<tr><td>When Applicable</td><td>2012-16</td></tr>
</table></td></tr>
<tr><td>Learning Outcomes:</td><td></td></tr>
<tr><td>Supporting resources</td><td>Project's deliverables available at: https://www.baas-project.eu/index.php/public/publicdocs</td></tr>
</table>

Use Case 23:

Use Cases Title	Occupant Aware, Intelligent and Adaptive Enterprises
Use Case type	R&D
Funding source	EU - 7TH FRAMEWORK PROGRAMME
Project Title	Adapt4EE
Web Link (URL)	http://www.adapt4ee.eu/adapt4ee/
Targeted Discipline	Architectural
Targeted Building type	All
Project type	enterprise model
Lifecycle applicability	all aspects of construction products (assets and facilities, occupants and processes, environmental conditions)
Brief description of the case study	Adapt4EE aims to develop and validate a holistic energy performance evaluation framework that incorporates architectural metadata (BIM), critical business processes (BPM) and consequent occupant behavior patterns, enterprise assets and respective operations as well as overall environmental conditions.
Key Highlights	Environmental state, multi-type sensors, information modalities, energy performance measuring, monitoring and optimization

<table>
<tr><td>Supporting best practice case study</td><td>Adapt4EE will deliver a holistic approach governing all aspects of construction products (assets and facilities, occupants and processes, environmental conditions), establishing a dynamic, enterprise-wide perspective on how well construction resources and occupant activities are aligned with business needs, allowing for a complete evaluation and optimization of overall construction product energy performance at an early design phase, prior to realization.
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>The Adapt4EE Model will incorporate business processes and occupancy data. It will also constitute a formal model for enterprise energy performance measuring, monitoring and optimization. The model will be calibrated during the training phase based on sensor data captured during operation and then applied and evaluated in real-life every day enterprise Operations. More specifically the Adapt4EE Enterprise Models will allow for the proactive identification of optimum local adaptations of enterprise utility operations, based on predictions of possible occupancy patterns and respective business operations and energy profiles.</td></tr>
<tr><td>Control Variables</td><td>Modelling, simulation and energy performance predictive precision, energy gains as well as end user acceptance applied to two distinct pilot areas, (a Hospital and a Multipurpose Office/Commercial Spaces).</td></tr>
<tr><td>Objectives</td><td>Not Applicable</td></tr>
<tr><td>Effective Environmental Variables</td><td>Environmental VS Occupancy Data/ Energy Consumption VS Occupancy Data/</td></tr>
<tr><td>Control Rules</td><td>Academica de Coimbra-Organismo Autonomo de Futebol PCUP (Portugal)</td></tr>
<tr><td>Actors</td><td>(Coordinator, Greece)- Fraunhofer - Gesellschaft zur Foerderung der Angewandten Forschung E.V(Germany)- BOC Information Technologies Consulting Limited (Ireland) - ISA - Intelligent Sensing Anywhere S.A. (Portugal) - Almende B.V. (Netherlands) - Hypertech AE (Greece) - Universidad de Navarra (Spain) - Technical University Kosice (Slovakia) - Associacao Academica de Coimbra-Organismo Autonomo de Futebol PCUP (Portugal)</td></tr>
<tr><td>When Applicable</td><td>Not Applicable</td></tr>
</table>
</td></tr>
<tr><td>Learning Outcomes:</td><td>Not Applicable</td></tr>
<tr><td>Supporting resources</td><td>at: http://www.adapt4ee.eu/adapt4ee/results/tools.html Open Reference Models available at: http://www.adapt4ee.eu/adapt4ee/results/orm.html</td></tr>
</table>

BRE

Use Case 24:

Use Cases Title	Robust decision making around building efficiency and occupant comfort
Use Case type	Real world application
Funding source	Interserve
Project Title	Using a BIM model to facilitate collaboration between construction team and FM to deliver a SMART building
Web Link (URL)	http://constructingexcellence.org.uk/ingenuity-house/
Targeted Discipline	Facility Management
Targeted Building type	Office
Project type	New build
Lifecycle applicability	In Use
Brief description of the case study	Ingenuity House is a 12,000m2 highly sustainable building, is currently under construction adjacent to Birmingham's International Airport and Railway Station. The building will be Interserve's new regional HQ and is being used a test bed to start to go beyond BIM Level 2 (BS 1192: 2007).
Key Highlights	Interserve has been certified to BIM Level 2, including its Engineering Division
	Use of BIMCollab to manage project design issues through a cloud basedtracker that allows issues to be captured and logged directly into design review software and tracked online
	Derive all 2D drawings from the 3D model and ensure they are always connected to ensure 'single source of truth'
	FM team brought into the project early to deliver whole life value by providing robust data models that can be used during the operational phase

<table>
<tr><td>Supporting best practice case study</td><td>Interserve's FM team has been working with CIBSE to define a new asset classification system and how these can be linked these to product data sheets. With a more structured means of defining assets that is aligned to industry standards, the FM team is in a better position to inform what data parameters it requires within its CAFM (computer-aided facilities management) systems. The FM team attended familiarisation workshop with the BIM core team to see a practical session using the BIM model to see how to navigate around the building a make the connection with FM.

The same BIM model is now being used as a driver for the head end graphical and user interfaces of the SMART integrated building management system. The central focus of the BMS is to provide the integration of base systems to provide added functionality, plus improved data and reporting. With a smarter data collection and reporting mechanism, the FM team is working to develop its requirements in terms of building analytics so decisions around building efficiency and occupant comfort when the building is in use, can be made more maturely.
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td></td></tr>
<tr><td>Control Variables</td><td></td></tr>
<tr><td>Objectives</td><td></td></tr>
<tr><td>Effective Environmental Variables</td><td></td></tr>
<tr><td>Control Rules</td><td></td></tr>
<tr><td>Actors</td><td></td></tr>
<tr><td>When Applicable</td><td></td></tr>
</table></td></tr>
<tr><td>Learning Outcomes:</td><td>Delivery of SMART building to be established once it is completed</td></tr>
<tr><td>Supporting resources</td><td></td></tr>
</table>

Use Case 25:

