SKILLS
INSTRUCT
INSTRUMENTS
CONSTRUCTION

D2.1 Evidencing the correlation between training and energy efficiency

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Disclaimer:

Table of Contents

List of Tables

List of Figures

List of Abbreviations

Abbreviation	Meaning
BEE	Building Energy Efficiency
BIM	Building Information Modelling
BREEAM	Building research Establishment Environmental Assessment Method
CU	Cardiff University
CPD	Continuing Professional Development
EE	Energy Efficiency
EERS	Energy Efficiency Resource Standards
Eeb PPP	Energy efficient buildings public private partnership
CEDEFOP	European Center for the Development of Vocational Training
ECCREDI	European Council for Construction Research, Development, and Innovation
EHPA	European Heat Pump Association
ENBRI	European Network of Building Research Institutes
EOTA	European Organisation for Technical Assessment
EU	European Union
EASME	Executive Agency for Small and Medium-sized Enterprises
GBC	Green Building Council
GDP	Gross Domestic Product
HVAC	Heating, ventilation, and Air Conditioning
ICT	Information and Communications Technology
IEA	International Energy Agency
IoT	Internet of Things
LEED	Leadership in Energy & Environmental Design
LIST	Luxembourg Institute of Technology
RIBA	Royal Institute of British Architects
SME's	Small Medium-sized Enterprises
SET	Strategic Energy Technology
URI	Uniform Resource Identifier
VET	Vocational Educational Training

Executive Summary

Current evidence that supports the correlation between training and energy efficiency in the construction industry is **sparse and lacks an in-depth and sector wide analysis**. Several context-specific(in terms of application, workforce segment, and country) studies have highlighted a number of barriers, challenges, and gaps in the training landscape in the European construction industry. However, these **do not scale-up and translate to robust evidence for the entire industry**.

The present report aims to address this gap by adopting a **Europe-wide consultation** that not only seeks to gather evidence correlating training with energy efficiency, but also **broadens the scope of the investigation beyond this objective to understand the complexity of the training landscape in energy efficiency** and **provide context to the resulting evidence**, in a way that promotes **generalisation of the results**.

More specifically, the present study attempts to evidence the correlation between training and energyefficiency by exploring the following research questions:

What is the state of awareness, access to information and dissemination of knowledge forenergy efficiency in the Construction sector?

What is the level of demand for skilled workforce in energy efficiency?

What is the state of the training programs for energy efficiency currently available in theindustry (in terms of scope, quality, content, cost, etc.)?

What is the state of the sector in terms of shared values and coordination of stakeholdersacross the supply chain for energy efficiency?

How efficient are legislative frameworks, policies, and government incentives?

To address the above questions, a **mixed-method approach** is adopted, involving **secondary** (in the form of industry studies and academic publications) and **primary sources of evidence**. The latter includes a survey (n= 52), a series of interviews (n= 27), an expert workshop, and 70 use cases drawn across Europe providing examples of correlation between training and energy efficiency.

The analysis of the results from the above instruments confirms the posited hypothesis on the correlation between training and energy efficiency, as illustrated and summarized in the table below. However, this points to number of policy measures, including the need for adapted instruments to promote **mutual recognition of energy skills and qualifications** in the European construction sector. This is being addressed in follow-on work of the H2020 INSTRUCT project.

	Inception	Design	Construction	In-use
Blue Collars	✓ **Site geotechnics teams** selected withthe right **skills and competencies**, including from an environmental impact perspective.		✓ **Construction site managers** selected with theright **skills and competencies**. ✓ **Blue collars** selected with the **right skills** and **competencies.** ✓ **Blue collars** continuously briefed about **bestpractice** in relation to their project tasks. ✓ **Building information** accurate and widely available to blue collars. ✓ **Building manuals** widely **accessible** to all bluecollars, including on portable devices. ✓ **Interfaces** between **Work Packages** rigorously managed. ✓ **Compliance** with design specification conducted **systematically.** ✓ **Rectify defects** as they occur and reported.	✓ **Monitor and inspect HVAC system components** on a continuous basis. ✓ **Detect and rectify malfunctions** as soon asthey occur.
White Collars	✓ Brief embeds **energy performance targets**. ✓ Consider interventions that best deliver **energy performance** targets. ✓ Site appraisal for **environmental impact mitigation**. ✓ Project Business case considers **environmental impacts**. ✓ **Sustainability outcomes** clearly articulated. ✓ **Compliance with energy building regulation** duly considered. ✓ Feasibility study **environmentally proofed.** ✓ **Procurement strategy** for **recyclingand re-use** considered**.** ✓ **Project information requirements** embeds environmental considerations. ✓ Delivery of a **performance-basedbrief.**	✓ **Design options** analysed through **lifecycleimpact assessment**. ✓ **Passive architectural design** principles considered and retained. ✓ **Integrated multi-disciplinary** low carbon design considered. ✓ Adoption of a **BIM-based information delivery** approach. ✓ Specialist design options that best deliver **energy performance** targets retained. ✓ Continuous **design review** against **Building Regulations.** ✓ **Lifecycle impact** of **structural design** consideredand optimized. ✓ **Lifecycle impact of MEP** (Mechanical, Electricaland Plumbing) interventions considered and optimized. ✓ **Material procurement strategy** considered froman **environmental impact perspective.** ✓ **Building Manuals** clearly drafted highlighting **environmental aspects.** ✓ **Detailed design** complies with energy **Building regulations** and meets **Low / Net-zero carbon targets**.	✓ **Site logistics and planning** optimized to **minimize environmental** impacts**.** ✓ Low carbon materials and products **procured.** ✓ Rigorous compliance with **construction planning** conditions. ✓ **Continuous quality site inspection.** ✓ **Commissioning** strategy discussed and firmed-up. ✓ **Review of project performance** rigorously conducted and **evidenced.** ✓ **Post occupancy evaluation strategy** discussedand firmed-up.	✓ **Facility management** strategy critically **reviewed and agreed.** ✓ **Monitor the energy performance** of the building on a **continuousand real-time basis.** ✓ **Continuously reduce and eliminate** the **gap** between **predicted and actual energy** performance. ✓ Implement a **continuous commissioning strategy** to identify malfunctions and defects. ✓ **Conduct actionable** (dynamic and real-time)**post occupancy evaluation**. ✓ **Review of project performance** rigorously conducted and **evidenced.**

1. Introduction

1.1. Background

Over the last decades, the collective efforts to focus on more sustainable solutions in the constructionsector have intensified on a global level. This has continuously informed energy efficiency policies as well as future targets and goals in the built environment. Furthermore, the construction market is setto grow exponentially by 2025 (Oxford Economics, 2013). However, there is evidence the industry needs to become more cohesive and effective, in order to achieve its goals towards energy efficiency and reducing carbon emissions, as currently there are several factors hindering this transformation (Rezgui & Miles, 2011; Petri and Rezgui, 2020). The literature highlights several barriers affecting the efficiency of the way that measures towards energy efficiency are applied in industry, ranging from policy aspects to economic challenges and market barriers, to adequate training and knowledge. In this context, it is crucial to keep investigating ways and pathways to increase the efficiency of the industry towards the desired targets of energy efficiency and clean energy, as set by the European Union. What has also emerged from the literature is an understanding that most efforts have placed alot of importance on technologies, rather than energy management. We are seeing an increase in the number of countries that make energy labels mandatory. Energy audits, energy management systems,energy manager training and certification, (Li et al, 2019) are also support and awareness-raising instruments that are usually effective in promoting energy efficiency and increasing the demand for askilled workforce, including blue collars, as well as creating awareness about energy consumption andwastage (Chai and Yeo, 2012). Training and education could, therefore, be argued to be a crucial enabler in these endeavours. In fact, staff training and change management tend to be relatively low-cost activities and have been demonstrated to have large positive effects on the promotion of EE (energy efficiency) in the industry (Bernstein et al, 2007).
The assessment of the current state of energy efficiency-related education and training programs andrelated training and education needs in BIM (Building Information Modelling) was conducted by both the BIM4VET (Guerriero et al., 2019) and BIMEET (Petri et al., 2017) projects. There is a need to extendthis assessment beyond BIM to infer wider needs to promote the development of value-added energyefficiency services and train the associated workforce accordingly. Related studies point to several interesting findings:
Integrate building and industrial process system efficiency into existing building and construction techniques, apprenticeship, and trades curricula. In fact, contractors and tradespeople constitute an important proportion of the workforce in the construction sector. This workforce segment often suffers from a lack of awareness. This could be cost-effective to achieve economies of scale by training large numbers of tradesman, including electricians, HVAC (heating ventilation and air conditioner) contractors, mechanical insulators, and home builders.
Coordinate and manage best practices across Europe by relying on dedicated initiatives such asBuild Up Skills. In fact, there is a need to (a) identify and determine the training programs and courses that will address the education and training needs related to energy efficiency, and (b) provide better coordination between the training programs across member states. This will be helpful to prevent duplication at a national and EU-wide level.

Promote the delivery of short duration, on-the-job, trainings, as opposed to focussing exclusivelyon academic-like trainings. Examples of this type of offering include design assistance to architects, lighting designers, and engineers, and provide classes for contractors and building owners to increase their understanding of energy-efficient building solutions.
Plan the training of trainers in that there is a lack of qualified trainers to train the workforce needed to support the projected growth in the Energy Efficiency services sector. These growth rates strain the capacity of existing trainers; additional resources from energy efficiency ratepayer and government funding could be directed towards training the next generation of trainers for the Energy Efficiency services sector.

Increase access to on-the-job training for mid- and senior-level engineers and managers throughdedicated Continuing Professional Development (CPD) and courses and related vocationalconferences and certification programmes offered by various institutions, such as Metropolia inFinland.
Prepare the next generation of energy efficiency professionals as there is a shortage of trained and knowledgeable workers.
Key to any successful stimulation of training initiative, such as in the context of Energy Efficiency, is effective communication of the required changes and adequate support during the process. The INSTRUCT consortium partners have an established track record in working with vocational and academic institutions to identify new ways to face this Europe-wide training challenge. The consortiumis drawing on (a) the engagement of internationally leading industry best practice, as well as vocationaltraining, delivered by CPD through an established training value chain, (b) the educational excellence of leading institutions in Europe, (c) the robust experience of accrediting bodies in the construction domain, and the breadth of required industry-led research excellence. The consortium argues that this approach of engaging providers in the development and delivery of the material and standards will notonly stimulate the demand for energy efficiency skills and competencies, but also will align the level and calibration of existing workforce (ranging from professional practitioners to blue-collar workers) and future industry professionals, thus providing a structure for lifelong development learning aroundin the field of energy efficiency.

1.2. Evidencing the correlation between training and energy efficiency

The aim of this study is to deliver the industry and academic evidence that corroborates and reinforcesthe correlation between (a) skills and education, and (b) energy performance and quality. This involves:

a desk review to collect, organize and synthesize available evidence from authoritative sourcesacross Europe and beyond. The review included both existing practices but also legislative frameworks.
The desk review fed into a series of consultations with key stakeholders, including BUILD UP Skills initiative key representatives across Europe with a view of reinforcing the gathered evidence with further cases drawn from industry and practice.

This involves a participative and incremental approach in collaboration with the INSTRUCT project Expert Panel with a view to reach key stakeholder communities, including consortia of the EeB PPP community (Energy efficient buildings Public-Private Partnership), members of the E2B association andits network of national liaison points across member states, representatives of European associations and federations dealing with the building sector such as ECCREDI (European Council for Construction Research, Development and Innovation), EOTA (European Organisation for Technical Assessment), ENBRI (European Network of Building Research Institutes), and national Build-Up skills initiatives witha view to help identify and then screen / analyse past and ongoing projects related to energy efficiencyin the built environment. The objective is to assemble evidence-based measurable scenarios and use cases that demonstrate the role of training and education in achieving energy efficiency in buildings across the whole value chain. The resulting evidence will be structured by stage and discipline, highlighting stakeholder targets ranging from blue-collar workers to decision makers.
The present document is structured into 6 chapters, with Chapter 7 and 8 providing the references andAnnexes that underpin and support the research. Following this introduction, Chapter 2 provides a thorough review of the related literature, identifying secondary sources of evidence that corroborate the correlation between training & education and energy efficiency in the Construction sector. Chapter3 elaborates on the methodology that underpins the research. Chapter 4 presents the results, which are then discussed in Chapter 5 using a triangulation approach. Finally, Chapter 6 confirms the posited hypothesis and provides concluding remarks.

2. Review of the Global Training Landscape for Energy Efficiency in the Construction Industry

2.1 Introduction

In this chapter, the literature review for the study is presented. The review has as its aim to evidence the correlation between training and energy efficiency in the building sector.

2.2 Energy & Energy Efficiency & Quality: Global Perspectives and the BuildingSector

Since the establishment of the International Energy Agency (IEA) in 1974 the goal to develop strategiesin order to tackle the challenges of energy use and management has been the focus of attention for various disciplines and fields of knowledge, so as to achieve better results towards clean energy, including energy efficiency and low-carbon technologies (Oettinger et al., 2013). In this spirit, policies across the globe have integrated this need in robust energy efficiency frameworks of actions, which present a long-term engagement and can be reviewed over time. For example, in 2019, The AmericanCouncil for an Energy Efficient Economy, reviewed the Energy Efficiency Resource Standards (EERS), which in the last two decades have been a driving force towards electricity and gas savings, across 27 states. Notable results have been observed in this framework, such as, for instance, 80% savings in theutility sector in 2017 (Gold et al., 2019). Overall, and on a worldwide level, it could be argued that, overthe last few decades, there have been changes, which point to a hopeful outcome towards this endeavour. As highlighted by Waide et al. (2005), “In the year 2000, total final energy consumption per unit of Gross Domestic Product (GDP) was only 60% of the 1973 level, while total primary energy supply per unit of GDP was about 67% of the 1973 level”. The efforts to reduce CO_2 emissions are intensive, integrate a number of sectors, and aim at a long-term timeframe of actions and policies (Figure 1). In this context, energy efficiency is characterised as “the first fuel” by the IEA, predicted to be even more significant than, for example, renewable energy in the next decades (Pears, 2020).
Yet, there is evidence that overall energy efficiency has fallen behind in terms of how it is presented as a priority, even if it is still considered important. In some cases, energy efficiency has been characterized as the “forgotten fuel”, for example in Australia, something which, as Pears suggests is not atypical (Pears, 2020). This phenomenon seems to be a manifestation of a global issue that has also been raised by the IEA Executive Director in 2018, who argued that: “In 2018, global primary energy intensity improved by only 1.2%, the slowest rate since the start of the decade and the third consecutive year that energy intensity improvements have weakened. This trend is worrying in a worldwhere there is a growing disconnect between political statements and global energy-related greenhouse gas emissions, which, in 2018, grew at their fastest rate since 2013” (Pears, 2020). It is indeed a landscape of knowledge which raises questions, due to the complexity of its nature and the many parameters and actors which contribute to its successful course.

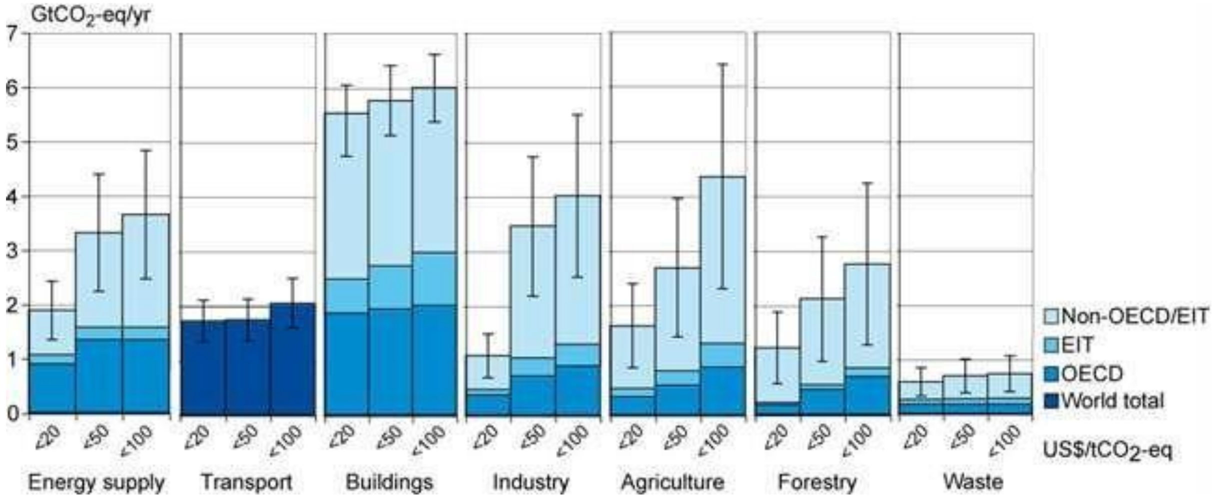

Figure 1. energy supply, transport, and industry combined Estimated Potential Reductions in Annual CO2 Emissions by Sector in 2030

(IPCC, 2007). Source: (Levine et al., 2012)

In fact, there has been a long-standing and ongoing debate between sceptics and advocates, with regards to the analysis of causes and solutions on the field of the efficiency of energy efficiency. This debate and antithetical positions, which were collected and are presented in Figure 2 by Brown and Wang (2017), have, however, contributed to the endeavour of highlighting weaknesses. They have acted as fertile ground in order to think of synthetical solutions and improve our understanding of thefield of energy efficiency, its problematics, but also its possibilities (Brown and Wang, 2017).

In the building sector, the recent climate conferences, including the 2015 United Nations Climate Change Conference (COP21) in Paris, have evidenced, and raised awareness about the impact of our built environment on climate change. Furthermore, Levine et al. observe that energy efficiency has thepotential of improving several areas, including "the natural environment, human dignity in terms of having decent jobs, and good health" (Levine et al., 2012). As presented in Figure 3, Figure 4 and Figure5 the so far but also future estimated impacts on energy from buildings on a global scale are significant. In the EU, energy for the building sector represents more than 40% of Europe's energy and CO2 emissions (European Construction Technology Platform, 2015). The 2030 climate and energy framework include key targets to reduce at least 40% cuts in greenhouse gas emissions (from 1990 levels), at least 32% share for renewable energy, and at least 32.5% improvement in energy efficiency. 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.