Use Cases Title	Delivering highly energy efficient hospital centre
Use Case type	Real world application
Funding source	Walton Centre NHS Foundation Trust
Project Title	Not Applicable
Web Link (URL)	http://www.interserve.com/case-studies/2014/delivering-outstanding-environments-at-the-walton-centre
Targeted Discipline	Facility Management
Targeted Building type	Hospital centre
Project type	New build
Lifecycle applicability	Technical Design
Brief description of the case study	The Walton Centre is the only specialist hospital trust in the UK which provides dedicated comprehensive neurology, neurosurgery, spinal and pain management services.
Key Highlights	The use of BIM and 3D modelling how our design and construction innovation could give the Trust a third storey to the centre
	Based on Passivhaus principles contractor developed a fabric first calculator demonstrating potential energy savings versus payback; allowing the Trust to make informed decisions using holistic fully costed options.
Supporting best practice case study	(see table below)
Learning Outcomes:	The Metsec steel frame and prefabricated panel solution created by Interserve not only accelerated the programme and minimised disruption to the busy hospital site but the increased insulation of the fabric will also lead to: - 41% reduction in fabric loss heat, generating £95,745 saving in engineering capital costs - 29% reduction in carbon emissions, future proofing the building under the NHS Carbon Reduction Commitment until 2020 - 96,400 kg of CO_2 saved per annum - Total annual energy usage 21 GJ/100m³, some 14GJ/100m³ under the NHS benchmark - 15% reduction in overall energy usage
Supporting resources	

Supporting best practice case study:

Scenario Definitions	Holistic Solution
Scenario Definition	
Control Variables	
Objectives	
Effective Environmental Variables	
Control Rules	
Actors	
When Applicable	

Use Case 26:

Use Cases Title	Design for future climate change - Developing an adaptation strategy
Use Case type	Real world application
Funding source	Admiral Insurance - TSB competition on innovation strategies
Project Title	Not Applicable
Web Link (URL)	
Targeted Discipline	Architectural design
Targeted Building type	Office
Project type	New build
Lifecycle applicability	Technical Design
Brief description of the case study	Admiral Insurance employed a sustainable design advisor on the design and construction of it new office HQ in Cardiff through a TSB to develop an adaptation strategy to reduce the building's vulnerability to changing climate
Key Highlights	Building was modelled in 3D BIM model using IES to determine its energy performance
	Project sought to devise a tenant-focussed, cost-effective adaptation strategy to address the impacts posed by project climate change
Supporting best practice case study	Energy modelling established: - greatest load was for lighting and equipment with cooling load increasing under future scenarios - infiltration rate and performance of fabric would not allow significantly discharge heat from IT and solar gains - overall strategy should focus on creating a more efficient building use profile rather than implement physical changes to the building - Final adaptation was to consider a more efficient M&E system to reduce the electrical cost of providing chilled air to the building. A 5% improvement be sought at an estimated cost of £641k - Physical adaptations modelled were not shown to be cost-effective so were not included - Utilizing thermal mass in the building's cooling strategy would necessitate a concrete frame. It was neither cost-effective nor practical to retrofit thermal mass into the existing steel frame, but using a concrete frame in the initial design would have been sensible

Scenario Definitions	Holistic Solution
Scenario Definition	
Control Variables	
Objectives	
Effective Environmental Variables	
Control Rules	
Actors	
When Applicable	

Learning Outcomes:	The project would have benefited from fully integrating BIM into IES. The energy model had to be built without using standard naming conventions and the developer's 2D dataset could not be included.
Supporting resources	https://www.bre.co.uk/filelibrary/pdf/projects/D4FC.pdf

Metropolia

Use Case 27:

Use Cases Title	Shopping Center using around half the energy of a typical development
Use Case type	Real-world application
Funding source	Renor Oy property investment company and Ilmarinen Mutual Pension Insurance Company
Project Title	Holistic use of BIM in achieving high sustainability goals in retail building development
Web Link (URL)	http://www.skanska-sustainability-case-studies.com/index.php/latest-case-studies/item/232-puuvilla-shopping-center-finland
Targeted Discipline	Architectural design / Structural engineering / HVAC engineering / Electrical engineering / Builders / Construction companies / Building managers
Targeted Building type	Commercial
Project type	Renovation and extension
Lifecycle applicability	Preparation and Brief, Concept Design, Developed Design, Technical Design, Construction, In Use
Brief description of the case study	The development is situated in Pori, southwestern Finland. Complex design with high environmental goals was managed with help of BIM throughout the design and construction phases. The model provided a basis for energy simulations, helped integrating existing old industrial buildings structures to new ones and boosted cooperation among all participants. Puuvilla BIM model contains information that is planned to promote efficient Facilities Management, including information on the materials, fixtures, fittings and equipment installed throughout the shopping center. Additional information can be added to the model as the building is modified and upgraded over time.
Key Highlights	BIM was in holistic use throughout the project, altogether 13 different parties of the project used BIM.
	BIM model was used as the basis for the energy simulations.
	Model works as facilities management tool throughout the operation of the shopping center.

<table>
<tr><td>Supporting best practice case study</td><td>Puuvilla achieved LEED Platinum certification (Core & Shell) and won the “Best BIM Project” Award at the Tekla Global BIM Awards in 2013 for its innovative use of modeling during design and construction. High in energy efficiency. Measured energy production of geothermal heatpumps has been bigger than calculated. Estimated persentage of annual free energy source usage for heating and cooling was 60 %, mesured 70 %. In 2017 Puuvilla also got Finlands biggest solar panel roof-installation (600 kWp).
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>Whole HVAC-system underwent three phases of thorough commissioning to ensure their optimal operation involving real operation situations to fine-tune and ensure the systems functioned optimally together. Automation contractor works to optimize the equipment during operation over an initial 2-year period, together with other project contractors, in order to ensure the system operates as efficiently as possible.</td></tr>
<tr><td>Control Variables</td><td>Ventilation system optimized by CO_2-sensors and temperature sensors and is automatically switched off during the night. Air handling units in shopping center automatically switch to nighttime cooling mode when conditions allow. The ventilation system in the parking garage is controlled by CO_2 and carbon monoxide sensors to properly ventilate the spaces.</td></tr>
<tr><td>Objectives</td><td></td></tr>
<tr><td>Effective Environmental Variables</td><td></td></tr>
<tr><td>Control Rules</td><td></td></tr>
<tr><td>Actors</td><td></td></tr>
<tr><td>When Applicable</td><td></td></tr>
</table>
</td></tr>
<tr><td>Learning Outcomes:</td><td>BIM was effectively used in a project where 50 % energy savings were achieved compared with Finnish Code and 50 % savings in water consumption compared with conventional retail development in Finland. Also measured energy production of geothermal heat pumps and gains of free energy for heating and cooling have exceeded expectations.</td></tr>
<tr><td>Supporting resources</td><td>http://www.skanska-sustainability-case-studies.com/index.php/latest-case-studies/item/download/276_bb182b7f47e1114b65458859014e1606</td></tr>
</table>

Use Case 28:

Use Cases Title	Use of BIM in design and construction phase to achieve sustainability goals of an office building
Use Case type	Real-world application
Funding source	Skanska Commercial Development Nordic
Project Title	Innovative use of BIM in construction phase, BIM also used in designing and carbon analyses of structures for benchmarking an office building
Web Link (URL)	http://www.skanska-sustainability-case-studies.com/index.php/latest-case-studies/item/172-skanska-house-finland?start=1
Targeted Discipline	Architectural design / Structural engineering / HVAC engineering / Electrical engineering / Builders / Construction companies /
Targeted Building type	Public
Project type	New Build
Lifecycle applicability	Concept Design, Developed Design, Technical Design, Construction
Brief description of the case study	Headquarters in Helsinki, Finland, that has achieved LEED Core & Shell Platinum certification. BIM was used throuout the design and construction project.
Key Highlights	Holistic use of 3D BIM through project
	Trialed use of BIM carbon analyses during the design.
	Pioneering use of BIM 4D to plan and carry the construction of the project with a delivery timeline.
	Building envelope achieved good of air tightness. Window placements were optimized (for natural light) and sunshades to avoid excessive solar heat gain and the need for additional cooling.

<table>
<tr><td>Supporting best practice case study</td><td>Skanska House uses around a third less energy than the Finnish energy code (2010) requires. Water usage is around half than a typical Finnish office building. The project was awarded “Best Project” in the 2011 Tekla Global BIM competition and the “Work Site of the Year 2011” also for the pioneering use of BIM. Equipped with the necessary infrastructure to accommodate a photovoltaic solar system in the future. Achieved the LEED Core & Shell Platinum Certificate.
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>The building is equipped with an outdoor air delivery monitoring system. Demand based ventilation with occupancy sensors and low-speed air handling units. The building’s occupants can control the indoor temperature locally to promote individual comfort. Cooling peak loads are monitored via centralized monitoring system. Through monitoring system air flow and cooling capacity can be increased for each individual work space. Lighting system optimized by daylight and occupancy sensors. Building Management System monitors the building’s total energy consumption and includes sub meters, which can promote more energy efficient tenant behavior.</td></tr>
<tr><td>Control Variables</td><td></td></tr>
<tr><td>Objectives</td><td></td></tr>
<tr><td>Effective Environmental Variables</td><td></td></tr>
<tr><td>Control Rules</td><td></td></tr>
<tr><td>Actors</td><td></td></tr>
<tr><td>When Applicable</td><td></td></tr>
</table></td></tr>
<tr><td>Learning Outcomes:</td><td>Holistically BIM-based project achieved LEED Core & Shell Platinum Certificate.</td></tr>
<tr><td>Supporting resources</td><td>http://www.skanska-sustainability-case-studies.com/index.php/latest-case-studies/item/download/110_e5719b55648a979d25e5f3929dc2412d</td></tr>
</table>

Use Case 29:

<table>
<tr><td>Use Cases Title</td><td>Design of energy-efficient library with high architectural goals</td></tr>
<tr><td>Use Case type</td><td>Real-world application</td></tr>
<tr><td>Funding source</td><td>Helsinki City</td></tr>
<tr><td>Project Title</td><td>Dynamic energy simulations part of whole design process. BIM helped designing and executing a structurally complex building and hiding visually unpleasant HVAC-systems</td></tr>
<tr><td>Web Link (URL)</td><td>http://keskustakirjasto.fi/en/</td></tr>
<tr><td>Targeted Discipline</td><td>Architectural design / Structural engineering / HVAC engineering / Electrical engineering / Builders / Construction companies / Suppliers</td></tr>
<tr><td>Targeted Building type</td><td>Public</td></tr>
<tr><td>Project type</td><td>New Build</td></tr>
<tr><td>Lifecycle applicability</td><td>Preparation and Brief, Concept Design, Developed Design, Technical Design, Construction</td></tr>
<tr><td>Brief description of the case study</td><td>New Central library with hybrid structures and high architectural and indoor-climate demands. Nearly zero-energy building (national standards, max. design E-value of the building 120 kWh/m2). Energy and indoor simulations were run by HVAC designers in close cooperation with architects to optimize building performance in different heating loads and weather conditions in different areas of the building. Simulations were especially important in areas with big glazed facades to reduce cooling demand (shading solutions) and ensuring the thermal comfort of the indoors. The building model was very detailed from the early stages of the design. Routings for HVAC-systems were designed in concept design phase to make sure everything will fit. Ventilation units were not allowed on the roof and ventilation terminal devices were integrated into interior design with cooperation of different equipment suppliers.</td></tr>
<tr><td rowspan="4">Key Highlights</td><td>Holistic use of 3D BIM through project</td></tr>
<tr><td>Dynamic energy-simulation model (Ida Ice) was in active use and frequently updated throughout the design process from the earliest stages.</td></tr>
<tr><td>In pre-design the model was used in goal assessing (energy efficiency, indoor climate quality etc.) for the further and more developed design stages.</td></tr>
<tr><td></td></tr>
<tr><td>Supporting best practice case study</td><td>BIM modelling was used in architecturally demanding building to fit multiform hybrid structures together and achieve demanded energy-efficiency. Dynamic simulations played essential part starting from the earliest design stages.
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>Demand based ventilation. Several different cooling strategies to keep indoor climate comfortable in the multiple use-cases of the building.</td></tr>
<tr><td>Control Variables</td><td></td></tr>
<tr><td>Objectives</td><td></td></tr>
<tr><td>Effective Environmental Variables</td><td></td></tr>
<tr><td>Control Rules</td><td></td></tr>
<tr><td>Actors</td><td></td></tr>
<tr><td>When Applicable</td><td></td></tr>
</table>
</td></tr>
</table>

Learning Outcomes:	According to HVAC -engineers building would be impossible to execute without BIM and constant co-operation with architects. Energy optimization results impacted for the building and HVAC design. Because the detailed early stage design of the building, remodelling or changes in later design phases would have been more difficult and time demanding than typically. But no changes came in this project.
Supporting resources	Kärkkänen, Minna. 2016. Uuden aikakauden kirjasto. Talotekniikka -magazine 5/2016, p. 18-21.