Skeptics	Advocates	Synthesis
1. Imperfections in energy markets are insignificant and are not a strong basis for assuming that an energy efficiency gap exists. Energy prices are reasonable reflections of total producer costs and consumer demand.	Energy prices do not fully reflect the cost of a range of significant negative externalities associated with energy use, including climate change. Other market failures exist as well.	Market-based policies such as putting a price on carbon can fix this important market imperfection.
2. Competing opportunities for using capital are more rewarding. Scarce capital is allocated to other options with higher returns.	Reward for energy efficiency investment may appear to be low because of market flaws such as the global commons problem posed by climate change.	Maturing finance programs that lower transaction costs and lower perceived risks will make EE more attractive over time.
3. Energy efficiency improvements are often overestimated and attribute too much of the change in total energy consumption to efficiency.	Decomposition methods are now available to isolate the energy efficiency effect, and experience with them is growing.	Policy analysis can separate efficiency effects from activity and structure effects based on decomposition methods.
4. Double counting occurs when program evaluators and modelers attribute natural occurring efficiency to policy interventions.	Naturally occurring energy efficiency is increasingly called out in program evaluations and forecasts and are not considered on the benefit side of the ledger.	EM&V methods need to count naturally occurring efficiency as part of the baseline.
5. Analysts often underestimate the discount rates used by consumers and firms and fail to recognize its heterogeneity. Firm and household discount rates are high because of opportunity costs, risks, rational inattention, and the illiquidity energy efficiency investments.	Discount rates can be lowered by reducing market uncertainties with improved benchmarking and labeling. Uncertainty over discount rates is also routinely evaluated using sensitivity analysis to better estimate the potential for energy savings.	Information-based programs can be effective in lowering discount rates, and sensitivity analysis is also recommended in estimating energy savings potentials.
6. Program evaluations often overlook hidden costs, such as the effort required by participants to find and install new equipment and process rebates of incentive payments.	These hidden transaction costs are increasingly considered in program evaluations and in assessing the size of the EE gap. Better program designs are also being developed to minimize these costs.	Transaction costs can be effectively reduced with user-friendly program designs that provide information, education, demon-stration, and workforce development.
7. Because of the rebound effect, engineering spreadsheets usually overestimate energy savings.	Models are increasingly accounting for the rebound effect and various behavioral "wrinkles." Additionally, the magnitude of the takeback effect can be reduced with policy design.	Practitioners can use educational programs to reduce the magnitude of the rebound effect; EM&V needs to consider the size of the effect.
8. Models do not always reflect the difficulties of delivering energy efficiency. Assimilating policy instruments into large-scale polycentric systems is only an emerging science.	Policy and program experience is growing. Leaders and laggards have been identified at the national, state, and local level, as have best practices.	Learning from leaders, neighbors, and past experience is now enabled by scorecards, case studies, and networking. Experiments with innovative instruments can also improve policy effectiveness.
9. Energy efficiency should be seen as a customer service and not as a utility resource.	New business models are able to integrate energy efficiency into utility resource planning. This will help inform what role it should play.	Utility revenue should be decoupled from sales; performance-based incentives for EE achievements can motivate greater savings.
10. Most of the cost-competitive energy ef-ficiency has been fully exploited; it has been largely tapped out and is challenged going forward by low-cost natural gas and sluggish US growth rates for electricity demand.	New opportunities for low-cost-energy sav-ings are being invented every day. The value of EE could also increase with the expanded electrification of transportation and heating in buildings and industry, un-der the assumption that renewables grow substantially.	Opportunities will grow with policy support for R&D, financing innovations, and ICT technologies. The future value of EE depends on growth rates for electricity services, which are a function of competing fuel prices and electrification trends.

Figure 2. Ten opposing views of skeptics and advocateSource: (Brown and Wang, 2017)

What is more, the global construction market is forecast to grow by over 70% by 2025 (Oxford Economics, 2013). As presented by Alhamami et al. (2020), in the British context, this includes reductions in the construction costs, greenhouse gas emissions, reductions in the timelines of the construction, as well as a reconciliation of the trade gap which are present at the moment. Furthermore, in the UK, as argued by Patterson in 2010, the retrofit industry pointed towardsexponential growth, with a goal of 25 million homes (Fien and Winfree, 2014). The construction industry hence presents a major challenge and opportunity to reduce energy demand, improve process efficiency, and reduce carbon emissions. The industry is 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 (Rezgui & Miles, 2011; Alhamami et al., 2020). Chaudhary et al. (2012) and Alhamami et al. (2020) observe how in order to achieve sustainable innovation there needs to be a holistic approach which integrates the entire innovation chain. 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. 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.

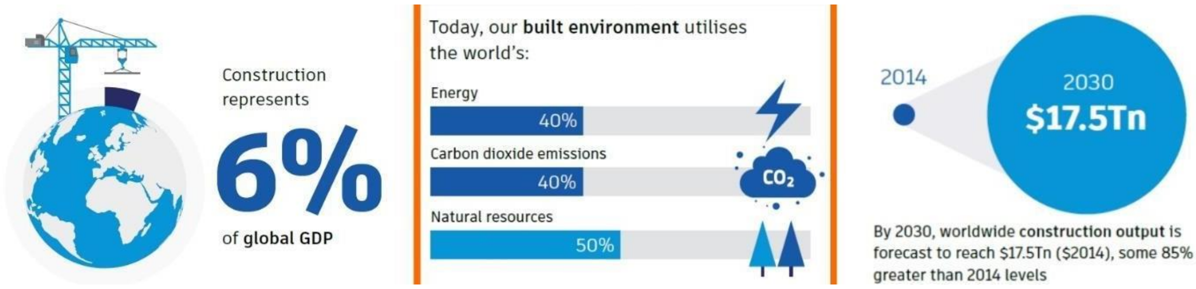

Figure 3. Impacts of the construction industry.

(Left: World Economic Forum, Middle and Right: Global construction 2030 as seen in Constructing with the power of digital, Autodesk Source: (Suwal et al., 2019)

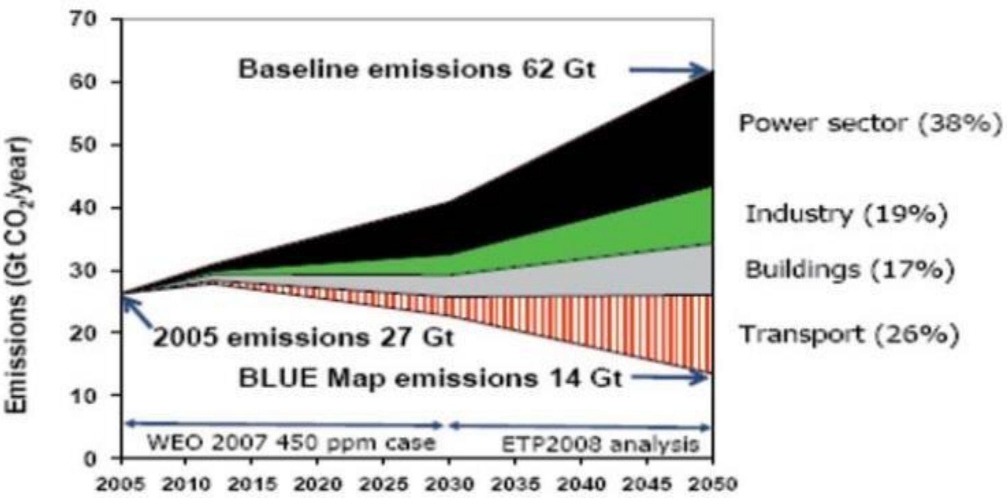

Figure 4. Buildings to contribute 17% of emissions savings by 2050 (IEA)Source: (Aerschot et al., 2009)

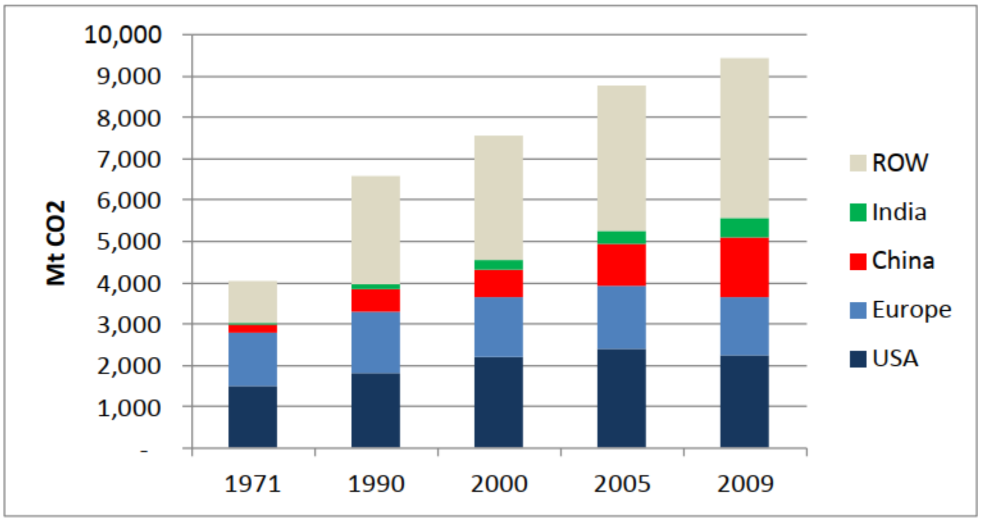

Figure 5. Building CO2 Emissions for the United States, the EU 27, China, India and the rest of the world

Source: (Levine et al., 2012).

2.3 Skills & Training in the Building Sector and the Link to Energy Efficiency

Research into energy use and efficiency has focused mainly on the diffusion of efficient technologies, such as high energy performance construction products (e.g. windows and doors) as well as renewabletechnologies, but less on energy management best practice. Chai and Yeo (2012) comment on the matter that “All too often, the issue of climate change is treated as a purely technical one, outside therealm of social sciences or education unless to raise awareness. […] A vital element in this transition isan energy literate labour force equipped with the knowledge, skills and competences (KSCs) to carry out the work”. As Backlund et al. (2015) state, it is of utmost importance to consider not only technologies but also energy management practices so as to be able to reach the proposed targets forefficiency, where policy instruments are bound to play a critical role (See Figure 6). While studies of barriers to energy efficiency and the energy efficiency gap have largely focused on the diffusion of energy-efficient technologies, it is argued that the overall potential for energy efficiency would, in fact,be higher if successful training initiatives are put in place. Investments in technology and upgrading equipment generate improved efficiencies, but without adapted training, the efficiency potential will not be attained. This involves an intangible dimension that is less capital intensive and requires knowledge and awareness. Also, studies of the potential for improved energy efficiency tend to emphasise technologies in isolation but fail to provide best practice examples where the energy savingtechnology is described with its context. In addition to that, a significant observation is that training seems to hold the capacity to facilitate and promote compliance to regulations. This can prove to be of immeasurable value, as it could bridge the gap between intentions and actions, and towards a greater efficiency of the implementation of measures, towards energy efficiency (Garmston and Pan, 2013).

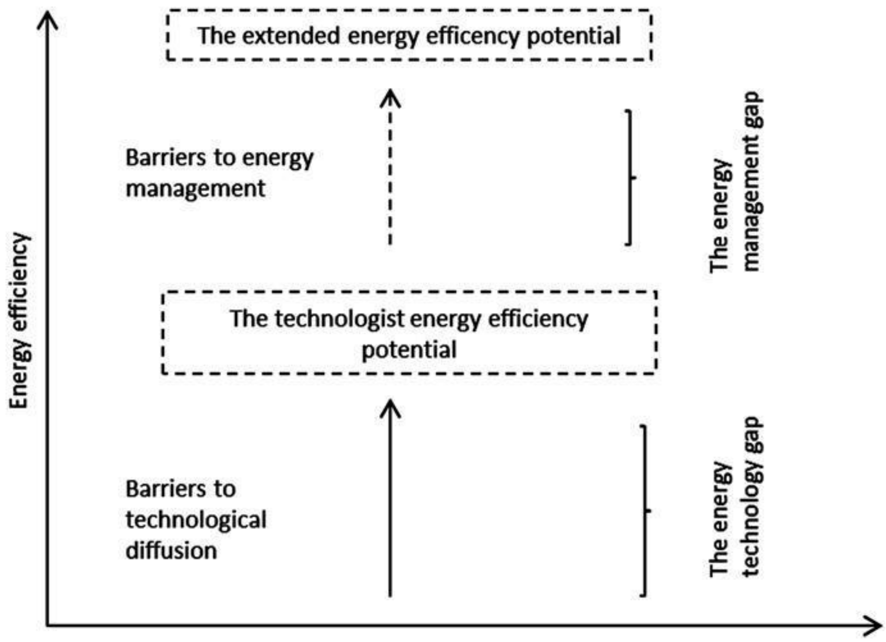

Figure 6. The extended energy efficiency gap

The energy efficiency potential level is increased if energy management practices are also included. Source: (Backlund et al., 2012)

Relevant efforts concerning training and energy efficiency, on a worldwide level, are reflected in the shifts in policies, long-term goals, and constant considerations of the efficiency of these measures. After all, education emerges as a very important element towards a sustainable future.

As highlighted by (Fine and Winfree, 2014): 'As the International Labour Organisation's International Institute for Labour Studies argues, as industry sectors change to support a greening of the economy, education and training systems must also change, if they are to be ''capable of equipping future workers and small and medium-sized businesses with the requisite breadth of competencies needed to take full advantage of the new [green] technologies''.

Further, ''If the right human capital strategies are implemented, a green economy can unlock the potential of higher employment, better employment conditions and higher resource productivity'. Specifically in the construction sector the European Centre for the Development of Vocational Training (CEDEFOP)estimated that the need for blue-collar workers would increase "by 12.9% in 2020 compared with 2010" (Vilutienė et al., 2014). In Lithuania, a study presented calculations about three different types of scenarios (a pessimistic, most likely and optimistic scenario), specifically with regards to this increasein need for training. The calculations came up with a most likely scenario of 36,676 blue-collar workersto be needed by 2020 (Vilutienė et al., 2014).

Further to that, and with regards to policies, in Sierra Leone, in recent considerations about the 2030 target to have a sustainable, energy efficiency system focusing on training and education is included, among other important parameters such as: "financing; legislation, regulation and standards; research and development; gender and environmental issues; planning and policy implementation" (Ministry of Energy, 2016). In India, despite the recent construction boom and promising policies aiming at cleanenergy, it has been suggested that training is one of the key elements, in order to achieve long term energy-efficiency goals for 2050 (Yu et al., 2017). Similarly, in Russia, even though there has been an effort to train 19,000 workers in the field of energy efficiency, the endeavour has been assessed to beinsufficient and characterised as nothing more than a "drop in the ocean" that needs much more attention (Larionov and Nezhnikova, 2016). Studies have brought to the surface key factors that couldbe taken into account, in several sectors and knowledge fields, by examining some successful cases where training resulted brought positive results with regards to energy efficiency, as seen in Figure 7.What also emerges from the literature is the importance of keeping in mind that different historical, physical, economic, political, and social contexts demand different strategies and policies. Levine et al.(2012) argue that, for instance, that in the Indian context, lessons from other countries can offer valuable insights, but it is not possible to integrate the exact same solutions due to a multitude of differences in the context. Still, there are cases where for the experience and successful implementation of strategies in one geographical region has resulted in suggesting following the positive example in other regions. In this way, successful policies can transcend frontiers, in terms of providing a useful blueprint for action. Such an example can be found in a recent study comparing theenergy efficiency labelling systems in the EU and Brazil, where it was suggested that the shaping of training programs of energy assessors in Brazil should follow the example set by the EU in this field (Wong and Krüger, 2017).

In the building sector, the efforts of integrating training and development of skills in the aims towardsenergy efficiency have been intensified during the last decade, on a worldwide level. The literature points to several empirical findings highlighting the benefits of training for energy efficiency. For example, it has been argued how lack of training is one of the four "primary challenges to realizing the benefits of up-to-date codes", which would significantly facilitate compliance to the adoption of policies tackling with climate change, and towards a sustainable future, in the building sector (Shapiro,2016). Furthermore, in 2006, a study conducted in Johor Bahru, in Malaysia, training emerged as one of the three most important factors that contribute to the integration of GBM (Green Buildings Materials) (Kuppusamy et al., 2019). In a study in South Africa, training also emerged as the third driverof green building projects (Oguntona et al., 2019). Further to that, in 2009, the Energy Efficiency in Buildings (EEB) project, which reviewed six different geographical regions around the world (Brazil, China, Europe, India, Japan, USA), identified training as one of the core components for further development towards achieving the vision of better energy efficiency in buildings (Aerschot et al.,2009). In the European Union, as part of such efforts, the Roadmap on Education and Training has beenestablished, in the context of the Strategic Energy Technology (SET) plan (Maier et al., 2019). There hasbeen growing evidence emerging that there is an imminent need for collaborations between educational institutions and businesses. There is also the need for drastically further developing the education of the workforce, both the existing, as well as future generations (Maier et al., 2019). Criticalrealisations and lessons include the acquired overview of a more accurate idea of the timeframes withregards to the training of the workforce, as well as the importance of proper training and careful designof relevant tools (Levine et al., 2012).

Domain	Country	Name of programme	Higher rates of economic change	Continuing market failures constraining demand	Greater uncertainty of skills forecasts	Increasing demand for new industrial alliances	Increasing need for environmental awareness	Increasing need for higher education/VET links	Overcoming occupational boundaries	Increasing costs of technical training
Wind	DE	Jobstarter	Support of matching process; four additional qualifications	Fund studies to identify regional demand; and focus on growth sectors	Assess future sector skills needs	Strong social partner, provider and employers engagement	n/a	n/a	Common VET provision across standard sectors	Limited pooling of resources and shared finance
Wind	IE	Wind skillnet	Sectoral recognition for all training; access for job-seekers	Driven by policy strategy to develop wind sector	Training needs analysis; flexible design to adjust training	Strengthen existing alliances and employer engagement (especially SMEs)	Training of jobseekers and workers on regulatory environment	VET and higher education providers involved in training delivery	Flexibility to tailor training to diverse needs	Best-value procurement and matched funding
Solar thermal	AU	Klima:aktiv	Support development of national certification	Test market demand prior to course development	Identify need to act; flexible design to adjust training	Interventions guided by collaboration of government and the social partners	Focus on short courses and target trainers – the catalysts for change	n/a	Target range of occupations	e-learning platforms; nominal course fees
Buildings	FR	Training for energy savings in buildings (FEE Bat)	Accredited training provided	Adjusted objectives in light of evidence on demand	Monitor outcomes to assess training relevance to learner needs	Committees to bring together all stakeholders	Structure modules to communicate low-carbon objectives	n/a	Group training encourages exchange of experience across trades	Use of ESCO, the energy saving certificate scheme funds for training
Buildings	UK	Delivering low-carbon skills (DLCS), Wales	Nationally accredited training provided	Deliver pilots to test market, wait-and-see approach	Conduct skills gap analysis	New coalition of sector skills councils (employer representatives)	Focus on short courses and target trainers	Delivery of training by VET and higher education providers	Group training encourages exchange of experience across trades	Best-value procurement and employer contributions
Road freight	FR	Objective CO_2	n/a	Energy saving benefits of training drive market demand		State, industry body and employer cooperation	Employer commitment to reduce emissions	n/a	n/a	Short one-day courses, nominal fee

NB: Orange – moderate response to challenge; blue – strong response to challenge; n/a– limited evidence of response to challenge available.

Figure 7. Strength of best practice case study responses to the key challenges for VET systems driven by the transitions to a low carbon economy. Source: (CEDEFOP, 2013)

It has been suggested that the development of the workforce involved in the collective efforts towardsa low-carbon Europe depends on three main factors. As argued by the European CEDEFOP (2013) theseare: “1. The skills of the existing workforce are effectively developed and/or realigned through relevant upskilling and reskilling programmes 2. (Re)integration of the unemployed and economically inactive population into the workforce is supported 3. The transition of young people and those vulnerable to exclusion into the workforce is facilitated”. Some successful examples of such integration of the workforce, with regards to VET (Vocational Educational Training) are presented in Figure 7. Strengths of such projects in the construction sector highlight the preparedness, flexibility, and systematic strategic updates, in order to overcome and tackle the challenges that emerge in training systems andprogrammes.

Furthermore, key to any successful stimulation of training initiative is effective communication of the required changes and adequate support during the process, but also recognising and offering further room for improvement when it comes to the role of properly informing and integrating professionals into the process (Milovanović et al., 2019). What also emerges is the importance of involving the totality and different layers of stakeholders in the building sector value chain (Richards et al., 2016) (Geros et al., 2006), (Bosch González et al., 2013). In addition to that, it is significant to highlight how the perception of training for energy efficiency has been shifting. As Alsaadani and Bleil De Souza (2019) argue, a recent survey called attention to the fact that both an increasing number of professional architects as well as schools of Architecture hold the belief that the integration of modules to their curricula connected to building performance needs to be a compulsory part of the training.

On a European Level, the BUILD UP Skills initiative created a basis for the education and professional development of “craftsmen and other on-site construction workers and systems installers in the building sector” (BUILD UP, 2020) in the EU, across 28 Member States. A critical finding includes the realisation that a more focused demand for energy efficiency will inevitably increase the need for thetraining of white and blue-collar workers, as it was suggested that, in most countries, there is still a long way to go, in that direction (European Commission, 2016). Overall, the BUILD UP Skills programmeis considered a very successful initiative in this regard, which has offered many significant insights, such as the importance of continuing in this direction for the development of both white collar and blue- collar workers, as well as to place emphasis on the function of the worker and not only on their qualifications (European Commission, 2016). Indicatively, some successful examples that took place inthe BUILD UP Skills context, and were highlighted as successful for various reasons, are presented in Figure 8.