Use Case 30:

Use Cases Title	Use of Optimization tool to compare hundreds of concepts energy efficiency before actual design
Use Case type	Real-world application
Funding source	YIT, Etera, Onvest and Fennia
Project Title	Office building energy efficiency optimized with Optimization tool
Web Link (URL)	https://tripla.yit.fi/en
Targeted Discipline	Architectural
Targeted Building type	Public
Project type	New Build
Lifecycle applicability	Concept Design
Brief description of the case study	A big construction project in Helsinki, Finland. The development will consist of office, apartment houses, hotels and shopping mall. Energy efficiency and environmental target in Tripla is LEED Platinum, also 'nearly zero energy' principles have been used. In office-building a new Optimization Tool, that can compare 100-1000 alternatives in couple of hours, was used before design phase. Parameters are collected from BIM. In Tripla results and alterative options were discussed in two-day workshop with decision makers and designers before design phase. Tool was developed in RYM PRE Model Nova and ISES-projects and in a Masters Thesis by Granlund Ltd.
Key Highlights	Optimisation tool gave quickly an overall view of impacts of different variables of the building and what was most effective in energy saving. In Tripla building envelope energy efficiency less significance than demand based lighting and ventilation.
	Optimisation tool helped in finding placements for windows, type of windows, shadings and designing more adaptable indoor spaces by calculating directly their effects on energy demand, indoor air quality, and investment and energy costs.
	Two day workshop (called Solmu) had architect, HVAC-engineer, electric engineer, energy-calculator, leader of the workshop, and clients present evaluating results of the Optimization tool. Improved solutions were calculated and visualized then real-time in the meeting.
Supporting best practice case study	Use of Optimization Tool made it possible to quickly calculate, visualize and compare multiple different concept variables, such as different energy efficiency measures and their impact to indoor air quality or cost-effectiveness at very early stages of design. Tool was utilized in workshops with designers and decision makers and found very useful. Without the tool only a couple of options would had been able to analyse as deeply from the almost infinite number of alternatives.

Scenario Definitions	Holistic Solution
Scenario Definition	
Control Variables	
Objectives	
Effective Environmental Variables	
Control Rules	
Actors	
When Applicable	

Learning Outcomes:	Compared to business as usual where a only few alternatives/building concepts might be studied more deeply for decision making, use of Optimization tool has the potential to save money and time while directing to more optimal energy efficiency solutions.
Supporting resources	https://europa.eu/investeu/projects/new-development-helsinki_en; http://docplayer.fi/7956154-Energiasimuloinnin-parametrisointi-ja-rakennuksen-energiatehokkaan-suunnitteluratkaisun-tuottamisen-analysoinnin-ja-paatoksenteon-kehitysperusteet.html

Use Case 31:

<table>
<tr><td>Use Cases Title</td><td>Improving Energy Performance of Office Buildings Based on Light Building Information Model (BIM)</td></tr>
<tr><td>Use Case type</td><td>R&D; Master's thesis</td></tr>
<tr><td>Funding source</td><td>PRE-program; Grandlund Oy</td></tr>
<tr><td>Project Title</td><td>Improving Energy Performance of Office Buildings Based on Light Building Information Model (BIM)</td></tr>
<tr><td>Web Link (URL)</td><td>https://aaltodoc.aalto.fi/handle/123456789/11442</td></tr>
<tr><td>Targeted Discipline</td><td>Energy Modeler</td></tr>
<tr><td>Targeted Building type</td><td>Office</td></tr>
<tr><td>Project type</td><td>Existing, Renovation</td></tr>
<tr><td>Lifecycle applicability</td><td>In Use</td></tr>
<tr><td>Brief description of the case study</td><td>The case study is a multitenant office building called "Hakaniemenranta 6" located in Helsinki and owned by Senate Properties. The work studies BIM enabled energy efficiency service possibilities for the tenants of the case building. It provides a comparative results on energy simulations and actual energy consumption along with the possible renovation strategies to meet the energy demand. In the study, a light BIM refers to a BIM that only consists of required information in adequate accuracy to investigate the energy performance of a building. The light BIM of the case building was created when the building was renovated in 2009. The light BIM was in IFC form from where the geometry information was red to the Riuska energy simulation application.</td></tr>
<tr><td rowspan="3">Key Highlights</td><td>The different energy efficiency measures were simulated to demonstrate if the requirements of the decree of renovations (2013/4) were achieved.</td></tr>
<tr><td>The simulations proved that the energy performance of the case building can be improved in different ways to achieve the requirements of the decree (2013/4).</td></tr>
<tr><td>Tenant based energy performance simulation for about 2500sq m area shows the difference of 0.9% between realised heating consumption.</td></tr>
<tr><td>Supporting best practice case study</td><td>A light BIM can be created by two methods; either modelled based on an existing building’s architectural drawing or created from an existing 2D space model of a building, in which case the modelling work is reduced.
A light BIM can be used in calculating e-value and creating energy performance certificate (EPC) for an existing building as well as helps in setting energy efficiency goals for a tenant.
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td></td></tr>
<tr><td>Control Variables</td><td></td></tr>
<tr><td>Objectives</td><td></td></tr>
<tr><td>Effective Environmental Variables</td><td></td></tr>
<tr><td>Control Rules</td><td></td></tr>
<tr><td>Actors</td><td></td></tr>
<tr><td>When Applicable</td><td></td></tr>
</table></td></tr>
<tr><td>Learning Outcomes:</td><td>Minimal information requirements for energy simulation is highlighted in the study.</td></tr>
<tr><td>Supporting resources</td><td></td></tr>
</table>

Use Case 32:

<table>
<tr><td>Use Cases Title</td><td>Retrofit alternatives based on energy simulations</td></tr>
<tr><td>Use Case type</td><td>R&D; Master's thesis</td></tr>
<tr><td>Funding source</td><td>Grandlund Oy; NewTREND EU Projec</td></tr>
<tr><td>Project Title</td><td>New energy analysis process for the design of building retrofits</td></tr>
<tr><td>Web Link (URL)</td><td>https://aaltodoc.aalto.fi/handle/123456789/23259</td></tr>
<tr><td>Targeted Discipline</td><td>Architectural Design, HVAC Engineering</td></tr>
<tr><td>Targeted Building type</td><td>Public</td></tr>
<tr><td>Project type</td><td>Existing, Renovation</td></tr>
<tr><td>Lifecycle applicability</td><td>In Use</td></tr>
<tr><td>Brief description of the case study</td><td>The pilot project neighbourhood is located in the city of Seinäjoki, Finland. The neighbourhood consists of four buildings that were originally built in 1930 to serve as county hospital of Seinäjoki, but since the 1980s the hospital moved elsewhere. The buildings are owned by the City of Seinäjoki and are being used for multiple different purposes.</td></tr>
<tr><td rowspan="4">Key Highlights</td><td>BIM is the more accurate simulation results, since all the rooms and envelope elements can be modelled in their precise locations. Also, utilizing BIM makes the data input faster. Simulations provided possibilities for assessment of energy saving potential for the buildings. A difference of 4.7% between simulated and measured (actual) heat consumption. Parametrization of ranged input parameters for sensitivity analysis simulations were carried out which had a total of 52488 different combination possibilities.</td></tr>
<tr><td>Simulations provided possibilities for assessment of energy saving potential for the buildings.</td></tr>
<tr><td>A difference of 4.7% between simulated and measured (actual) heat consumption.</td></tr>
<tr><td>Parametrization of ranged input parameters for sensitivity analysis simulations were carried out which had a total of 52488 different combination possibilities.</td></tr>
<tr><td>Supporting best practice case study</td><td>Four different types of buildings are used as a case for energy simulations and compared with the best retrofit possibilities. Sensitivity analysis is imposed and verified as a new energy analysis process for the retrofits.
Retrofit design alternatives and impact on LCC based ion the most important KPI's were carried out.
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td></td></tr>
<tr><td>Control Variables</td><td></td></tr>
<tr><td>Objectives</td><td></td></tr>
<tr><td>Effective Environmental Variables</td><td></td></tr>
<tr><td>Control Rules</td><td></td></tr>
<tr><td>Actors</td><td></td></tr>
<tr><td>When Applicable</td><td></td></tr>
</table>
</td></tr>
<tr><td>Learning Outcomes:</td><td>BIM model used for sensitivity analysis simulations as well as AHU groups, room specific internal loads and ventilation rates need were model based input.</td></tr>
<tr><td>Supporting resources</td><td></td></tr>
</table>

Use Case 33:

<table>
<tr><td>Use Cases Title</td><td>Collaborative optimisation of building performance during concept design phase</td></tr>
<tr><td>Use Case type</td><td>Real world application involving R&D aspect</td></tr>
<tr><td>Funding source</td><td>Senate Properties (client) and Finnish Funding agency for Innovation, Tekes (R&D)</td></tr>
<tr><td>Project Title</td><td>Onerva Mäki school</td></tr>
<tr><td>Web Link (URL)</td><td></td></tr>
<tr><td>Targeted Discipline</td><td>All</td></tr>
<tr><td>Targeted Building type</td><td>Public</td></tr>
<tr><td>Project type</td><td>New Build</td></tr>
<tr><td>Lifecycle applicability</td><td>Concept design</td></tr>
<tr><td>Brief description of the case study</td><td>This study presents a BIM-based and project team collaboration based approach to building performance assessment. Target is to understand dependencies and impacts of design changes into different targeted aspects. A workshop method called "knotworking" was used for project team collaboration during concept design phase. A carefully prepared workshop was used for assessing and developing design options. Energy consumption was assessed together with other characteristics of the building.</td></tr>
<tr><td rowspan="3">Key Highlights</td><td>BIM is developed and energy simulations done regularly in Senate Properties building projects. In this case the integration of energy specialists with the design and management teams was done with new approach.</td></tr>
<tr><td>The assessment in the workshop was made regarding
-Space layout (functionality)
-E-luku (Finnish energy metric required by the building code)
-Energy consumption
-Investment cost
-Energy cost
-“Healthy building criteria” (building physics and structural risks)</td></tr>
<tr><td>All necessary project participants were included in the facilitated workshop. Results to produce in the workshop were clarified to the team.</td></tr>
<tr><td>Supporting best practice case study</td><td>The case study is a school building located in Jyväskylä, FInland. A new building was developed for a special school for visually impaired children. The design process was more participatory than current traditional project including lots of involvement from the school users’ side and collaborative workshop process for design.
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>In concept design phase 3 alternatives were developed of the building concept. Architect modelled the solutions as spatial models (as space groups). The whole project team come together for a full day workshop where the design options were presented, simulated for energy and cost, and validated for their functionality as a school.</td></tr>
<tr><td>Control Variables</td><td>Architects space model was well suited for energy consumption analysis but not detailed enough for accurate cost estimation and indoor condition simulation</td></tr>
</table></td></tr>
</table>

	Objectives	In the workshop the project team assessed energy efficiency and other metrics that could be defined form the early stage model (and other design information at this stage). -Space layout (functionality) -E-luku (Finnish energy metric required by the building code) -Energy consumption -Investment cost -Energy cost -“Healthy building criteria” (building physics and structural risks)
	Effective Environmental Variables	Assessment results were visualized by graphs and with help of the model
	Control Rules	At the workshop all main participants of the project were present -the architect -structural engineer -HVAC and electrical engineer -energy simulation expert -cost estimation consultant -building user’s representatives -project manager (client) -project management consultant -BIM coordination consultant and BIM adviser (client) -knotworking facilitator
	Actors	Instant sharing of thoughts and decision making was possible when all were present in the same room. Energy consumption was improved during the workshop by adding the U-value of windows and adding the air-tightness requirement for the envelope. The target for E-number was lowered because it was shown during the workshop that the original set target was not realistic
	When Applicable	The best chosen design option was developed based on the feedback from the workshop. However, it was also decided to develop two more design/layout options that are more different from first three and repeat the assessment workshop. In later workshop also indoor conditions were simulated based on the architects BIM.
Learning Outcomes:	The use of BIM and energy specialised experts has helped achieving rapid assessment of energy aspects as one part of total assessment of suitability and performance of design proposals. Also visualisation of results help all participants to understand and assess the energy specific results. Collaborative method "Knotworking" to design and assessment is crucial factor for gaining results that all stakeholders can contribute to and agree upon.	
Supporting resources	http://rymreport.com/pre/wp-content/uploads/2014/09/PRE-Results-Report.pdf , page 89, page 29	

Experts

Use Case 34:

<table>
<tr><td>Use Cases Title</td><td>De Lacy Row (BRE)</td></tr>
<tr><td>Use Case type</td><td>Real world (prototype)</td></tr>
<tr><td>Funding source</td><td>Plus Dane (RSL)</td></tr>
<tr><td>Project Title</td><td>De Lacy Row</td></tr>
<tr><td>Web Link (URL)</td><td>http://www.johnmccall.co.uk/portfolio_page/ni-smartbuild/</td></tr>
<tr><td>Targeted Discipline</td><td>Architecture</td></tr>
<tr><td>Targeted Building type</td><td>Domestic</td></tr>
<tr><td>Project type</td><td>New Build</td></tr>
<tr><td>Lifecycle applicability</td><td>Stages 0-6 with 7 operations and maintenance considered by client</td></tr>
<tr><td>Brief description of the case study</td><td>See https://www.youtube.com/watch?v=aJcYVZMJCHs&feature=youtu.be</td></tr>
<tr><td rowspan="4">Key Highlights</td><td>Whilst its focus was more on BIM than environmental efficiency, the selection of materials and ventilation strategies was considered in order to deliver a set of houses that were to be maintained by the client's in-house team.</td></tr>
<tr><td>Passive ventilation system type 2.</td></tr>
<tr><td>Timber frame inner leaf. Radiators designed out (with provision for future installation if the client decide to add).</td></tr>
<tr><td>The client was worried that the tenants might feel cold because of the psychological effect of the absence of a radiator in the upstairs rooms.</td></tr>
<tr><td>Supporting best practice case study</td><td>
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>Option Appraisals</td></tr>
<tr><td>Control Variables</td><td>Other similar projects in the same area</td></tr>
<tr><td>Objectives</td><td>To provide housing without using contractors and subcontractors but instead using the client's own workforce</td></tr>
<tr><td>Effective Environmental Variables</td><td>Passive ventilation instead of mechanical.</td></tr>
<tr><td>Control Rules</td><td></td></tr>
<tr><td>Actors</td><td>Tenants, RSLs, Project Manager, Architects, Timber frame contractor, ground works contractors</td></tr>
<tr><td>When Applicable</td><td></td></tr>
</table>
</td></tr>
<tr><td>Learning Outcomes:</td><td>It achieved the timber frame design co-ordination, the trade's co-ordination on site, the passive ventilation design system. Whilst no LCA or WLC was carried out in a quantitative manner, the client had in mind that the whole life cycle would benefit from its social agenda for providing local jobs to is workforce and good quality affordable housing at a price that is no greater than what it would cast to get external contractors to build.</td></tr>
<tr><td>Supporting resources</td><td></td></tr>
</table>