BEET (FYROM)
BUS BEET made a pioneering step towards the introduction and validation of previous non-formal and informal learning in FYROM. During the project, a process for recognition of previous learning was developed. This process consists of identification, documentation, evaluation and certification. The process is completely compatible with the recommendations for necessary phases from the European Training Foundation. This new recognition process was well received. Most of the construction companies in FYROM acknowledged the new recognition process. During the project, 967 workers were certified through the process of recognition of energy efficiency skills. The candidates for skill recognition indicated the following benefits of the recognition of previous learning:

- Much shorter process than the previous training that led to the same qualification;
- Validated qualifications increase employability;
- Valorisation of previous knowledge, skills and experience;
- Qualifications can be acquired without formal training;
- The certificate is identical to the one obtained through more formal training;
- Insufficient competences can be completed by partial or modular training.

BUS BUILDEST II (Estonia)
BUS BUILDEST II can be considered as a good practice example in terms training material. The project provided video learning materials for VET trainers. Video materials covered many different fields, e.g. insulation of the cold-water piping with flexible foam covers, insulation of ventilation flume with strengthened aluminium paper covered flexible mat wool, insulation of heating piping with foil covered wool. These training materials were welcomed very positively by trainers and were largely supported by entrepreneurs.

In addition, BUILDEST II managed to integrate energy efficiency skills into professional standards. The project introduced incentives for more extensive awarding of occupational qualifications in the sector by developing an output-based evaluation of occupational competences. This included the accreditation of prior and experiential learning-based awarding of occupational qualifications in the construction sector. One of the lessons learned during the project is that the most effective method of training the non-qualified workforce is flexible integration of these participants into the existing vocational education system.

BUS N@W (Netherlands)
The project developed and implemented a qualification structure for post-initial training. This bridged the gap between initial and post-initial education in both building and installation sector. In post-initial education, the visualisation of the qualification structure made professional HR-advice for sustaining the built environment possible. In initial education, the developed qualification structure led to the development of several add-ons to the traditional curriculum.

Source: developed by the project team, based on the project reports

Figure 8. BUS project summary Source: (European Commission, 2018).

What is more, the assessment of the current state of energy efficiency-related education and trainingprograms and related training and education needs in BIM (Building Information Modelling) was conducted by both the BIM4VET and BIMEET projects, involving LIST and CU. BIMEET is a platform forthe collection and elaboration of training in the construction sector, regarding BIM and energyefficiency that considers several stages and stakeholders involved in the construction process (Suwal et al., 2019). There is a need to extend this assessment beyond BIM to infer wider needs to promote the development of related energy efficiency services and train the associated workforce accordingly. Related studies point to several interesting findings. As summarised and argued by Rezgui (2020), it isimportant to: “1. Integrate building and industrial process system efficiency into existing building and construction technical, apprenticeship, and trades curricula 2. Coordinate and manage best practices across Europe by relying on dedicated initiatives such as Build Up Skills. 3. Promote the delivery of short duration, on-the-job, trainings, as opposed to focussing exclusively on academic-like trainings. 4.Plan the training of trainers. 5. Increase access to on-the-job training for mid-and senior-level engineers and managers 6. Prepare the next generation of energy efficiency professionals".

In addition to that and with regards to successful cases that have emerged from the industry, let us focus on an exemplary, impact-related case, which was brought to the attention of the consortium ofthe INSTRUCT project by the project partners. The Fit – to – NZEB project, which targeted Bulgaria, Croatia, the Czech Republic, Greece, Ireland, Italy and Romania, focused on training at universities, professional high school and colleges and vocational training centres. The project's main objective wasto "increase the number of qualified construction specialists at all levels, which is directly related to the accessibility and quality of the educational programmes and the inclusion of training on intelligent EE and RE solutions in building renovation" (Center for Energy Efficiency EnEffect, 2017) towards nearly zero energy buildings. As brought forth by the industry report, key outcomes included: "1. New knowledge,skills, and competences for deep energy retrofits 2. Development of demonstration and practical training models 3. Trained trainers and 4. Model training programs" (Center for Energy Efficiency EnEffect, 2017).

For the purpose of this review, one specific example will be presented, the St. Bricin's park by Dublic City Council, which "exceeded the Passive House EnerPHIt standard of 25% kWh/m^2.year by almost 20%" as mentioned in the report.

The project received praise by the building owners, the project energy consultant, Dublin's City Mayor, Dublin City Council City Architect, Dublin City Executive Architect, Dublin City Council Clerk of Works. Different stakeholders seem to agree that this is a project which has exceeded expectations and has set a feasible model for future reference. Currently, and as mentioned in the relevant industry report,the project was also among the selected projects for the annual SEAI Energy Awards, the Irish Energy Efficiency Award, and Irish Building and Design Awards (Center for Energy Efficiency EnEffect). What isalso quite significant is that by comparison, an identical apartment block nearby, did not achieve the same results via the renovation project with regards to the desired goals of energy efficiency, due to lack of training. It could, therefore, be argued that the importance of training is quite crucial. Furthermore, such evidence suggests that exemplary cases of practice in the building sector with regards to energy efficiency are feasible and can work as an example and basis for similar future projects.

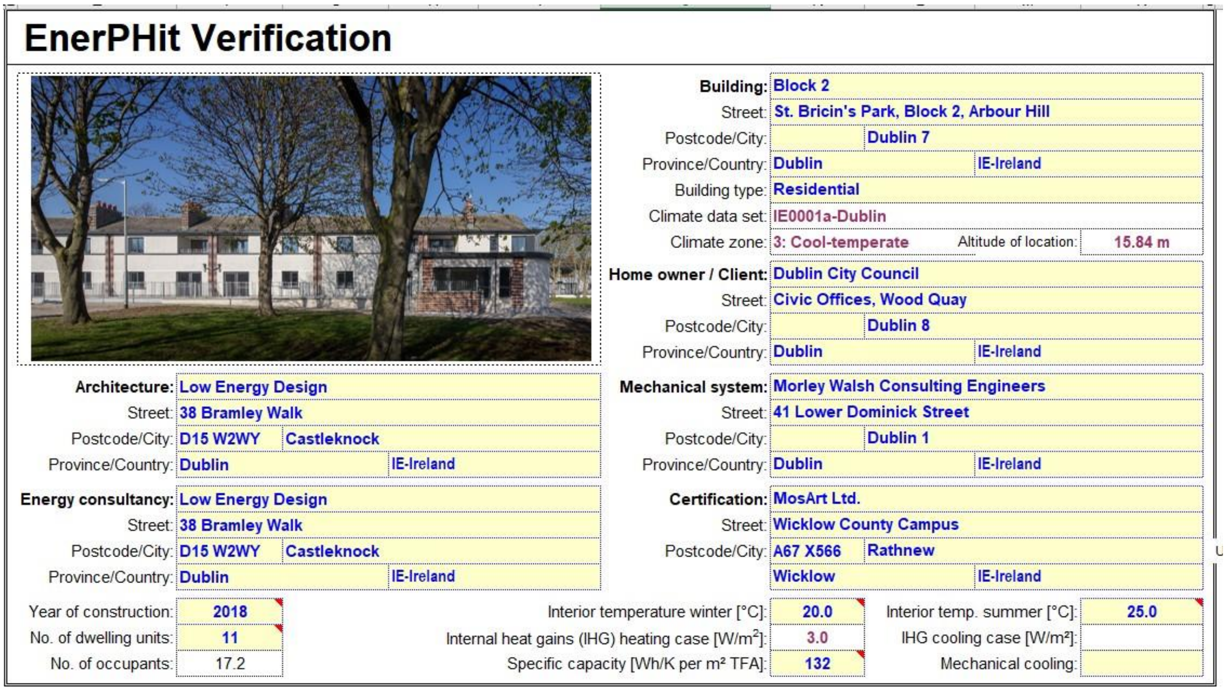

Figure 9. St. Bricin's park by Dublin City Council

Overall, there is a strong case that can be made with regards to putting further emphasis on education and training so as to increase energy efficiency, and which includes societal & environmental contributions (Pears, 2020). However, as it will be analysed in the next section of the chapter, there are significant barriers which need to be taken into consideration.

2.1. Barriers & challenges, proposed solutions, and further research

Evidence suggests that energy efficiency measures in the industry are not applied for a wide range of reasons, including lack of information, procedural barriers, non-environmental friendly work process routines and socio-organizational issues, including the existence of particular values, unsupportive of energy efficiency, in the dominant networks of a trade industry segment (Chai and Yeo, 2012). The academic literature points to a number of key energy efficiency barriers, including: Fear of technical risk/cost of production loss, perceived high cost of energy investment, the preference to support other capital investments, uncertainty about future energy price, lack of experience in technology, lack of information in energy efficiency and savings technology, lack of trained manpower/staff, lack of accessto capital/budget, lack of government incentives, weak policies and legislations, resistance to change,and full reliance on legacy systems (Backlund et al., 2012). More specifically, a review of literature on barriers found in the energy efficiency field can be seen in Figure 9, as summarised by Chai and Yeo (2012). Barriers that characterise the relation between energy efficiency and training cover a wide range of parameters. Shoemaker and Ribeiro (2018) mention how the importance of “creating demandfor energy efficiency”, “replacing a retiring workforce”, “funding uncertainty”, coordinatingstakeholders”, and “increasing diversity” are some of the most notable.

In the construction sector, the importance not only of well-informed professionals to work in the fieldbut also of strengthening of the educational tools towards that goal, has emerged, on a worldwide level (Li and Yao, 2009). What is more, the barriers that impede the growth of energy efficiency and are connected to the importance of training have been acknowledged in empirical knowledge and the literature. In the United States, a study conducted in Southwest Virginia, with regards to identifying gaps and barriers in the green building training, highlighted a number of observations. Suggestions include the following, as presented by McCoy et al. : “1. For employers to send their current workforceto receive training in energy efficiency and green skills and practices, 2. A more holistic approach to understanding the building as a system and the underlying scientific principles is key, 3. The target audience is not limited to builders, and should include finance, marketing, accounting, and management professionals. 4. The target audience is not limited to builders, and should include finance, marketing, accounting, and management professionals” (McCoy et al., 2012). In addition to that, in the USA context, the Building Energy Codes has called attention to a number of parameters that hindersmooth implementation of energy efficiency measures and policies (Oettinger et al., 2013). This includes the complex state of the sectors with regards to “conflicting interests of its representatives, limited resources as well as plans of short payback period getting in the way of the required quality ofenergy performance” (Oettinger et al., 2013). According to the IEA, “The best way to implement a building energy codes policy, analysis for the Policy Pathway has shown, is for a governmental co- ordination body to ensure the development of training tools and compliance software and to give all stakeholders free access to them” (Oettinger et al., 2013). In India, the observations have fed into an effort to include higher education for the preparation and proper training of the workforce. However,a lack of market support has created many obstacles, and efforts need to be in backed up by government-supported incentives (Levine et al., 2012). In the last decade, has China also faced a number of challenges in trying to implement strategies towards energy efficiency, due to a combination of factors, which stand in the way of integration of training in policies, which, as stated by Li and Yao (2009), include “insufficient local regulatory and financial support, difficulties in financing building retrofit, the discrepancy of Building Energy Efficiency (BEE) implementation progress across regions, slow progress on heat reform (moving from local coal-fire boilers to district heating, and moving from charge based on floor area to actual energy use), and also the enormous scale of promoting building energy efficiency in rural areas that has only just begun”.

In the EU, the BUILD UP Skills initiative points to a number of barriers such: 'Economic barriers (lack oftime for training, cost of training), awareness-related barriers (lack of understanding of the importanceof skilled / trained workers), legal barriers (delays in introducing energy efficiency related definitions),market barriers (low demand for energy efficient buildings and thus for the skills required to build them), and knowledge barriers (language, varying levels of competence of the trainees, and lack of facilities for practical training)' (European Commission, 2018). For example, in the Greek context of theBUILD UP Skills initiative, the impact of these barriers has been assessed (Figure 10).

Identifying key barriers to energy efficiency from reviewed literature.

Category	Typical barriers	References	Key barriers identified
Economic non-market failure or market barriers (Sorrell et al., 2000; Brown, 2001)	Low priority of energy issues	Brown (2001)	• Fear of technical risk/ cost of production loss • Perceived high cost of energy investment • Other capital investments are more important • Uncertainty about future energy price • Lack of experience in technology • Lack of information in energy efficiency and savings technology • Lack of trained manpower/staff • Lack of energy metering • Lack of access to capital/ budget • Lack of government incentives • Weak policies and legislations • Resistance to change • Legacy system
	Cost of production disruption	Rohdin and Thollander (2006), Thollander and Ottosson (2008), Thollander and Dotzauer (2010)	
	Other priorities for capital investments	Rohdin and Thollander (2006), Thollander and Dotzauer (2010), Sardinou (2008)	
	Lack of time/other priorities	Rohdin and Thollander (2006), Nagesha and Balachandra (2006), Thollander and Dotzauer (2010)	
	Reluctant to invest because of high risk	Wang et al. (2008)	
	Technical risk such as risk of production disruptions	Thollander and Ottosson (2008)	
	Competition from other projects	Ren (2009)	
	Lack of management support	UNEP (2006)	
	Limited access to capital	Rohdin and Thollander (2006), UNEP (2006), Thollander and Dotzauer (2010), Sardinou (2008)	
	Capital market barriers	Brown (2001)	
	Lack of investment capability	Nagesha and Balachandra (2006)	
	Lack of funding/financing capabilities	Wang et al. (2008)	
	Uncertainty about future energy price	Thollander and Dotzauer (2010), Sardinou (2008)	
	Increased perceived cost of energy conservation measures	Sardinou (2008)	
	Cost of identifying opportunities, analyzing cost effectiveness and tendering	Thollander and Ottosson (2008), Thollander and Dotzauer (2010), Rohdin and Thollander (2006)	
Economic market failure (Sorrell et al., 2000; Brown, 2001)	Split incentives	Brown (2001)	
	Un-priced cost and benefits	Brown (2001)	
	Insufficient and inaccurate information	Brown (2001), Wang et al. (2008), Ren (2009), UNEP (2006), Nagesha and Balachandra (2006), Thollander and Ottosson (2008)	
	Lack of experience in technology and management	Wang et al. (2008), Ren (2009)	
	Difficulties in obtaining information about the energy consumption of purchased equipment	Thollander and Dotzauer (2010)	
	Lack of technical skills	Thollander and Dotzauer (2010), Sardinou (2008)	
	Lack of trained manpower	Wang et al. (2008), Thollander and Dotzauer (2010), Thollander and Ottosson (2008), Rohdin and Thollander (2006), Sardinou (2008)	
	Lack of information on profitability of energy saving measures	Sardinou (2008), Wang et al. (2008)	
	Lack of information with respect to energy conservation opportunities	Sardinou (2008)	
Behavioral (Sorrell et al., 2000)	Resistance to change	Nagasha and Balachandra (2006)	
Institutional (Weber, 1997)	Weak legislations and/or enforcement	UNEP (2006), Nagesha and Balachandra (2006)	
	Lack of government incentives	UNEP (2006)	
Organizational (Sorrell et al., 2000; Weber, 1997)	Lack of sense of corporate social responsibility or environmental values	Rohdin and Thollander (2006)	
	Lack of environmental policies within company	UNEP (2006)	

Figure 10. Barriers to Energy Efficiency. Source: (Chai and Yeo, 2012)

Furthermore, as suggested by a study in the Australian context in 2015 concerning "green skill programmes", it was highlighted how a number of barriers prevent a smooth course and efficiency of the training taking place. Among others, the following are highlighted:

Fragmented sets of information are developed ad hoc.

Generic information and training programmes predominate.

Pre-employment training in energy efficiency is perceived as uneven; many instructorsare seen as needing significant professional development in this area.

The content delivered in training is ''washed out'' when on-site priorities, especiallycost factors, undermine the importance of skills in energy efficiency.

Members of industry and trade associations fail to take advantage of the excellent training opportunities they provide, as few associations mandate certification in energyefficiency.'

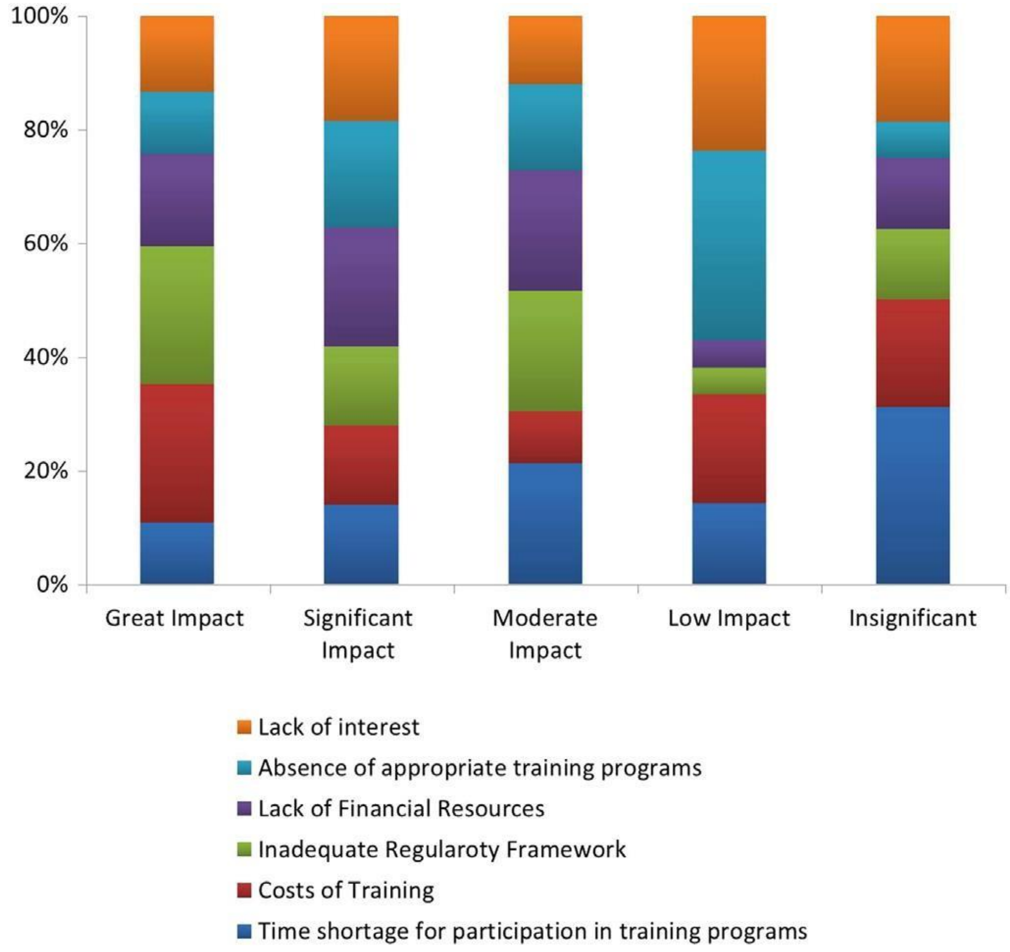

Figure 11. Graph illustrating the impact of barriers, in the Greek context of construction industry.

Source: (Doukas et. al, 2016)

In the BUILD UP Skills initiative, suggestions have been made by the official assessment document forthe road ahead for future efforts, which include suggestions for the European Commission, for EASME,for authorities, and for project developers (European Commission, 2018). Among other suggestions, some general ones for the European Commission include (European Commission, 2018):

Setting more ambitious targets for energy efficiency in buildings.

Adapting the legislative framework. For example, by: Setting a requirement for mandatorytraining courses for blue-collar workers for energy efficiency related construction skills.

3.Tackling the issue of mutual recognition so that training accredited in one EU country isrecognised in another EU country.

Ensuring that every EU country has a working definition of nZEB and that this and otherconcepts are harmonised and promoted across the EU.

Overall, the findings and learnt lessons from BUILD UP Skills initiative provide a significant and up to date blueprint for future reference and research in the field of energy efficiency and training in the building sector, in the EU.