Use Case 35:

<table>
<tr><td>Use Cases Title</td><td>Energy properties of solar shading devices and their impact on the visual comfort of occupants (LIST).</td></tr>
<tr><td>Use Case type</td><td>R&D</td></tr>
<tr><td>Funding source</td><td>Wallonia - Belgium</td></tr>
<tr><td>Project Title</td><td>PROSOLIS</td></tr>
<tr><td>Web Link (URL)</td><td>www.prosolis.be</td></tr>
<tr><td>Targeted Discipline</td><td>Architectural Design</td></tr>
<tr><td>Targeted Building type</td><td>Public</td></tr>
<tr><td>Project type</td><td>Existing</td></tr>
<tr><td>Lifecycle applicability</td><td>Design Stages</td></tr>
<tr><td>Brief description of the case study</td><td>Energy properties of solar shading devices and their impact on the visual comfort of occupants</td></tr>
<tr><td rowspan="4">Key Highlights</td><td>Solar shading. Energy Consumption. Daylight supply.</td></tr>
<tr><td></td></tr>
<tr><td></td></tr>
<tr><td></td></tr>
<tr><td>Supporting best practice case study</td><td>
<table>
<tr><th>Scenario Definitions</th><th>Holistic Solution</th></tr>
<tr><td>Scenario Definition</td><td>Representative rooms Belgian climate</td></tr>
<tr><td>Control Variables</td><td>Energy Consumption; Visual Comfort; Thermal Comfort</td></tr>
<tr><td>Objectives</td><td>Comparison of energy properties of solar shading devices and their impact on the visual comfort of occupants</td></tr>
<tr><td>Effective Environmental Variables</td><td>Orientation, glazing, solar shading</td></tr>
<tr><td>Control Rules</td><td>Solar radiation</td></tr>
<tr><td>Actors</td><td>NA</td></tr>
<tr><td>When Applicable</td><td>NA</td></tr>
</table>
</td></tr>
<tr><td>Learning Outcomes:</td><td>Integration of multidisciplinary approach for the choice of solar shading</td></tr>
<tr><td>Supporting resources</td><td>www.prosolis.be</td></tr>
</table>

Use Case 36:

Use Cases Title	Use of BIM for ESD Analysis of BCA Academic Tower
Use Case type	Real world project
Funding source	Building Construction Authority
Project Title	Design and Construction of BCA Academic Tower
Web Link (URL)	http://www.rsp.com.sg/project/show?id=224
Targeted Discipline	Architectural, Mechanical & Structural
Targeted Building type	Public
Project type	New Build
Lifecycle applicability	RIBA Stage Concept Design and Stage Developed Design
Brief description of the case study	BCA Academy Project consists of a new 10-Storey Academic Block, with an adjoining new 6-Storey Training Workshop Block and new Pavilion. The design aim to provide a climatically responsive and incorporate active and passive features wherever possible to lower energy consumption. These includes proper orientation of the buildings, appropriate choice of materials, use of energy fittings, fixtures and devices (such as light fittings), good fenestration and daylight design, etc. Vertical greenery and roof garden should be provided, where possible. Building Information Modelling (BIM) plays a pivotal role in achieving the required sustainable design features.
Key Highlights	Using BIM for ESD analysis and simulation, sustainable features achieve 35% energy savings for this building. Preliminary Wind studies were carried out leveraging the BIM model applied with the site's prevailing wind conditions.
	The results allowed the design team to make an informed decision for the model to be carefully tweaked to obtain the optimum natural cross ventilation level.
	o assist in achieving the required Green Mark Platinum rating (equivalent to US LEED Platinum Certification), and to ensure that optimal number of light fittings is provided, the M&E engineers had taken advantage of BIM's ability to integrate with IES to generate artificial lighting analysis and simulation.
Supporting best practice case study	The designers were able to test several options for improving the shading but aiming not to affect wind flow. This was done by using the BIM model in performing shading analysis.

Scenario Definitions	Holistic Solution
Scenario Definition	
Control Variables	
Objectives	
Effective Environmental Variables	
Control Rules	
Actors	
When Applicable	

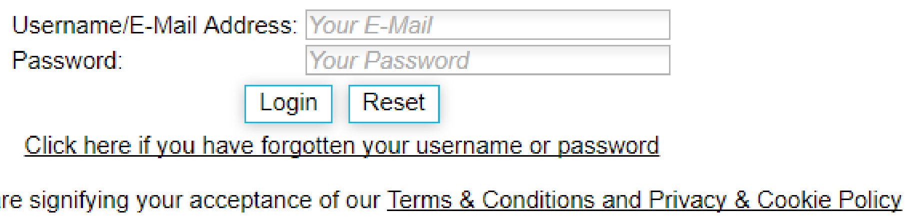
Learning Outcomes:	BIM plays a pivotal role in achieving energy efficiency by leveraging the BIM model and performing several types of energy analysis and simulations.
Supporting resources	ESD tools, simplified version of the BIM model

Appendix C: Use-case input user guide.

This document explains how to input a new use-case study within the BIMEET platform.

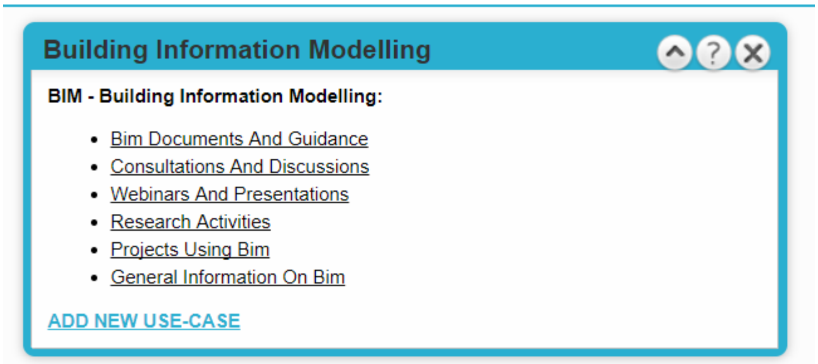
Step 1: Please type the url: www.energy-bim.com to access the BIMEET platform aggregator.