2.3 Conclusion

To summarise, from the analysis of the literature, there are certain themes that keep emerging, in terms of their significance and relevance, as to what plays a crucial role in determining the correlationbetween training and energy efficiency. To begin with, issues that stem from the overall fragmented state of the construction industry, with conflicting interests and not enough coordination between stakeholders have been highlighted. Secondly, there is a need to establish a coherent and systematic framework of actions, with regards to awareness and the dissemination of knowledge in the sector. And further to that, it is of great importance to make sure that training is constantly developed and tailored to the needs of the workforce. Also, it is crucial to make sure that more focused attention is placed on tackling and coordinating the dynamics of the market and of workforce demand for energyefficiency in the sector. Lastly, resolving issues of legislations and regulatory frameworks and improving their efficiency at a local, country and EU-wide levels, with regards to how to shape the training landscape for energy efficiency, seems to also emerge as a significant factor.

Overall, the literature review has highlighted that the **evidence that supports the correlation between training and energy efficiency is sparse and lacks an in-depth and sector wide analysis**. Several **context-specific** (in terms of application, workforce segment, and country) studies have highlighted a number of barriers, challenges, and gaps in the training landscape in the construction industry. However, these do not **scale-up and translate to robust evidence** for the entire industry.

The present report aims to address this gap by adopting a Europe-wide consultation that not only seeks to **gather evidence correlating training with energy efficiency**, but also **broadens the scope of the investigation** beyond this mere objective (i.e. identifying the evidence correlating training with energy efficiency) to **understand the complexity of the training landscape in energy efficiency** and **provide context to the resulting evidence,** in a way that promotes **generalisation of the results**. This methodology is described in the follow-on chapter.

3. Methodology

3.1 Hypothesis

Based on the outcomes of the literature review the following hypothesis is formulated: *"Quality training can have a positive impact on energy efficiency in the construction sector and can contribute to sustainable interventions in the industry"*. The research sets out to evidence that there is acorrelation between quality training and energy efficiency in the construction sector and that can contribute to sustainable practices.

Based on the conclusions from the literature review and the themes that emerge, as well the main barriers highlighted by BUILD UP Skills, in the European context, the following themes were formed:

Lack of access to useful information, knowledge, and best practice guides for energy efficientinterventions.

Lack of demand for skilled workforce in energy efficiency.

Lack of availability, or inadequate training programs (in terms of scope, quality, content, cost,etc.).

Lack of shared vision and values for energy efficiency across the supply chain.

Inadequate policy landscape, including lack of government incentives. These themes translate into the following research questions:

What is the state of awareness, access to information and dissemination of knowledge forenergy efficiency in the Construction sector?

What is the level of demand for skilled workforce in energy efficiency?

What is the state of the training programs for energy efficiency currently available in theindustry (in terms of scope, quality, content, cost, etc.)?

What is the state of the sector in terms of shared values and coordination of stakeholdersacross the supply chain for energy efficiency?

How efficient are legislative frameworks, policies, and government incentives?

In order to answer these questions, a set of consultation instruments has been created,which will be analysed in the following subchapter.

3.2 General plan of action

Overall, the research methodology draws on the Saunders research model (as illustrated in Figure 11).

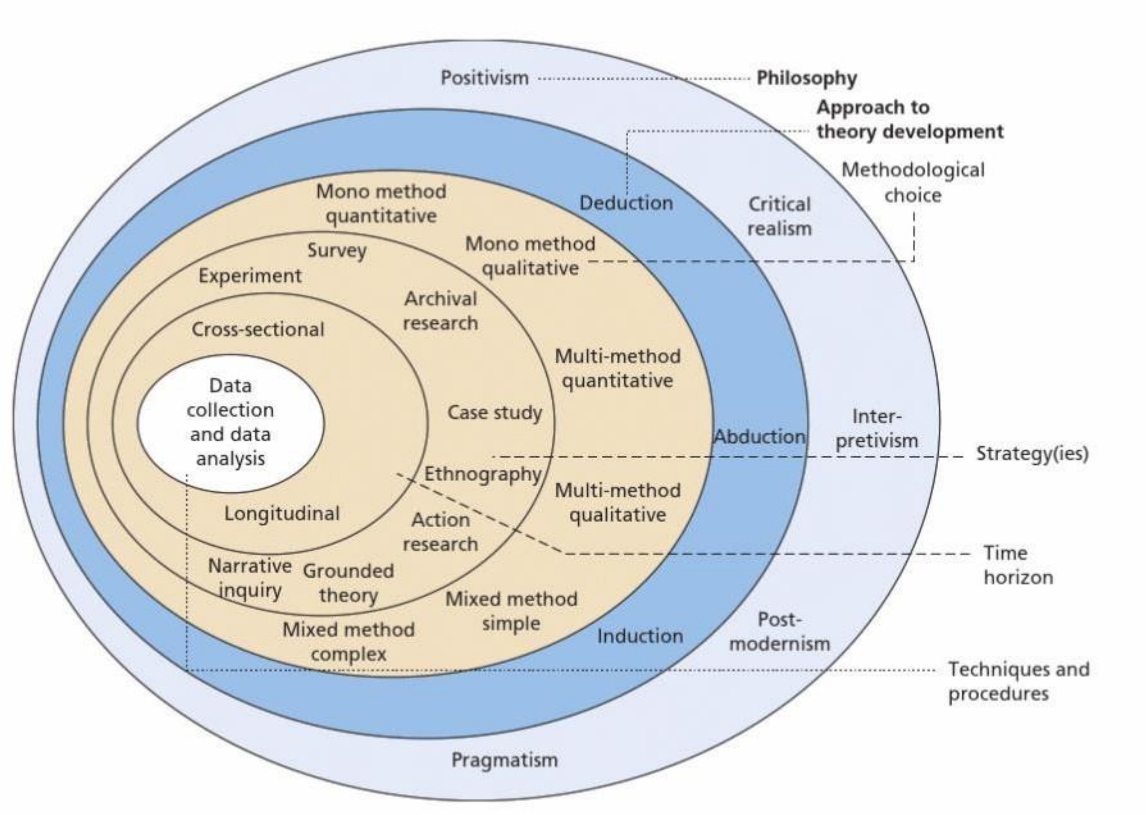

Figure 12. The Research Onion. source: Saunders et al, 2016

What is recognised for the specifics of the study's aims is the need to have a mixed method approachwhich combines qualitative and quantitative sources of evidence. It has also been argued that mixed methods are traditionally linked to the pragmatic framework (Descombe, 2014). Mixed methods are defined by three main characteristics:

Use of qualitative and quantitative approaches within a single research project.

Explicit focus on the link between approaches (triangulation).

Emphasis on practical approaches to research problems (pragmatism)' (Descombe, 2014).

In Figure 12 one can see how a pragmatic approach expresses the stance of the study, in terms of ontology, epistemology, axiology and methods used. There is a sustained focus on the question at hand(what- in the case of this research the link between training and energy efficiency) which focuses on how to resolve the problems, based on practical observations and experiences from practice (barriers& challenges in the construction field). Furthermore, the approach focuses on how to facilitate "successful action" (what to do-the aim of the research) and on practical solutions.

Pragmatism			
Complex, rich, external 'Reality' is the practical consequences of ideas Flux of processes, experiences and practices	Practical meaning of knowledge in specific contexts 'True' theories and knowledge are those that enable successful action Focus on problems, practices and relevance Problem solving and informed future practice as contribution	Value-driven research Research initiated and sustained by researcher's doubts and beliefs Researcher reflexive	Following research problem and research question Range of methods: mixed, multiple, qualitative, quantitative, action research Emphasis on practical solutions and outcomes

Figure 13. Ontology, epistemology, axiology and methods for pragmatism

(Source: Hassan et al, 2006)

3.3 Plan overview and explanation

The proposed mixed methods approach translates into a number of instruments orchestratedaccording to a proposed process methodology illustrated in Figure 13.

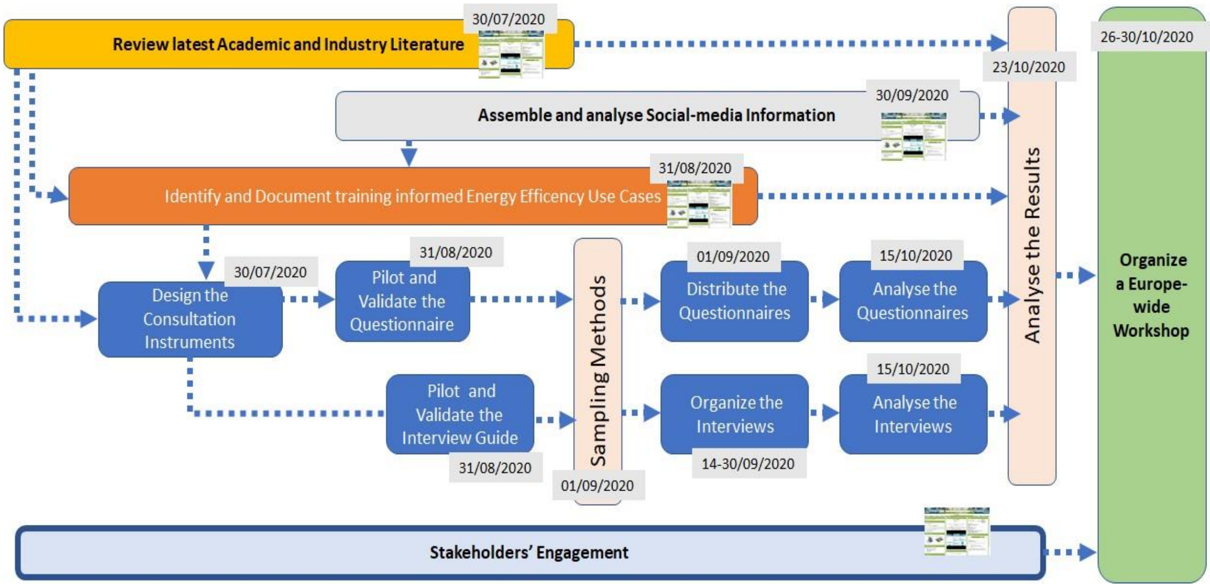

Figure 14. The methodological plan for this study

The detailed steps are as follows:

Step 1: Review latest Academic and Industry Literature

The review of academic and industry literature is the first methodological step to inform this research. The purpose was to gather and synthesise several academic literature and industry documents, with a specific question in mind, which informed the research strategy. The question being explored was whether and to what extend training and

energy efficiency in the construction sector are connected. In this sense, it belongs to a type of systematic review, which is defined by Saunders et al (2016). Overall, the literature review could be said to be a systematic review, in that, itset out to gather & analyse knowledge around a specific question, as argued by Saunders et al (2016) "Uses a comprehensive pre-planned strategy for locating, critically appraising, analysing and synthesising existing research that is pertinent to a clearly formulated research question to allow
conclusions to be reached about what is known".

For this purpose, the scope of the review spanned across relevant material of the last 15 years in the field. The language of publication was English, and the literature type were journal articles, industry reports and conference proceedings. The review considered reports and papers from around the world, not solely focused on a European level. As suggested previously, the aim was that of demonstrating the link between training and energy efficiency, but also to identify challenges and barriers, while focusing more on latest relevant developments and projects (e.g. BUILD UP Skills). Google Scholar and Scorpus were used as search engines and the literature was scanned through usinga number of keywords (including Skills, Education, Training, Energy efficiency, Energy EfficiencyBarriers). A number of 170 papers was skimmed through with on Google Scholar with these keywords.Out of these around 40 of them were assessed to be relevant to the several aspects and questions thatthe review poses. Eventually 30 of them were integrated in the review, as they were assessed to holdthe most critical information.

At a second stage, a search was also conducted in Scopus, with the keywords: "construction industry", "training" and "energy efficiency". From this search, 37 articles and conference papers were found, skimmed through, and eventually from this a totality of 17 were analysed, out of which 6 were deemedrelevant and included in the literature, based on the relevance of the results and insights of the paperto the purpose of this literature review.From this process some statistics/graphs were collected, which are presented below (see Figures 15-19) where some observations emerge.

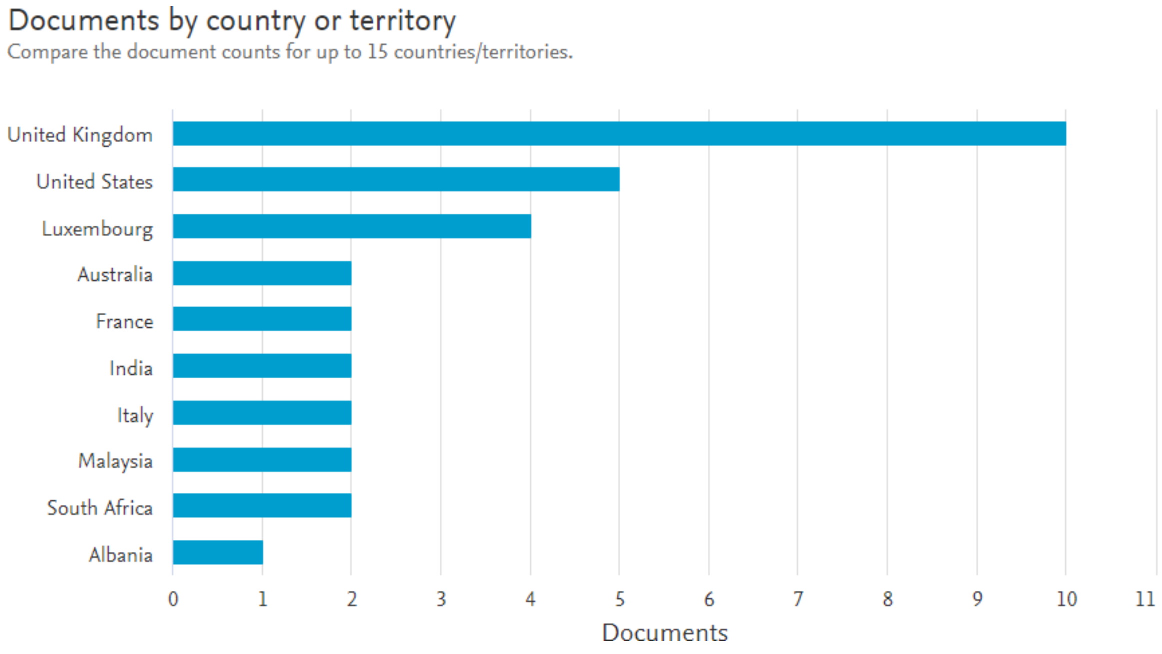

Figure 15. Documents by country or territory

(Source: Scopus)

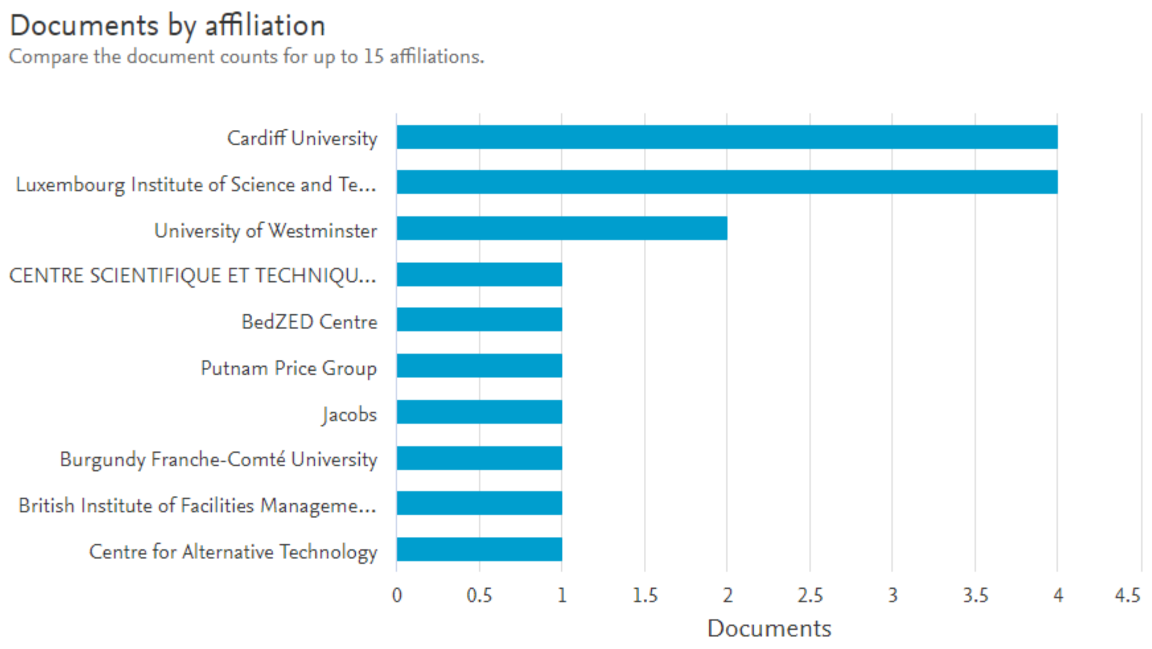

Figure 16. Documents by affiliation

(Source: Scopus)

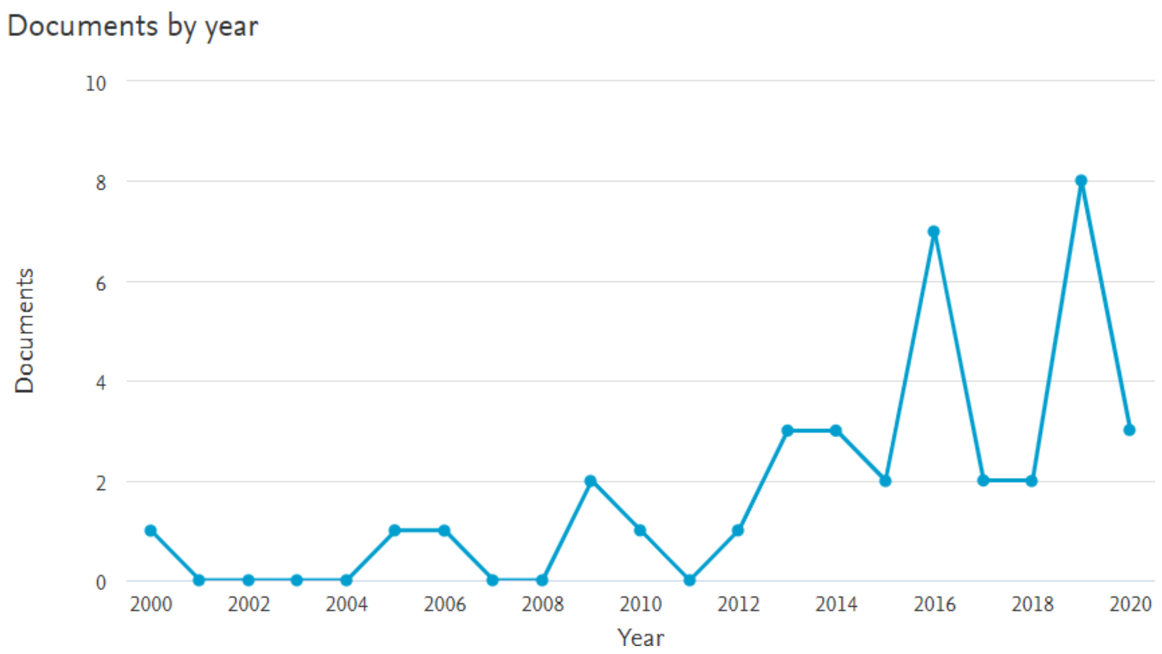

Figure 17. Documents by year

(Source: Scopus)

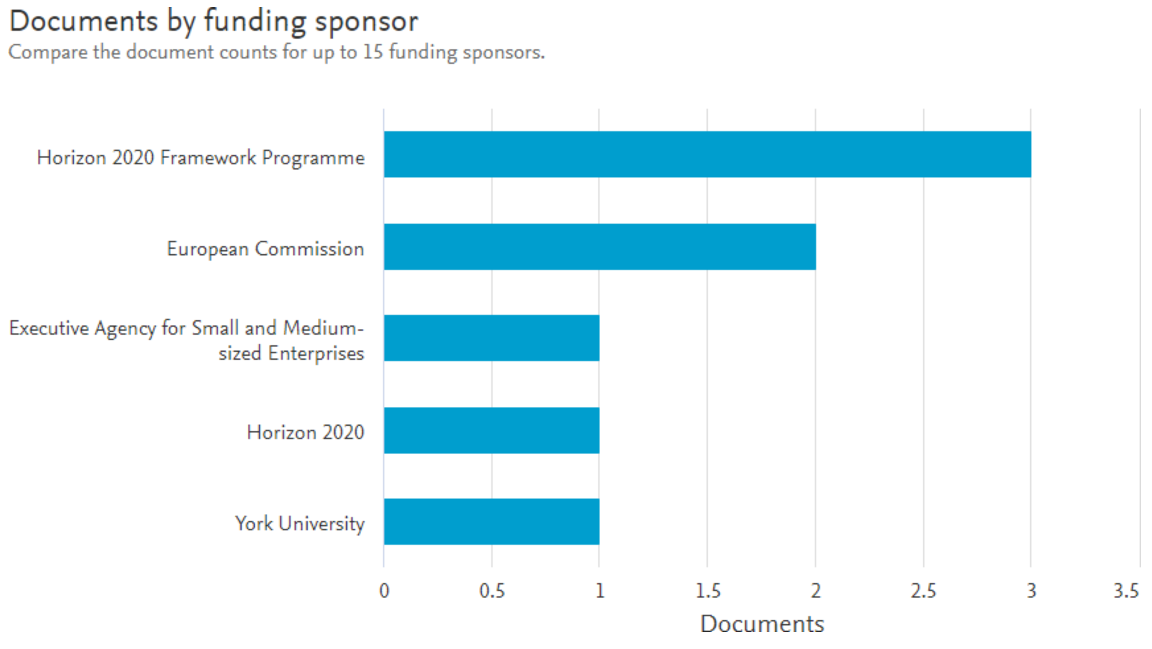

Figure 18. Documents by funding sponsor

(Source: Scopus)

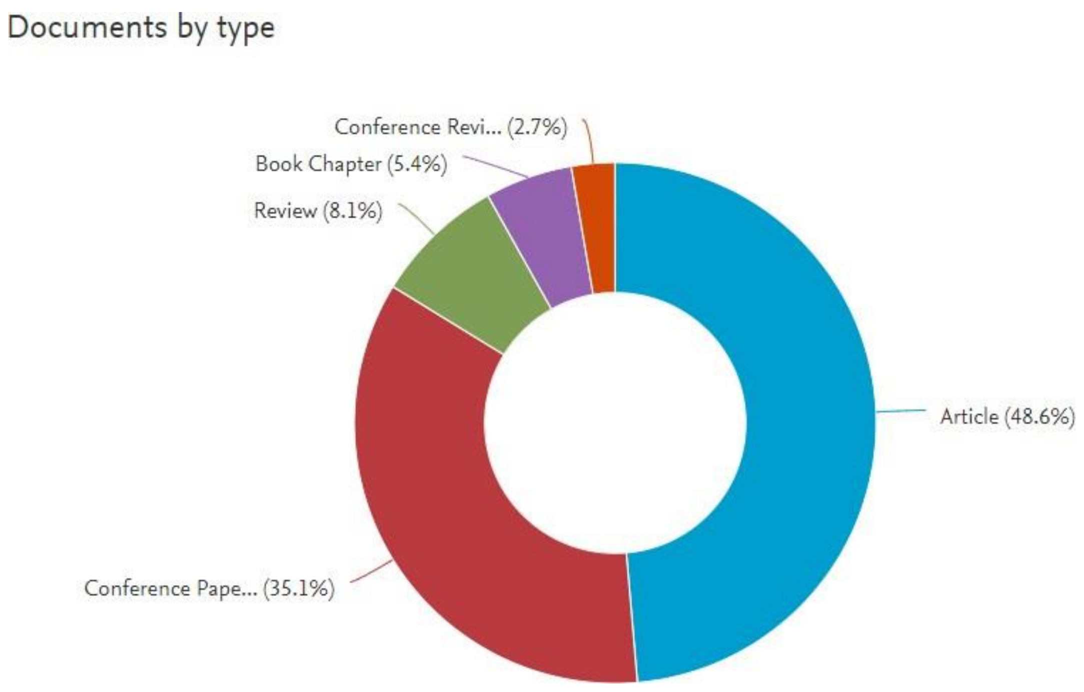

Figure 19. Documents by type

(Source: Scopus)

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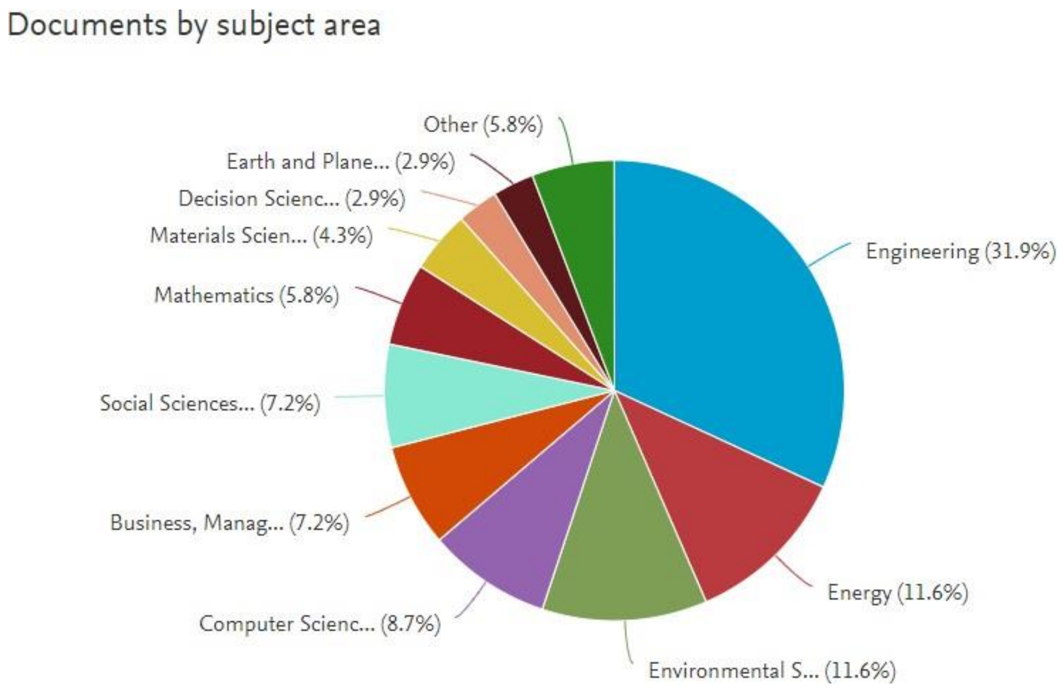

Figure 20. Documents by subject area

(Source: Scopus)

The structure of the literature was developed and presented in small subchapters so as to give the reader an overview of the field and an understanding of the connections emerging. The sequence of presenting the information develops from the general field of energy efficiency & quality towards themore specific question at hand, i.e. the link between training and energy efficiency in the building sector. These subchapters are: "1. Energy & Energy Efficiency & Quality: Global Perspectives and the Building Sector", "2. Skills & Training in the Building Sector and the Link to Energy Efficiency", "3. Barriers & challenges, proposed solutions, and further research".

As a second step of the literature review, stakeholders were approached and asked to provide relatedindustry reports evidencing the link between training and energy efficiency or providing examples of best practice in energy efficiency. Any relevant evidence of training resulting in positive examples for energy efficiency was integrated in the literature review document, as a separate sub-section, chapternamed: "4. Reports from the Industry".

Step 2: Design the Consultation Instruments The interviews and questionnaires were formed after identifying gaps of knowledge in the field, barriers, and current challenges emerging from the literature review. Following a qualitative approach, in order to interpret and discern potential themes emerging from the literature, the aim was to **(a) identify the barriers and challenges in training in the industry** and (b) **establish the training landscape** in energy efficiency but also (c) **evidence the significance of training on energy efficiency**. The questions that were more open-ended were left for the interviews, so as to leave more space for elaboration. Indeed, the interviews are semi-structured, and leave room for further and spontaneous reflections and elaboration, during the interviewing process. Questions that can easily responded to with a limited number of possible answers, were left for the questionnaires. This included a common section for all stakeholders, and then separate sections/set of questions; one for **blue-collar workers** and one for **white-collar workers**. The consultation material also drew on previous relevant consultation material, in terms of the typology and scope of questions. This material was questions from relevant questionnaires and interviewing process from the following sources:

Final Report on the Assessment of the BUILD UP Skills Pillar II
Through the Local Government Lens: Developing the Energy Efficiency Workforce
H2020 BIMEET research: BIM for Energy Efficiency Requirements Capture
Kent County Home Energy Efficiency Program
The interviews involved 21 questions in total and the questionnaire included 31 questions in total.

In the following section there will be an analysis of how the consultation tools and primary research collected, have been categorised and grouped to provide insights about the five major themes that thestudy seeks to explore. The questions from the questionnaire and the interview, as well as insights from the workshop fall within these five themes, as mentioned previously:
Lack of access to useful information, knowledge, and best practice guides for energy efficientinterventions.
Lack of demand for skilled workforce in energy efficiency.

Lack of availability, or inadequate, training programs (in terms of scope, quality, content,costs, etc.).
Lack of shared vision and values for energy efficiency across the supply chain.
Inadequate policy landscape, including lack of government incentives.
The order of the questions, for the interviews and questionnaires did not follow this specific order during the collection of data, but rather a more organic order, to promote a logical flow to the consultation process. However, for the purposes of the categorisation below, and to avoid confusion,these will be presented with the number that the appear in the study. Furthermore, certain questions in the questionnaire, present an overlap in themes, as they were structured to provide multiple pre-given questions/checkboxes for their answers. For the purposes of the analysis below, they will be included in every category that they integrate.

More specifically:

Interview Guide:

Theme	
Lack of access to useful information, knowledge, and best practice guides for energy efficient interventions.	▪ Q4. What barriers can you identify in the field of training for energy efficiency, in the construction sector? ▪ Q9. In your opinion, is the importance for energy efficiency skills in the construction sector being taken into consideration adequately, in your field? ▪ Q19. What market challenges can you identify, concerning demand & economic changes? Are there any strategies that have been identified as successful in dealing with these challenges? ▪ Q21. In your opinion, have initiatives such as the BUILD UP Skills been successful and in what manner?

Lack of demand for skilled workforce in energy efficiency	▪ Q4. What barriers can you identify in the field of training for energy efficiency, in the construction sector? ▪ Q5. What can be done, in your opinion, to increase demand for energy efficiency, in the construction sector? ▪ Q8. Could you please give your opinion on the level of demand for energy efficiency training and what you think will happen in the foreseeable future? ▪ *Q12. Could you please describe the skills that are needed in the new energy efficiency technologies, in your field?*
Lack of availability, or inadequate, training programs (in terms of scope, quality, content, cost, etc.).	▪ Q10. Is the focus placed on training for energy efficiency sufficient? Please elaborate on your opinion? ▪ Q4. What barriers can you identify in the field of training for energy efficiency, in the construction sector? ▪ *Q11. Could you give any examples of other training programs in the construction industry that you believe are contributing to energy efficiency, in the construction sector?*
	▪ Q14. How comprehensive is the training material for energy efficiency in the construction sector that you are familiar/involved with (and if you can elaborate on what that training is)? How can it be improved? ▪ Q15. How much of previous knowledge is considered in training programs for energy efficiency in the construction sector? Is informal learning & training being properly integrated? ▪ Q18. How much do training programs develop synergies between academic and vocational training? What could be done to further strengthen this link?
Lack of shared vision and values for energy efficiency across the supply chain.	▪ Q3. How does training and skill development in the construction sector contribute to the increasing need for environmental awareness, in our societies? ▪ Q6. What is the current state of knowledge and experience sharing, with regards to energy efficiency, in your organisation, in your opinion? What can be done to improve it? Are there any conflicting interests? ▪ Q7. What is the current state of knowledge and experience sharing, with regards to energy efficiency, in the industry, in your opinion? What can be done to improve it? Are there any conflicting interests? ▪ *Q13. Does energy efficiency in the construction sector contribute to a vision of long-term employment?*

Inadequate policy landscape, including lack of government incentives	▪ Q16. Does completing training result in any formal (e.g. accredited) qualification? Do these qualifications increase employability? ▪ Q17. With regards to policies & legislation, how effectively do you believe they integrate training? (e.g the European Green Deal, which focuses on making EU's economy sustainable and EU climate neutral by 2050) ▪ Q19. What market challenges can you identify, concerning demand & economic changes? Are there any strategies that have been identified as successful in dealing with these challenges? ▪ Q20. Have any aspects/insights of the training that you have been involved with been included into national strategies?

Questionnaire:

Theme	
Lack of access to useful information, knowledge, and best practice guides for energy efficient interventions.	▪ Q6. What are the common barriers for training for energy efficiency in your organisation? ▪ Q7. What are the common barriers for training for energy efficiency in the industry? ▪ Q10. Are you aware of the BUILD UP Skills initiative? ▪ Q11. In your opinion, was BUILD UP Skills, succesful? ▪ Q12. Should initiatives like BUILD UP Skills be undertaken in the future? ▪ Q15. What are your recommendations to enhance training & skill development ptograms in your organisation? ▪ Q16. What are your recommendations to enhance training & skill development ptograms in the construction industry? ▪ Q19. Overall, is the focus placed on energy training for energy effciency sufficient, in the construction sector, in your opinion? ▪ Q20. Have you been involved with knowledge and experience sharing for energy efficiency in the construction sector? ▪ Q23.Have you ever received any training concerning energy efficiency in the construction sector?

Lack of demand for skilled workforce in energy efficiency	▪ Q6. What are the common barriers for training for energy efficiency in your organisation? ▪ Q7. What are the common barriers for training for energy efficiency in the industry? ▪ Q22. Could you please identify any issues linked with the financial implication of training (hidden transaction costs)? ▪ Q27. In what manner does training for energy efficiency deal with retiring workforce, in the construction sector? ▪ Q28. In what manner does training for energy efficiency deal with non-qualified workforce, in the construction sector? ▪ Q29. In what manner does training for energy efficiency deal with next-generation workforce, in the construction sector? ▪ Q30. In what manner does training for energy efficiency deal with next-generation workforce, in the construction sector?
Lack of availability, or inadequate, training programs (in terms of scope, quality, content, cost, etc.).	▪ Q6. What are the common barriers for training for energy efficiency in your organisation? ▪ Q7. What are the common barriers for training for energy efficiency in the industry? ▪ Q15. What are your recommendations to enhance training & skill development ptograms in your organisation? ▪ Q16. What are your recommendations to enhance training & skill development ptograms in the construction industry? ▪ Q24. What type of material was used in the training program for energy efficiency in the construction sector that you have been involved with? ▪ Q25. Was the training of trainers in programs of energy efficiency in the construction sector efficient & adequate, in your opinion? ▪ Q26. Was the frequence and level of detail, including duration of the training that you have been involved with, appropriate?

Lack of shared vision and values for energy efficiency across the supply chain.	▪ Q6. What are the common barriers for training for energy efficiency in your organisation? ▪ Q7. What are the common barriers for training for energy efficiency in the industry? ▪ Q8. What is the current state of knowledge and experience sharing with regards to energy efficiency in your organisation, in your opinion? ▪ Q9. What is the current state of knowledge and experience sharing in the industry, with regards to energy efficiency, in your opinion? ▪ Q18. On what level does the positive impact/results of training in the construction sector for energy efficiency becomes more evident, in your opinion?

Inadequate policy landscape, including lack of government incentives	▪ Q6. What are the common barriers for training for energy efficiency in your organisation? ▪ Q7. What are the common barriers for training for energy efficiency in the industry? ▪ Q13. In your opinion, is the importance of energy efficiency training being taken into consideration adequately by the construction industry, on a European level? ▪ Q14. In your opinion, is the importance of energy efficiency training being taken into consideration adequately by the construction industry, on a national level?

Workshop Insights:

Theme	Key insights
Lack of access to useful information, knowledge, and best practice guides for energy efficient interventions.	▪ Demand and access go hand in hand. Without demand, there will inevitably be a lack of access, therefore the priority should be on building demand. ▪ The people that should be pushing for energy efficient solutions are not pressing hard enough for it, however it is thought this could change once policy landscape also changes. ▪ Whilst the building sector is making strides towards energy efficiency, other areas of infrastructure are behind in this regard. i.e., transportation infrastructure. ▪ There is an abundance of information, knowledge and guides available, however the challenge is sourcing targeted training that relates to specific roles. ▪ Workers should be guided to appropriate training that relates only to their role. This targeted training is more likely to be absorbed by the worker and used in practice. ▪ There is a need to develop awareness of the various end user groups.

Lack of demand for skilled workforce in energy efficiency	▪ Construction workers are in high demand and is leading to the employment of lower skilled workers. ▪ European countries are setting stringent carbon neutral targets; however, there are not enough skilled workers to produce energy efficient buildings. ▪ Companies should be shown the correlation between a skilled workforce and quality of a building to highlight the importance of skilled workers. ▪ Companies need to value the importance of upskilling workers, and to not see it as a drain on time/finances. ▪ Companies are more inclined to use the same processes instead of innovating and adapting to tackle new markets. ▪ Companies will not upskill their workers until clients demand change. ▪ A skilled workforce is desirable but difficult to access. ▪ Demand for a skilled workforce and legislation are interlinked. Financial/tax incentives appear to be successful motivators for increasing the demand for energy efficiency in the construction sector. ▪ The adoption of Artificial Intelligence, ICT tools etc. can be used as a contributor/instrument to deliver a skilled workforce.
Lack of availability, or inadequate, training programs (in terms of scope, quality, content, cost, etc.).	▪ There are lots of training programs available, however they are similar in content, quality, and theory. They do not meet the needs of the workforce. ▪ Training for blue collar workers should be less theory based and more practical. ▪ 'On the job' training would be more suitable for blue collar workers. ▪ Whilst the participants agreed that 'on the job' training was the best approach. It was also highlighted that there would be challenges in providing such training on site. ▪ Lack of time is preventing workers from accessing training. ▪ Prioritising training would require a top-down approach. ▪ It is important to integrate qualifications into on-site training.
Lack of shared vision and values for energy efficiency across the supply chain.	▪ Finland has formulated carbon neutral road maps for 2030-2050 (for all industries). It will be interesting to see if they have considered energy efficiency at a workforce level, to ensure carbon neutrality throughout the whole value chain. ▪ It was suggested that to become truly energy efficient all the sectors involved must behave in the same way and share the same vision for energy efficiency. This, however, is not currently the case.
	▪ Companies will transition to energy efficiency when legislation pressurises them to do so.

Inadequate policy landscape, including lack of government incentives	▪ Government support is essential for any real changes in energy efficiency to occur. ▪ Policy landscape varies depending on the countries priorities. ▪ It was argued that pressure from industry can influence policy. There should be scope in the policy landscape that would allow for construction experts to mandate such policies. ▪ Better communication is required amongst countries to share energy efficiency instruments, best practice guides etc. and to improve policy landscape.

In addition, a number of questions deal with the necessary demographics & procedural questions for the study, in order for the interviews and questionnaires to take place:

Interviews:

Theme	
Demographics & procedural questions	▪ Q1. Please could you confirm that you consent to this interview? ▪ Q2. Could you please introduce yourself, and your professional role/position?

Questionnaires

Theme	
Demographics & procedural questions	▪ Q1. Consent ▪ Q2. Age ▪ Q3. Gender ▪ Q4. Professional Experience ▪ Q5. What is your field of expertise? ▪ Q31. If you have any comments you would like to make, please write them below

A detailed analysis of the results, as well as the correlation of the insights from the triangulation followsin the chapters 4 and 7, respectively.