Step 2: After creating the account please click "**Login**" in order to login with corresponding credentials

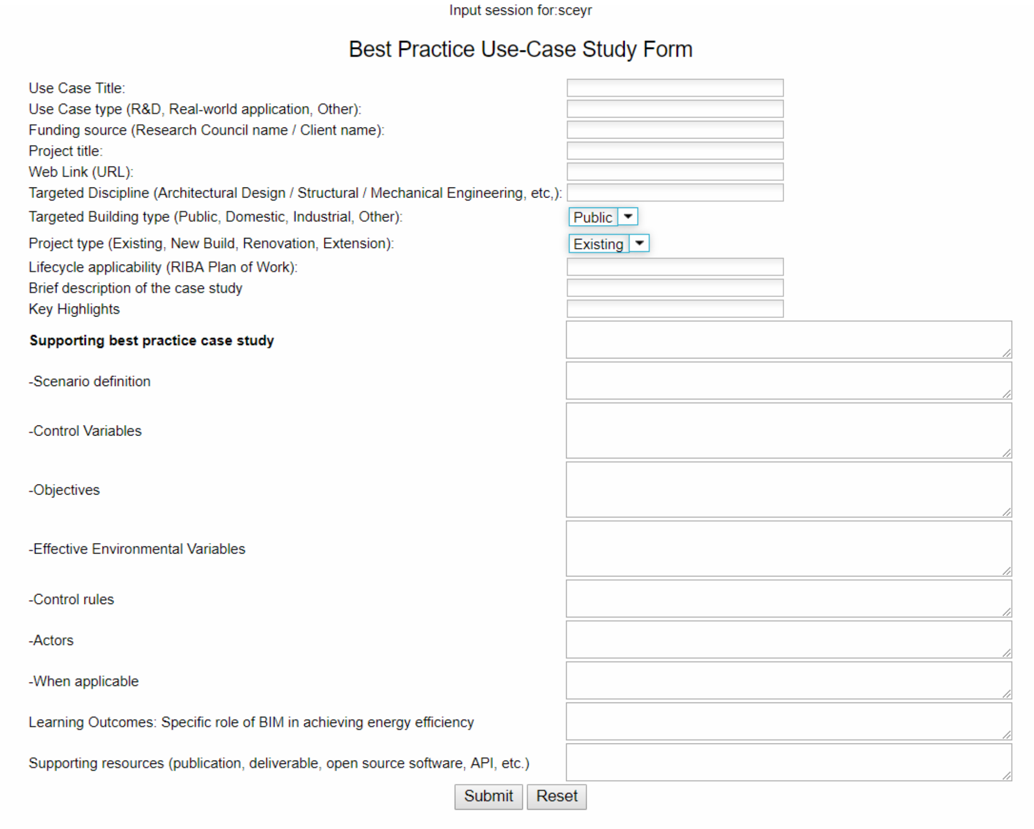


Step 3: After login, please make sure the BIM widget has been activated form the "Configure" menu on the left side and appears within the platform.

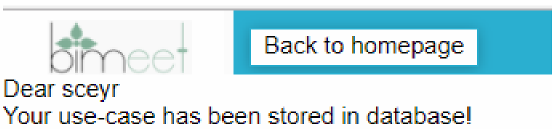
Step 4: Please expand the BIM widget and click on “ADD NEW USE-CASE” link. A form will be displayed for recording your selected use-case.



Step 5: Please fill all the fields in the “Best practices use-case form”.



Step 6: Once provided all the fields please click submit and a confirmation page will appear. Then click on “Back to homepage” to continue with the platform.

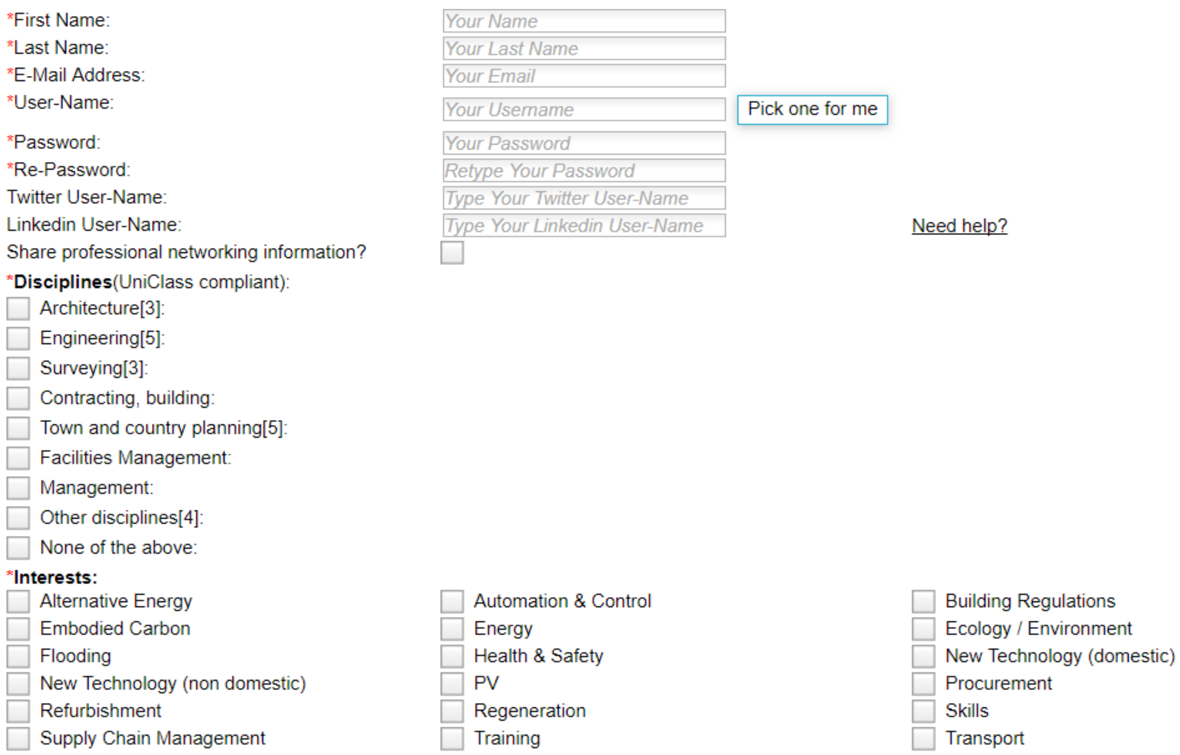


Appendix D – Search user guide and community engagement.