Steps 3 & 4: Pilot and Validate the Questionnaire & Pilot and Validate the Interview Guide

As argued by (Hassan et al, 2006) “a pilot study can be defined as a small study to test research protocols, data protection instruments, sample recruitment strategies, and other research techniquesin preparation for a larger study”. For this study, the instruments which were created in the previous stage were tested out, firstly, within the Cardiff University research team, which resulted in a more detailed and clearer structure of the consultation instruments. Secondly, both the questionnaire on

SurveyMonkey and the interview were piloted through a process of asking partners to nominate two people from their organisation, from a network of the following project partners:

ASM – Market Research and Analysis Centre
R2M SOLUTION
LUXEMBOURG INSTITUTE OF SCIENCE AND TECHNOLOGY
SUOMEN RAKENNUSINSINOORIEN LIITTO RIL RY
Teknologian tutkimuskeskus VTT Oy – VTT
DISTRETTO TECHNOLOGICO TRENTINO SCARL
ENERGY EFFICIENCY CENTER – ENEFECTFOUNDATION

For the questionnaires, feedbacks in the forms of word document and/or e-mail were received. For the interviews, four interviews took place on Zoom, they were recorded and transcribed, and throughthis process the opportunity to clarify the content and structure of the questions, test the sequence ofthe questions. From the pilot of the questionnaires issues with regards to the functionality of the sequence were raised, and also feedback was given with regards to the possible additions that could give participants a better overall experience and more options. Following this process, the necessary corrections took place, and the material was ready for distribution.

Step 5: Identify and Document training informed Energy Efficiency Use Cases

Based on the use-case collection template, the consortia partners have been asked to provide 5 relevant use-cases from their country of origin in order to cover a wider European perspective. 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 (see Figure 21). To support in the process of use-case collection, and experts have been asked to contribute and register a list of authoritative URI sources.

These have been registered within the http://www.energy-education.com/ platform (see Figure 21). Such sources have been integrated in the search service aiming at facilitating the process of extractingbest practices, regulations and to support with requirements definition and training. A human based process has been utilised to validate these relevant sources and searching URIs (Uniform Resource Identifier) based on specialised keywords. These have been validated by experts inthe field of BIM and supported by the consortium partners. Such keywords include: energy efficiency,best practice, case study, training and education.

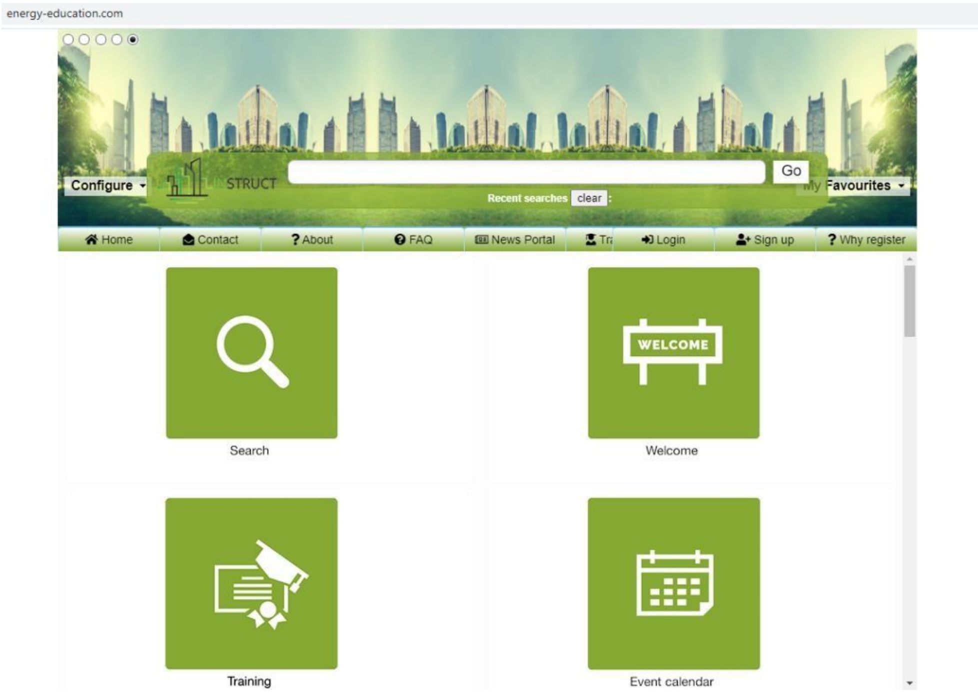

Figure 21. Screenshot of the energy-education platform

The energy-education platform can be found at the following address: http://www.energy-education.com/

Use Case Title:	
Use Case type (R&D, Real-world application, BIM guideline, Other):	
Funding source (Research Council name / Client name):	
Project title:	
Web Link (URL):	
Targeted Discipline (Architectural Design / Structural / Mechanical Engineering, etc,):	
Targeted Building type (Public, Domestic, Industrial, Other):	Public
Project type (Existing, New Build, Renovation, Extension):	Existing
Lifecycle applicability (RIBA Plan of Work):	
Brief description of the case study	
Key Highlights	
Supporting best practice case study	
-Scenario definition	
-Control Variables	
-Objectives	

Figure 22. Screenshot of the use-case input template

Step 6: Assemble and Analyse Social Media Information

For this process, these steps were followed:

Step 1: During piloting partners to share twitter accounts (endpoints) ofinstitutions/individuals/group that are active on social media

Step 2: Mining of social media accounts and extract knowledge related to the study including roles,skills, trends for energy education

Step 3: Inclusion of the outcome in the study

The list of the organisations utilised for the capturing process is obtained from three sources:

forensics algorithms for IP detection and organisation identification, followers of the @BIMEET twitter account and partners indication of training institutions.

Further to that, the NVIVO software was used to analyse the qualitative data. NVIVO is designed for qualitative studies with very rich text-based and/or multimedia information, where deep levels of analysis on small or large volumes of data are required. The analysis was applied to:

- Expert Interviews
- Training descriptions
- Publications from Relevant Literature
- 15 million tweets from relevant Social media

Step 7 & Step 8: Distribute the Questionnaires & Organise the Interviews

The questionnaires were distributed in the network of the aforementioned partners, via e-mail, by sharing the relevant link to the SurveyMonkey website. The audience of participants covers all the different layers of stakeholders in the construction sector. Approximately 35 questionnaires were expected to be gathered through the process.

The interviews were organised, similarly to the questionnaires, through approaching the partners ona European level and asking them to nominate people and local stakeholders to conduct five interviewseach. The sample of participants draws on a mix from both white-collar workers and blue-collar workers. The interviews were held electronically, through video conferencing, including Zoom, due tothe COVID-19 pandemic circumstances and cross-country nature of the process. The material was recorded, with the consent of the interviewees.

Name of organisation	Twitter account
Group CSI	https://twitter.com/groupecesi
INES Solaires	https://twitter.com/ines_solaire
BRE Academy	https://twitter.com/BREAcademy
Ecoles des Ponts ParisTech	https://twitter.com/EcoledesPonts
Buildup Skills	https://twitter.com/EU_BUILDUP
ESTP	https://twitter.com/estpparis
Universite de Liege	https://twitter.com/universiteliege
Universite Catholique de Louvain	https://twitter.com/uclouvain_be
Città di Modena	https://twitter.com/cittadimodena
ORSYS Luxembourg	https://twitter.com/orsys
BEC partners SA	https://twitter.com/becpartners
Middlesex University	https://twitter.com/MiddlesexUni
House of Training	https://twitter.com/houseoftraining
Sapienza Università	https://twitter.com/SapienzaRoma
Scuola Pesenti	https://twitter.com/master_pesenti
LeMoniteur	https://twitter.com/le_moniteur
Technical University of Denmark	https://twitter.com/DTUtweet
Norwegian University of Science and Technology	https://twitter.com/ntnu
UIC Barcelona	https://twitter.com/uicbarcelona
Mensch und Maschine	https://twitter.com/mumdach
Zigurat	https://twitter.com/ziguratdigital
BIMEET EU	https://twitter.com/bimeetEU
H2020EE	http://twitter.com/H2020EE
H2020BIMplement	http://twitter.com/H2020BIMplement
ECTPSecretariat	http://twitter.com/ECTPSecretariat

Figure 23. Examples of social media sources

Step 9 & Step 10: Analyse the Questionnaires & Analyse the Interviews

The data from the SurveyMonkey survey was documented and collected via the software's graphs and statistics as a way to collect and categorize key concepts and patterns, and process quantitative data. Confidentiality and anonymity of the participants was kept throughout the process. With regards to the interviews, after finishing the interviewing process, the transcripts of the interviews were analysed in an interpretive, qualitative manner to extract insights, understand the and discern patters and reach conclusions, about the questions that the study poses. NVIVO was used as a software to facilitate the process and help with the storage, coding and retrieval of data (Descombe, 2016). As with the questionnaires, confidentiality and anonymity of the participants was kept throughout the process.

Step 11: Results triangulation

Results are analysed in the "Results" section, feeding into the "Discussion" section of this document. For the analysis of the results, both a qualitative and quantitative approach were followed, as described in the introduction of the "methodology" section - following the overarching mixed methods approach of the study. As a last step, the previous steps led into a correlation of results which was then brought into a comparison with the initial insights from the Literature Review. This process is part of the triangulation aspect of the mixed-methods approach, as mentioned in the introduction. Triangulation, which is defined as "the practice of viewing things from more than one perspective", asDescombe argues (2016), in this case falls into the "methodological triangulation" type. In this case, insights are found by corroborating data from different methods (Dencombe, 2016) and the aim is to

achieve "improved accuracy" (Descombe, 2016) of the findings. The results were therefore analysed in an interpretative manner, in relation to each other, so as to forge connections between all the datathat has emerged from the process and the research.

Step 12: Organise a Europe-wide Workshop

After the interviews and questionnaire stages, were completed, a Europe-wide workshop was organised and delivered in order to present the results to a group of experts, to encourage discussions around our findings, and to further corroborate the correlation between training and energy efficiency in the building sector. In terms of organisation, a Doodle Link was sent out to partners, so that they could highlight their availability for the event. The participants of the workshop had knowledge and experience of the construction sector, from any part of the value chain, whether white-collar workers, or blue-collar workers. The aim of the workshop was to hold a workshop at which all participants had the time to share their thoughts and experiences. The event provided an opportunity for discussions, in greater detail. The discussions from the sessions have informed the research and aid in the development of tools, to improve energy efficiency training in the construction sector. Brainstorming sessions with experts have been organised as part of the workshop, in order to understand existing gaps in the field of training for energy efficiency and to aggregate new best practices use-cases.

4. Results

4.1. Data Analysis from Questionnaires

The findings from the questionnaires conducted on SurveyMonkey, included 52 participants and are analysed below, in three categories: (1) Demographic, (2) Correlation data between training and energy efficiency, in the construction sector, and (3) Data on quality and content of training for energy efficiency. The full list of questions and detailed analysis is presented in the Appendixes (10.3).

With regards to the correlation between training and energy efficiency in the construction sector, there are a number of useful observations. On an organizational /firm level, the barriers that stood out were financial/funding issues (50.00%) and not enough time for training (46.15%). When asked about the level of knowledge and experience sharing in the companies and organisations, most of the participants stated it was fair (34.62%). When asked about the level of knowledge and experience sharing in the construction sector, most of the participants stating it was good (40.08%). Concerning recommendations in the relevant organisations, the importance of training being flexible and adjusting to the needs of those who undertake it (62.50%) was the first choice.

On a construction industry level, when the participants were asked whether they thought that the importance of energy efficiency training is being taken into consideration adequately on a national level 56.25% responded negatively. With regards to barriers that are encountered in the construction sector, financial/funding issues is at the top of the concerns (42.31%). When asked about the manner with which training for energy efficiency deals with the retiring workforce, 30.56% did not know how to respond to this or were not sure and some responded with "poor" (30.56%). When asked about the manner with which training for energy efficiency deals with a non-qualified workforce, the majority responded they do not know how to answer this question, while most of the rest responses were divided between "poor" (29.63%) and "fair" (25.93%).

Regarding about the manner with which training for energy efficiency deals with the next-generation workforce, is in the construction sector, most answers were divided between "poor" (27.78%) and "good" (22.22%). When asked about the manner that the inclusivity and diversion are reflected within training for energy efficiency, most participants did not know or were not sure how to reply (31.71%). When asked if the focus placed on training for energy efficiency is efficient in the construction sector, the majority (54.17 %) replied with "no". In addition to that, most participants stated that (61.90%) have been involved with knowledge and experience sharing in the construction sector. When asked about areas that are affected positively by training for energy efficiency, participants highlighted that it affects not solely the construction sector (79.17%), but also the environment (85.42%), society (64.58%), and economy (64.58%).

On a European level, when participants were asked whether they thought that the importance of energy efficiency training is being taken into consideration adequately, 43.75% responded positively, and 37.50% negatively. When asked about the BUILD UP Skills initiative, 52.17% of them were aware of the initiative. The majority of those who knew about the initiative suggested it was successful (48.84%) and 57.50% suggested that initiatives like BUILD UP Skills should be undertaken in the future.

As far as the data on quality and content of training for energy efficiency, when asked about recommendations to enhance training & skill development programs in the construction industry, the majority (61.70%) chose "Make sure training has a significant practical contribution for those involved". Regarding any impact/results of training in the construction sector for energy efficiency participants stated that the effects are mostly perceived at a local (52.08%) and national level (43.75%). When asked about whether they had received any training concerning energy efficiency in the construction sector, the majority stated that they had received training (65.85%). When asked about whether the approach of training that the participants were involved with could be scaled up to other collaborating organisations across projects in the industry, the majority of (52.17%) confirmed that it can be upscaled. In addition to that, the training of trainers in energy efficiency programs was perceived as efficient and adequate (61.90%) by participants. When asked about whether the frequency and level of detail (including duration of the training) that participants had been involved with was appropriate, most participants confirmed it was (59.52%). Concerning financial implications of training, the most significant perceived difficulty was the "Difficulty in finding and training the required workforce" (50.00%). Lastly, when asked about the tendency concerning the type of material used for these trainings, most participants argued that the material used for training focuses mostly on "classes" (62.96%), "handouts, best practice guides" (which presents the highest percentage with 66.67%), and online & video training, and less on the literature on energy efficiency.

4.2. Data Analysis from Interviews

Overall, 28 interviews were conducted. NVIVO was used to analyse and group the data. The findings are presented in three categories: (1) Demographic, (2) Correlation data between training and energy efficiency, in the construction sector, and (3) Data on quality and content of training for energy efficiency. Regarding demographic observations, the data was collected from participants from nine countries in Europe from different fields and professions. One observation that needs to be stated, which is also a limitation of the data collected, is that most participants were white-collar workers, except for one participant.

Concerning the correlation data between training and energy efficiency, in the construction sector, interviewees were asked to comment on how training and skill development in the construction sector contributes to the increasing need for environmental awareness, in our societies. The majority of interviewees (except for one) pointed out at a correlation between training for energy efficiency and an increasing need for environmental awareness. With regards to barriers identified in the field of training for energy efficiency in the construction sector, training & education was at the top of concerns. Moreover, interviewees were asked to comment on what can be done to increase demand for energy efficiency, in the construction sector. To this question, various suggestions emerged, including solutions to the several barriers that were highlighted. When asked about the current state of knowledge and experience sharing, with regards to energy efficiency in their organisation, most interviewees sustained that the situation could overall be described as satisfying. When interviewees were asked to comment on what the current state of knowledge and experience sharing, with regards to energy efficiency in the industry, most participants sustained that knowledge and experience is currently insufficient. With regards to things that can be improved, a variety of suggestions came up, such as “improvement of dissemination of the knowledge, collaborative spaces and shared drives, the importance of training, a more in-depth focus on how energy efficiency is integrated into education from an early-stage, improvement in legislations, continuous professional development, a more intense focus on tangible results rather than theoretical ones, energy efficiency technologies”.

When asked to comment on the level of demand for energy efficiency training and what they thought will happen in the foreseeable future, and encouraging landscape was presented, but with significant room for improvement. Further to that, interviewees were asked to comment on whether the importance of energy efficiency skills in the construction sector is being taken into consideration adequately, in their field (Figure 17). To this question, responses were leaning more towards of negative perception.

With regards to whether energy efficiency in the construction sector contributes to a vision of long-term employment, most interviewees suggested that, indeed, it does(Figure 18).

In addition to that, interviewees were asked to comment on how much of previous knowledge is considered in training programs for energy efficiency in the construction sector, as well as whether informal learning & training is being properly integrated (Figure 19). The replies to this question were split between a negative and a positive perception.

When asked about policies & legislation, and how effectively they thought that they integrate training, the replies highlight that there is no clear link (Figure 20).

Interviewees were also asked to comment on how much training programs develop synergies between academic and vocational training (Figure 21). The replies to this question indicate that this link needs to be strengthened, as it is currently insufficient.

With regards to market challenges that interviewees were able to identify, concerning demand & economic changes, as can be observed from Figure 22, those that were mostly mentioned were around issues of funding, finance issues, and the economy.

When interviewees were asked whether the insights of the training that they had been involved with were included in national strategies, the data could be interpreted to suggest that this is an area of further development (Figure 23).

Interviewees were asked to present their opinions on whether initiatives such as the BUILD UP Skills had been successful and in what manner (Figure 24). Out of the people who were aware of the program, interviewees deemed it as successful. When asked about whether training results in any formal (e.g., accredited) qualification and if these qualifications increase employability, most interviewees answered positively (Figure 25).

Interviewees were asked to weigh on whether the focus placed on training for energy efficiency is sufficient, and the majority deemed it insufficient (Figure 26).

Interviewees were also asked to describe the skills that are needed in the new energy efficiency technologies in their field. The answers to this question were grouped in terms of relevance. Most replies pointed to skills that have to do with awareness, conceptual knowledge, and understanding skills, as being the most important.

Further, interviewees were asked to provide insight on how comprehensive the training material for energy efficiency in the construction sector that they were familiar/involved with was and how it could be improved (Figure 27). The majority of interviewees replied with a positive outlook on the matter. At the same time, several limitations were identified.

Lastly, interviewees were asked to comment on whether any aspects/insights of the training that they had been involved with had been integrated into national strategies (Figure 28). Not many interviewees provided relevant replies, yet out of those who did, there were some relevant examples.

5. Use-Case analysis

We have created a requirement capture use-case template based on which we have aggregated a numberof 70 best practice use-cases. In order to identify gaps and training requirements, the analysis is presentedbelow. The entire portfolio of use-cases can be accessed online and the status at the time this study is submitted, is presented in the Appendix 10-3.

5.1 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. Key themes and their frequency contributing to evidencing the correlation between training and energy efficiency

NO.	Objectives	Use Cases
1	Minimise energy consumption	14
2	Minimise operational costs	3
3	Minimise carbon emissions	7
4	Reduce water demand	1
5	Maximise energy comfort	5
6	Low impact building	4
7	Optimise energy performance-efficiency	7
8	Reduce energy demand (operation)	3
9	Management lifecycle data sets of relevance to building energy management	5
10	Deal with energy profiles and consumption through the product lifecycle	5
11	Enhancing the competitiveness of the energy distribution and control sector	2
12	Improving use and control of energy	5
13	Reduce cost and water consumption	1
14	LEED	3
15	Develop EU market for ICT	4

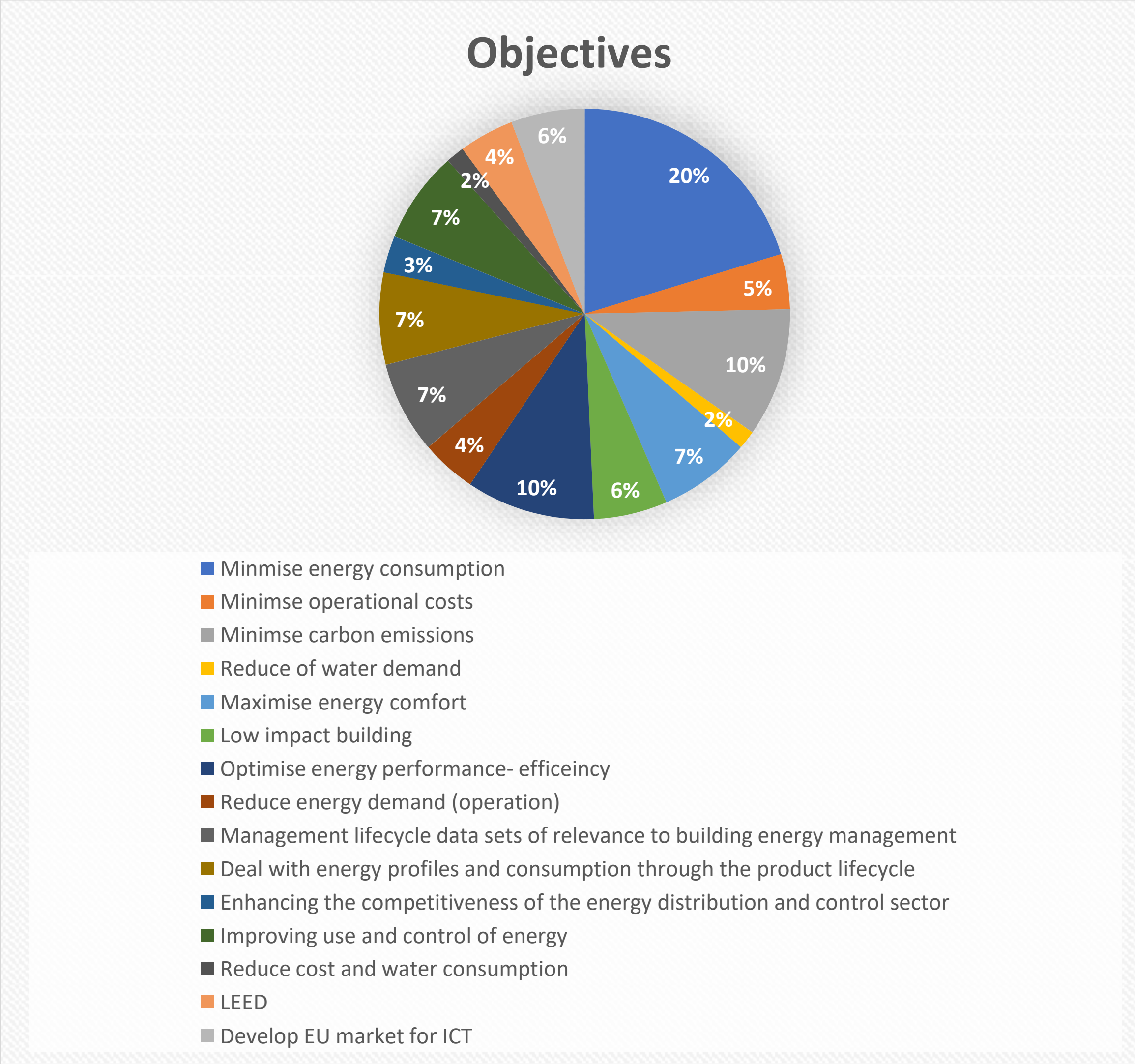

Figure 24. An objective based analysis of Energy Efficiency

The use-cases have multiple objectives as shown in Table 20. Minimise energy consumption is the most common objective for the identified best-practices use-cases, with a total of fourteen use cases. Optimise energy performance-efficiency has been recorded as an objective for seven use cases, whereas other frequent objectives are related to minimising carbon emission and improving the use and control of energy.

5.2 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.

No.	Use Case Type	Many of use cases
1	Research &Development	35
2	Real world application	29
3	BIM Guideline	4

4	Other	2

Table 2. Use-case type analysis of using BIM for Energy Efficiency

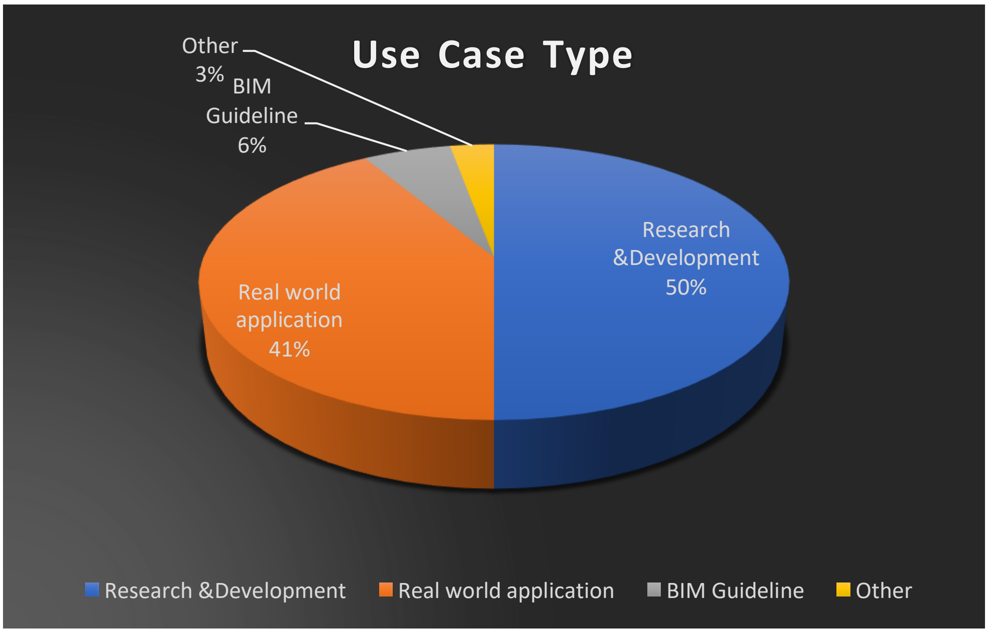

Figure 25. Use-case type analysis of using BIM for Energy Efficiency

There are four types of use cases in this evaluation which are Research & Development, Real-world application, BIM Guideline, and Other. As per the analysis, it can be observed that Research & Development cover a number of 35 use cases, and Real-world application has 39 use cases, BIM guideline has 4 use-cases, and Other has 2 use-cases.

5.3 Building type analysis

In this part, we assess the use-cases based on the type of building project involving training. As reported in Table 22, the majority of projects are for public buildings, whereas domestic, new build and industrial building seem less popular in adopting BIM.

NO.	Building Type	Many of use cases
1	Public	47
2	Domestic	10
3	Other	11
4	Industrial	1
5	New Build	1

Table 3. Building type analysis of using BIM for Energy Efficiency

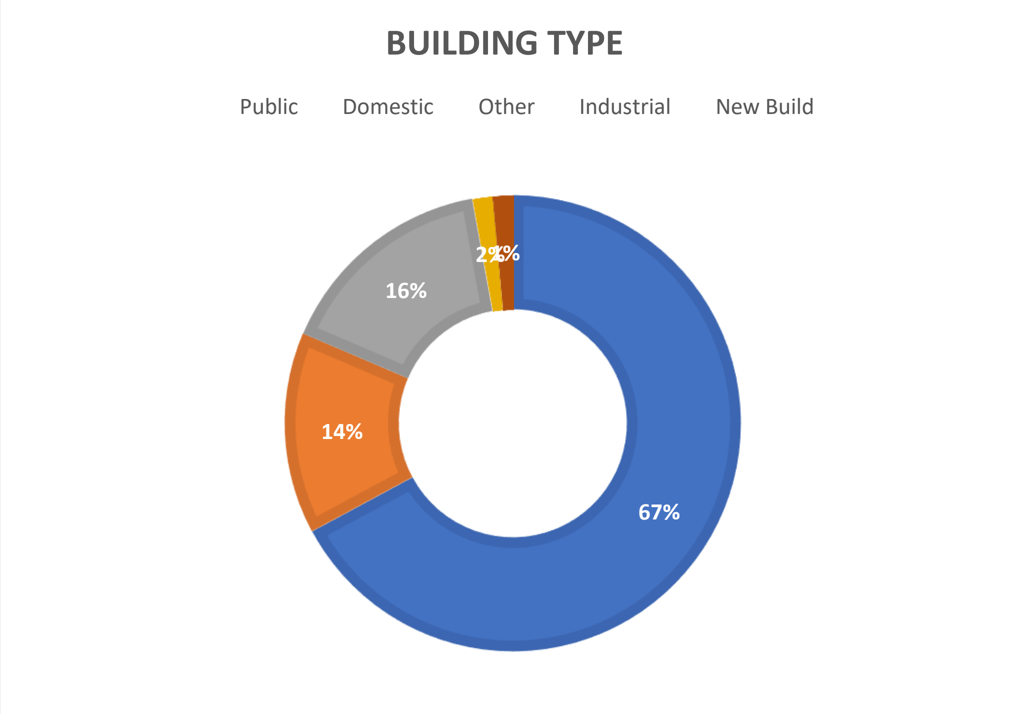

Figure 26. Building type analysis of using BIM for Energy Efficiency

From the set of building types that we have used in our evaluation, the most popular are public buildings. In contrast, domestic building, new build, other and industrial buildings have a lower percentage. As reported in Figure 74, 67% of these use cases have applied BIM in a public building, 16% in other building, and the rest of them in new build and industrial buildings.

5.4 Project type analysis

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

No.	Project type	Many of use cases
1	Existing	36
2	New build	25
3	Renovation	9
4	Extension	2

Table 4. Project type analysis of using BIM for Energy Efficiency

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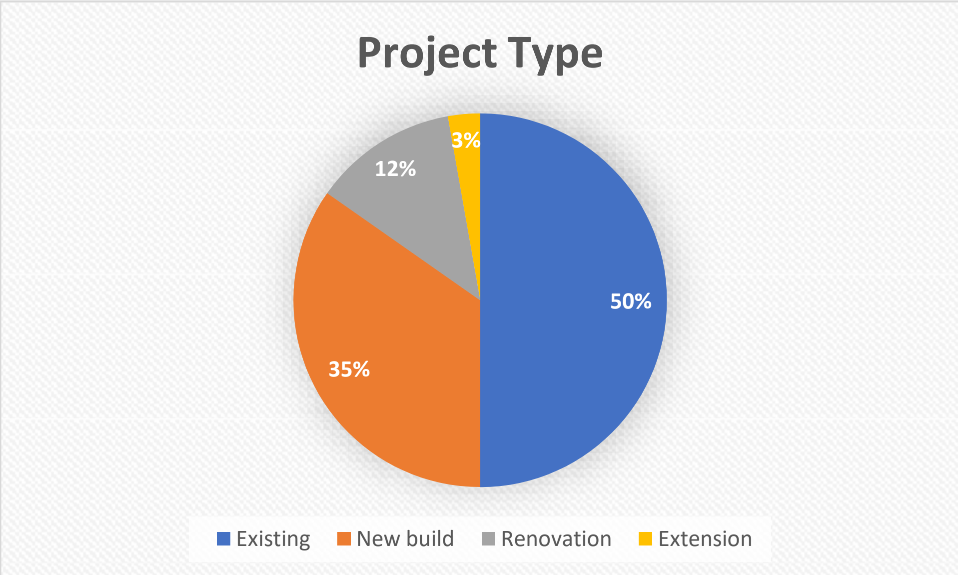

Figure 27. Project type analysis of using BIM for Energy Efficiency

From the analysis reported in Table 23 and Figure 75, it can be observed that a majority of use-cases rely on training for existing and new buildings. In contrast, extension and renovation projects are less likely to adopt training, for instance with a focus on BIM. In percentage, 50% of project types are existing, and new build projects and the rest of the project types are renovation and extension projects. These results should be considered with caution as they reflect the nature of the gathered use cases.

5.5 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 structure engineering discipline projects have a higher reliance on energy efficiency training, followed by facilitymanagement and mechanical engineer projects.

No.	Target Discipline	Many of use cases
1	Architecture design	28
2	Facility management	15
3	Structure engineer	24
4	Mechanical engineer	13
8	Other	10

Table 5. Target Discipline analysis of using BIM for Energy Efficiency

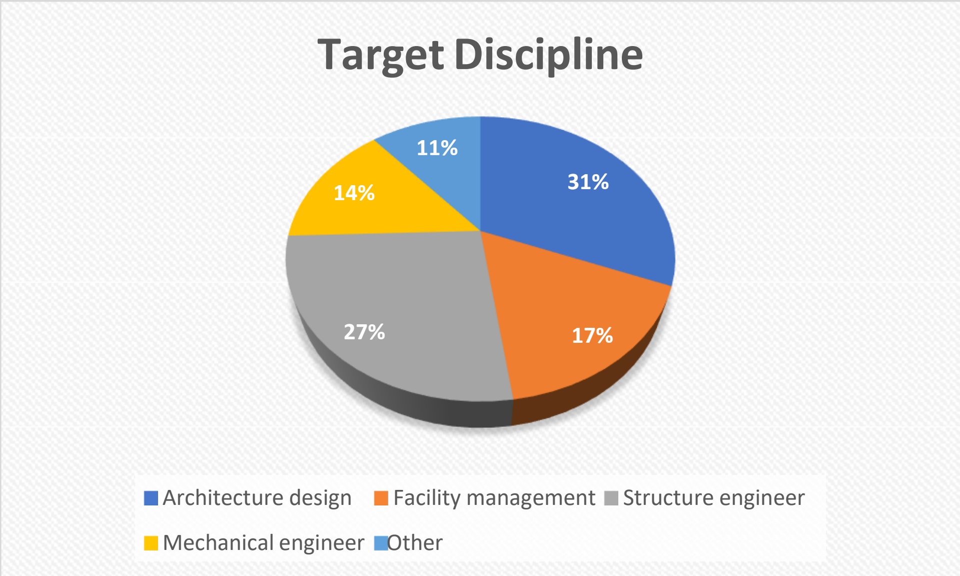

Figure 28. Target Discipline analysis of using BIM for Energy Efficiency

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 31%, structure engineers by 27% whereas the mechanical engineers and facility management are targeted by 14% and 17%, respectively.

5.6 Lifecycle stage analysis

For the analysis, we have used RIBA stage life-cycles and this part aims at determining associated life-cycle stages of each BIM best practice use-case.

No.	Lifecycle stage (RIBA)	Many of use cases
0	Strategic Definition	2
1	Preparation and Brief	11
2	Concept Design	10
3	Developed Design	2
4	Technical Design	8
5	Construction	9
6	Handover and Closeout	1
7	In Use	11

Table 6. Lifecycle stages analysis of using BIM for Energy Efficiency

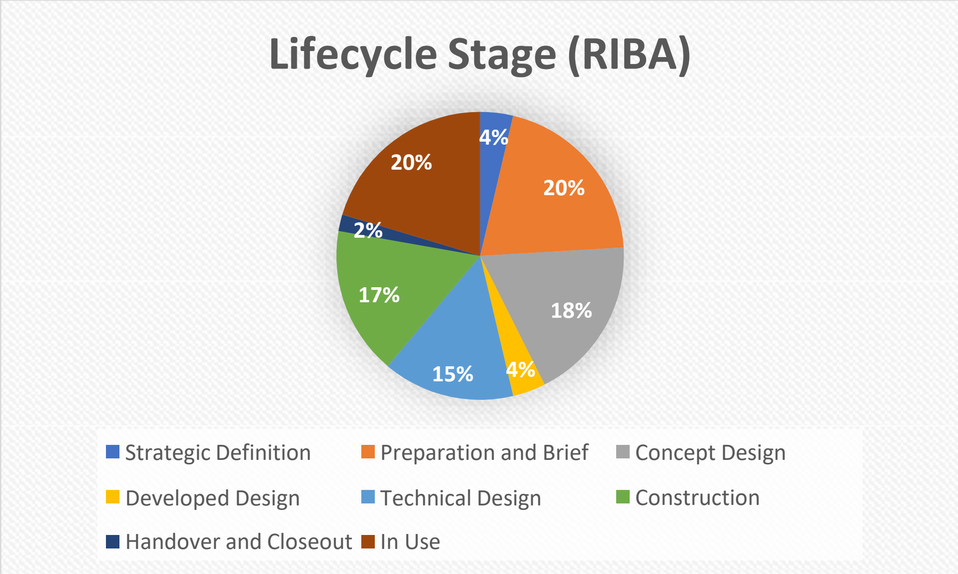

Figure 29. Lifecycle stages analysis of using BIM for Energy Efficiency

Figure 77, shows that, 37% from the recorded projects use BIM for energy efficiency in the design stages in lifecycle of the project, whereas handover and closeout stage identifies 2% in the lifecycle of the projects.

5.7 Impact based analysis

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

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

12	Achieved sustainable design	1
13	Saving water consumption	2

Table 7. An impact-based analysis of using BIM for Energy Efficiency

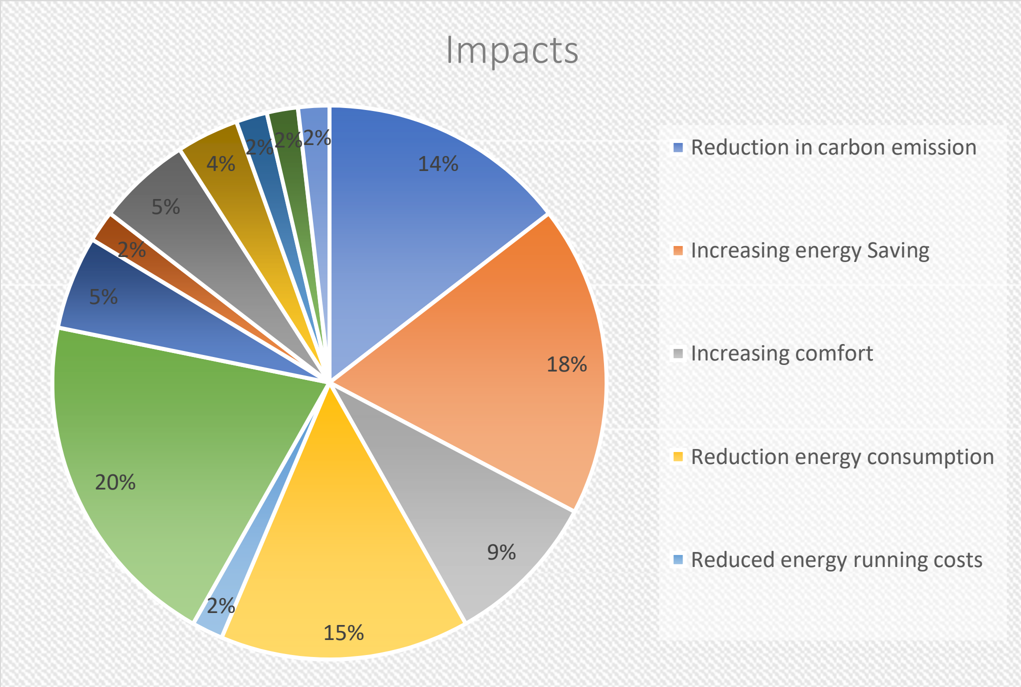

Figure 30. An impact-based analysis of using BIM for Energy Efficiency

From the range of impacts, the optimisation of energy performance has the highest percentage of 20%, meaning that optimisation of energy efficiency represents a common impact for projects that use BIM for energy efficiency. The second impact, as resulted from the use-cases, is related to increasing energy saving of 18%, reduction energy consumption is 15%, and reduction in carbon emission is 14%. Also, increasing comfort has an associated proportion of 9%.

5.8 Examples of use-cases evidencing link between training and energy efficiency

In line of the above observations and analysis of the use cases, some successful cases are presented. The aim is to further highlight the link between tangible examples of training and energy efficiency. BIM and BREEAM are used as examples of training in the construction industry and their effectiveness is presented with brief descriptions and specific achievements.