This document explains how to access, use and configure the BIMEET aggregator platform for conduction searching and validation of relevant BIM energy online data sources.

Step 1: Please type the url: www.energy-bim.com to access the BIMEET platform aggregator.

Step 2: Please click on "**Create Account**" and fill in the form to create an account



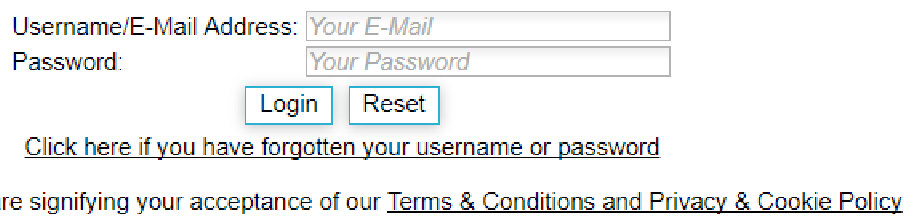
*First Name: Your Name
*Last Name: Your Last Name
*E-Mail Address: Your Email
*User-Name: Your Username [Pick one for me]
*Password: Your Password
*Re-Password: Retype Your Password
Twitter User-Name: Type Your Twitter User-Name
Linkedin User-Name: Type Your Linkedin User-Name — Need help?
Share professional networking information? ☐

***Disciplines**(UniClass compliant):
- ☐ Architecture[3]:
- ☐ Engineering[5]:
- ☐ Surveying[3]:
- ☐ Contracting, building:
- ☐ Town and country planning[5]:
- ☐ Facilities Management:
- ☐ Management:
- ☐ Other disciplines[4]:
- ☐ None of the above:

***Interests:**

☐ Alternative Energy	☐ Automation & Control	☐ Building Regulations
☐ Embodied Carbon	☐ Energy	☐ Ecology / Environment
☐ Flooding	☐ Health & Safety	☐ New Technology (domestic)
☐ New Technology (non domestic)	☐ PV	☐ Procurement
☐ Refurbishment	☐ Regeneration	☐ Skills
☐ Supply Chain Management	☐ Training	☐ Transport

Step 3: After creating the account please click "**Login**" in order to login with corresponding credentials



Username/E-Mail Address: Your E-Mail
Password: Your Password
[Login] [Reset]
Click here if you have forgotten your username or password

By Logging in your are signifying your acceptance of our Terms & Conditions and Privacy & Cookie Policy

Step 4: After login, click on "*Edit Profile*" going to the "Change Search Preferences" tab. In the "Add New Site" textbox please type the URI of the proposed web source to be indexed and crawled. Click "Add Site" and the site will be listed under section "My Sites" in the same page awaiting for approval from the BIMEET administrators.

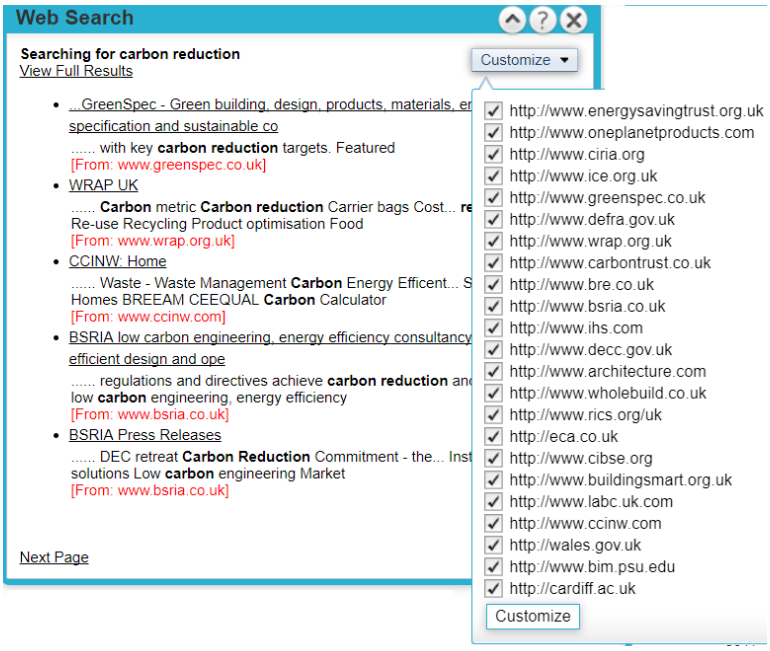
Edit Profile | Change Password | Change Search Preferences

Add New Site:

http://cardiff.ac.uk [Add Site]

Site Name	Status	Number of Pages
My Sites:		
http://www.bim.psu.edu	Site not yet indexed ✘	
Core Sites:		
http://www.energysavingtrust.org.uk	Last updated:2013-02-12	69 pages
http://www.oneplanetproducts.com	Last updated:2013-02-12	28 pages
http://www.ciria.org	Last updated:2013-02-12	1 pages
http://www.ice.org.uk	Last updated:2013-02-12	4024 pages
http://www.greenspec.co.uk	Last updated:2013-02-12	762 pages
http://www.defra.gov.uk	Last updated:2013-02-12	9087 pages
http://www.wrap.org.uk	Last updated:2013-02-12	1487 pages
http://www.carbontrust.co.uk	Last updated:2013-02-12	0 pages
http://www.bre.co.uk	Last updated:2013-02-12	74 pages
http://www.bsria.co.uk	Last updated:2013-02-12	969 pages
http://www.ihs.com	Last updated:2013-02-12	883 pages
http://www.decc.gov.uk	Last updated:2013-02-12	0 pages
http://www.architecture.com	Last updated:2013-02-12	0 pages
http://www.wholebuild.co.uk	Last updated:2013-02-12	579 pages
http://www.rics.org/uk	Last updated:2013-02-12	500 pages
http://eca.co.uk	Last updated:2013-02-12	729 pages
http://www.cibse.org	Last updated:2013-02-12	0 pages
http://www.buildingsmart.org.uk	Last updated:2013-02-12	710 pages
http://www.labc.uk.com	Last updated:2013-02-12	183 pages
http://www.ccinw.com	Last updated:2013-02-12	241 pages
http://wales.gov.uk	Last updated:2013-02-12	0 pages

Step 5: The newly added URI will appear under "Configure" button in "Search" widget at each search conducted within the BIMEET aggregator platform. However, pages will not be indexed until the administrator will approve the suggested URIs.



Step 6: Once all the partners have provided suggestion for indexed URIs, a decision will be taken by the consortium of the primary URIs that need to be kept as part of the crawling module.