Use-cases
1. Use of BIM in design and construction phase to achieve sustainability goals of an office building
Location: Helsinki
Training: BIM
Evidence of effectiveness of training for energy efficiency: "Holistically BIM-based project achieved LEED Core & Shell Platinum Certificate." (INSTRUCT - BIM for Energy Efficiency, 2022)
Brief description of case-study: Headquarters in Helsinki, Finland, that has achieved LEED Core & Shell Platinum certification. BIM was used throughout the design and construction project. Supporting Case-Study: 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". (INSTRUCT - BIM for Energy Efficiency, 2022)
Source:https://www.energy-bim.com/view/bim?use-case=60&doctitle=Best%20Practice%20Use-Case%20Study%20Form&q=&token=049d066905c848b3b521ff4e7c1ed552
2. Improving Energy Performance of Office Buildings Based on Light Building Information Model (BIM)
Location: Helsinki
Training: BIM
Evidence of effectiveness of training for energy efficiency: "Minimal information requirements for energy simulation is highlighted in the study." (INSTRUCT - BIM for Energy Efficiency, 2022)
Brief description of Case-Study: "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 result 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." (INSTRUCT - BIM for Energy Efficiency, 2022)
Supporting case-study: 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". (INSTRUCT - BIM for Energy Efficiency, 2022)
Source: https://www.energy-bim.com/view/bim?use-case=63&doctitle=Best%20Practice%20Use-Case%20Study%20Form&q=&token=049d066905c848b3b521ff4e7c1ed552
3. Use of BIM for ESD Analysis of BCA Academic Tower
Location: -
Training: BIM

Evidence of effectiveness of training for energy efficiency: "Achieving energy efficiency by leveraging the BIM model and performing several types of energy analysis and simulations." (INSTRUCT - BIM for Energy Efficiency, 2022)
Brief Description of 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. Supporting 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". (INSTRUCT - BIM for Energy Efficiency, 2022)
Source: https://www.energy-bim.com/view/bim?use-case=77&doctitle=Best%20Practice%20Use-Case%20Study%20Form&q=&token=049d066905c848b3b521ff4e7c1ed552
4. Deloitte's 1 New Street Square
Location: London
Training: BREEAM
Evidence of effectiveness of training for energy efficiency: "Highest scoring BREEAM 2014 Refurbishment & Fit-out project in the world creating a workplace that truly benefits people and the planet. Score & Rating: 93.6% Outstanding" (BREEAM, 2022)
Source: https://www.breeam.com/case-studies/offices/deloittes-1-new-street-square/
5. Lövhagen 32
Location: Sweden
Training: BREEAM
Evidence of effectiveness of training for energy efficiency: "A BREEAM certified nursing home creating a secure and sustainable living environment • Rating: Part 1: Very good, Part 2: Very good • Overall Score: Part 1: 63.4%, Part 2: 61.1% For part 1 the building scored maximum points for pollution and waste. For part 2 the building scored high on energy and pollution". (BREEAM, 2022)
Source: https://www.breeam.com/case-studies/healthcare/lovhagen-32-sweden/
6. IKEA Greenwich
Location: London
Training: BREEAM
Evidence of effectiveness of training for energy efficiency: "Score & Rating: 90.4% The scheme demonstrates exemplary energy performance throughout. The building implements zero carbon technologies such as PV and GSHP. Small power and refrigeration equipment were assessed against industry standards and have demonstrated a reduction in energy consumption. Expert studies were carried out into the energy efficient transport systems at IKEA Greenwich. IKEA Greenwich utilises 100% LED lighting that performs above industry standards. The acoustic performance and thermal comfort at the store are exemplary, both meeting required standards that optimise conditions for the building user. Indoor air quality has been designed inline with best practice, air quality monitoring was performed during the final construction and fit-out phases.

IKEA Greenwich has benefited from the installation of a biodiverse green roof and planted garden areas surrounding the store. Features that help enhance ecology and the gain of species on site are various substrate areas on the green roof including log mounds and sand mounds, bird boxes and bat boxes situated in the 'woodland' garden area and green roof bike shelters that incorporate insect habitats. During construction of IKEA Greenwich the project was managed in accordance with best industry standards informed by BREEAM in a sustainable manner. A BREEAM AP was appointed for the project. A Life Cycle Cost analysis was carried out to improve and inform design for the future use of the building. IKEA Greenwich boasts outstanding public transport links to London bus routes, rail links and tube stations, as well as providing cyclist facilities for staff and the public. The store is also within 500 meters of key public amenities. A sustainable travel plan is at the heart of the building's philosophy. Water saving initiatives at IKEA Greenwich include the installation of low flow sanitaryware with the addition of shut off valves for taps and toilets. The stores grey water is harvested from a rain water harvesting (RWH) tank, in addition RWH is also used for evaporative cooling in air handling units. Leak detection connected to the Building Management System ensures the store is as water efficient as possible". (BREEAM, 2022)
Source: https://www.breeam.com/case-studies/retail/ikea-greenwich/
7. Reduce the Gap Between Predicted and Actual Energy Consumption in Buildings
Location: The Netherlands
Training: BIM
Evidence of effectiveness of training for energy efficiency: "The use of BIM has helped achieve a reduction of 25% energy compared to baseline figures." (INSTRUCT - BIM for Energy Efficiency, 2022)
Brief description of 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." (INSTRUCT - BIM for Energy Efficiency, 2022)
Supporting case-study: "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." (INSTRUCT - BIM for Energy Efficiency, 2022)
Source: https://www.energy-bim.com/view/bim?use-case=14&doctitle=Best%20Practice%20Use-Case%20Study%20Form&q=&token=049d066905c848b3b521ff4e7c1ed552
8. Sustainable Design and Building Information Modelling: Case study Energy Plus House, Hieron's Wood, Derbyshire UK
Location: UK, Derbyshire
Training: ArchiCAD, BIM Technologies

Evidence of effectiveness of training for energy efficiency: “Successful integration of sustainable design analysis with building information modelling using integrated design technologies as well as simulation software.” (INSTRUCT - BIM for Energy Efficiency, 2022)
Brief description of 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.” (INSTRUCT - BIM for Energy Efficiency, 2022)
Supporting case-study: “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.” (INSTRUCT - BIM for Energy Efficiency, 2022)
Source: https://www.energy-bim.com/view/bim?use-case=29&doctitle=Best%20Practice%20Use-Case%20Study%20Form&q=&token=049d066905c848b3b521ff4e7c1ed552
9. Friendly and Affordable Sustainable Urban Districts Retrofitting (FASUDIR) - Heinrich-Lubke housing area, Frankfurt, Germany
Location: Frankfurt, Germany
Training: BIM system (FASUDIR IDST)
Evidence of effectiveness of training for energy efficiency: “GWP reduction of 60%. Operational energy consumption reduction of 35%” (INSTRUCT - BIM for Energy Efficiency, 2022)
Brief description of 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.” (INSTRUCT - BIM for Energy Efficiency, 2022)
Supporting case-study: 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.” (INSTRUCT - BIM for Energy Efficiency, 2022)
Source: https://www.energy-bim.com/view/bim?use-case=29&doctitle=Best%20Practice%20Use-Case%20Study%20Form&q=&token=049d066905c848b3b521ff4e7c1ed552
10. Friendly and Affordable Sustainable Urban Districts Retrofitting (FASUDIR) - Budapest Residential District
Location: Budapest, Hungary
Training: BIM system (FASUDIR IDST)
Evidence of effectiveness of training for energy efficiency: “Operational energy reduced by 35% and energy running costs reduced by 35%
Brief description of 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." (INSTRUCT - BIM for Energy Efficiency, 2022)
Supporting case-study: 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." (INSTRUCT - BIM for Energy Efficiency, 2022)
Source: https://www.energy-bim.com/view/bim?use-case=31&doctitle=Best%20Practice%20Use-Case%20Study%20Form&q=&token=049d066905c848b3b521ff4e7c1ed552
11. BIM-based Parametric Building Energy Performance Multi- Objective Optimization
Location: Indianapolis, Indiana, USA
Training: BIM tool (Autodesk Revit)
Evidence of effectiveness of training for energy efficiency: "Operational energy reduced by 35% and energy running costs reduced by 35%" (INSTRUCT - BIM for Energy Efficiency, 2022)
Brief description of 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". (INSTRUCT - BIM for Energy Efficiency, 2022)
Supporting case-study: Not applicable
Source: https://www.energy-bim.com/view/bim?use-case=50&doctitle=Best%20Practice%20Use-Case%20Study%20Form&q=&token=049d066905c848b3b521ff4e7c1ed552

6. Insights from hosted virtual Workshop

The purpose of the workshop was to share information and results from the INSTRUCT project and, discuss and corroborate our findings on energy efficiency and training in the construction sectorwith experts from across Europe. The participants represented a mixed and interdisciplinary group drawn from 8 different European countries, from national and international organisations in the private and public sector.

The salient outcomes from the research were presented and discussed during the first part of the workshop. Firstly, the project aims, and objectives were addressed, followed by a presentation of theinterview and questionnaire results. The final part of the workshop provided an opportunity for opendiscussion around 5 proposed themes. The themes were selected with a view to gathering inputs, based on participants' experiences, on the current state of training on energy efficiency for the construction sector, what could be strengthened, changed or implemented to improve such training in the future. A series of recommendations captured in the report emerged from the discussions of theworkshop and are presented in the following sections.

6.2 Key insights from the workshop

Workshop participants were presented with 5 themes and encouraged to share their views amongstthe group. The themes discussed were:

- Lack of access to useful information, knowledge, and best practice guides for energy efficientinterventions.
- Lack of demand for skilled workforce in energy efficiency.
- Lack of availability, or inadequate, training programs (in terms of scope, quality, content, costs,etc.).
- Lack of shared vision and values for energy efficiency across the supply chain.
- Inadequate policy landscape, including lack of government incentives.

The following section summarises the key insights derived from the workshop discussions. The detailed insights are presented in the Appendixes (10.4).

Lack of access to useful information, knowledge, and best practice guides for energy efficient interventions.

Participants suggested that the lack of access to useful information is not necessarily the issue at this stage, but rather demand is the more important issue. Without demand there will inevitably be a lackof access, and so the two go hand in hand.

Participants suggested that there is an abundance of information, knowledge, and best practice guides, however, targeted trainings etc. are more likely to be absorbed by the worker, as they are learning skills directly relating to their role. It was suggested that a better understanding of these skills will leadto confidence in applying it in practice.

Lack of demand for skilled workforce in energy efficiency.

During the discussion, it was suggested that there is a lack of demand for a skilled workforce. With many companies facing time, resource, and financial constraints, the priority seems to be to 'get the job done' as opposed to creating a more sustainable building. Another factor to consider, is that energyefficient buildings require a skilled workforce, and as suggested by participant 4, whilst there are plentyof workers available, not all of them have the skills to carry out energy efficiency; therefore some companies striving for energy efficient buildings are facing challenges and shortages when trying to recruit capable workers. The consensus from the participants was that demand for skilled workers is likely to increase when clients demands for energy efficient buildings also increases. As suggested by participant 5, clients demands are likely to change when legislation, such as tax incentives, are introduced.

Lack of availability, or inadequate, training programs (in terms of scope, quality, content, costs, etc.). The workshop participants agreed that a lack of training mateirals is not the issue, there is however a lack of relevant training for the workforce. This appears to be a European wide issue, according to partcipant 3. The training needs of blue-collar workers are not being met and there should be a focus on on-site training. It was highlighted that training for blue-collar workers should be practical and relevant to their role. For such an approach to be adopted, company directors, site managers etc. would have to want their workforce to adapt and learn new skills, because without their approval suchan initiative would not be viable.

Lack of shared vision and values for energy efficiency across the supply chain.

The overall message recieved from particpants was that raising awareness for energy efficiency shouldbe a priorty. Whether it is through legislation or campaigns, the importance of energy efficiency needsto be emphasised. A common approach to energy efficiency must be adopted throughout the supply chain, and it is thought that this can only happen when legislation changes. For example, Finland's lowcarbon targets have put pressure on all industries to operate more sustainably and so it will be interesting to see if this shared vision will have a positive impact on the adoption of energy efficiency in the construction sector, and whether it will bring about a change in training the workforce.

Inadequate policy landscape, including lack of government incentives.

The main message from this theme was that support from the government is essential for any real changes to happen. Whilst there are many initiatives for energy efficiency across Europe, it is rare thatthese will ever gain traction without political power behind it. Energy efficiency starts at the top, withthe Government, and this appears to be a European wide issue. Some participants advised how their country is looking at what works well in other countries and evaluating how it can be adapted to theircountry. More communication amongst countries is required to share energy efficiency instruments, best practice etc. and to improve the policy landscape.

7. Discussion

7.1 Introduction

The discussion section is structured according to the 5 themes as presented in the section.These are:
Lack of access to useful information, knowledge, and best practice guides for energy efficientinterventions.
Lack of demand for skilled workforce in energy efficiency.
Lack of availability, or inadequate, training programs (in terms of scope, quality, content, cost,etc.).
Lack of shared vision and values for energy efficiency across the supply chain.
Inadequate policy landscape, including lack of government incentives.
The analysis aims at the triangulation of the different data collected (interviews, questionnaires, insights from the workshop, insights from the literature review). These are brought forth, combined, and correlated below to create a synthesis for a coherent argument that aims to highlight and establishconnections for the specifics of the questions that the study has posed.

Lack of access to useful information, knowledge, and best practice guides for energy efficientinterventions.

In the literature review, it was highlighted by recent studies how the lack of training is currently one of the most significant challenges in the effort towards a sustainable future (Shapiro, 2016). In the construction sector, the importance of training has also emerged as a critical element towards energyefficiency, on a global level (Aerschot et al., 2009). In this spirit, strategies such as increasing access to on-job training, has been pointed out as significant towards the effort of improving the landscape of training for energy efficiency (Rezgui, 2020). These observations seem to point at the fact that: (a) on one hand there is a need to increase our efforts towards the dissemination of knowledge in the field of energy efficiency and (b) at the moment there are issues of access to information, lack of awareness, and, in general, not a very systematic effort towards education in the field. The results from the questionnaire may give us some data towards this direction. For example, to Question 23 (Q23) of the questionnaire (Have you ever received any training concerning energy efficiency in the construction sector?) a significant portion of the sample (34.15%) lacked this type of training. As argued in the results analysis, this shows there is a significant gap and space for improvement in this area. On the other hand, when in Q20 participants were asked to comment on whether they had been involved in any way with knowledge and experience sharing for energy efficiency in the construction sector, 61.90% answered with “yes”. This could be said to show how there is a certain awareness of initiatives that are available to promote training. One observation thatneeds to be made here, however, is that a vast majority of respondents were white-collar workers. Inthis sense, one might argue that the sample perhaps belongs to a group of people who are mostly likely to come across such initiatives, either in the context of academic conferences, part of their job (e.g trainer, researcher, educator) and/or due to their work networking circle which is likely to promotethese programs. In fact, when participants asked in Q19 to present their opinions with regards to whether the focus placed on training is sufficient, in general, the majority replied with a negative response, and many of them clarified with remarks about how the awareness and focus in not sufficient, thus indicating that the gap is indeed present. For example, in Q10 out of the sample of respondents that replied, there was an almost evenly spread of responses between “yes” and “no” tothe question of whether they are aware of the BUILD UP Skills initiative. This could be argued to showthat initiatives that promote training, even if they are on a larger scale (e.g in this case European) arestill not being at the centre of our attention. The majority of those who replied to Q11 about whetherthere should be more initiatives like the BUILD UP Skills, replied with “yes”. This, as suggested in the results section, could be argued to highlight not only the need to have such programs, but that this need is currently deeply felt by the workforce. Further to this, in Q15, when participants were asked to provide with some recommendations within their organisation, “adequate promotion of training” received 50.00%, while 50.00% highlighted that it is crucial to “raise awareness for the need of trainingfor energy efficiency". Recommendations to the same question, but in the context of the industry (Q16), also resulted in 46.81% of participants saying that there needs to be more focus on an adequate promotion of training. Also, 29.79% of participants argued how there needs to be a supportive attitude towards any initiative that promote awareness in the field. Furthermore, "not enough and proper information and awareness" emerged as one of the most selected barrier in the context of their organisation (Q6), while in the context of the industry (Q7) the results showed a similar insight. "Not-environmental friendly procedures" and "not enough facilities of training" were lower in the replies, however they were also chosen as barriers in both contexts, for Q6 and Q7.

The interviewing process highlighted some very similar issues. When asked about market challenges (Q19), 5 out of 28 interviewees brought up some level of lack of awareness, knowledge and experiencesharing in the industry. As with regards to barriers for training for energy efficiency in the construction sector (Q4), "training & knowledge not sufficient", and "access to training" were chose by 8 interviewees (6 & 2 respectively). To Q9 about whether the importance for energy efficiency skills in the construction sector is being taken into consideration adequately, the vast majority (20 out of 28 interviewees) replied with a negative answer. In Q21, interviewees were asked to provide their opinionon whether the BUILD UP Skills been successful, and only approximately half of the sample was awareof it (out of those who were almost everyone suggested that it was-indeed-successful). One thing emerging from the interviews, in the context of the question this subchapter explores, is that, as withthe questionnaire an unquestionable need for more awareness, access to information, dissemination of knowledge and knowledge sharing is required. When further looking into this question/theme, with the group of workshop participants, some observations emerged from the fruitful discussion. Overall, the participants that engaged with the questions suggested that that the lack of access is not necessarily the issue at this stage, but rather demand is the more important issue, as well as how well the need for training is communicated, and how much motivation to undertake training plays a role. One participant explained that without demand there will inevitably be a lack of access, and so the two go hand in hand. In their opinion, whilst clients are happy to consider energy efficient options, delivering energy efficient buildings is never a major priority, or an option that construction workers are pushing for. Further to that, and despite a plethora of information about the issue, this content seems to remain the margins of interest, when the demand for energy efficiency is not high enough to stimulate significant actions towards training. Similarly, another participant suggested that there is an abundance of information, knowledge, and best practice guides. There is a responsibility to guide blue collars and advise them ontrainings/ programmes that are relevant for the person in that role. Targeted trainings etc. are more likely to be absorbed by the worker, as they are learning skills directly related to their role. A better understanding of these skills will lead to confidence in applying it in practice. Lastly, a third participantargued, along the lines of the first two, how there is an abundance of information etc. From working on projects that involve construction workers, they noticed that it has been quite challenging to stimulate demand for training programmes, for example, they experienced problems with motivatingstakeholders to access materials. It was suggested that they need to draw a comparison between qualified workers involved in the best practice cases and what happens without qualified workers working on site. There is a need to develop awareness of the various end user groups.

To summarise, and from the analysis of the data that was collected and analysed, it could be said thatcertain significant observations emerge. To begin with, the multiple sources of data confirm that thereis indeed an issue with regards to the dissemination of knowledge in the field. The overall awareness needs to be improved and the expansion of the field of training for energy efficiency is of utmost importance. However, what is currently missing is a consistent understanding, across the sector, aboutthe importance of energy efficiency and the demand that will motivate to place more focus on the issue and to facilitate access to knowledge. It, therefore, seems that even though the information is present, training is available, and initiatives for training are taking place what needs to significantly improve is the overall culture about educating professionals on energy efficiency in the construction sector. Discrepancies seem to appear when it comes to establishing an ongoing, fervent climate in the construction sector that will bring training at the centre of these efforts. This leads us into the next theme/subchapter of this analysis, which tackles with the issue of demand, in more detail.

Lack of demand for skilled workforce in energy efficiency.

The literature has pointed to a landscape of efforts in different countries aiming at a substantial increase in skilled workers. However, this does not always result in results which sufficiently tackle with the issue, and it has been pointed out how more effort needs to be integrated into that endeavour(Larionov and Nezhnikova, 2016). Further to that there needs to be an approach which closely focuses of the various needs of the groups of workers within the sector (CEDEFOP, 2013). It has also been pointed out that a more focused demand for energy efficiency will lead to the increase of the need oftraining of workers, which is currently one of the challenges (European Commission, 2016). The BUILDUP Skills initiative in Europe has also pointed out how one of the most critical barriers, in terms of themarket, is the “low demand for energy efficient buildings and thus for the skills required to build them”(European Commission, 2018).

From the questionnaires, several observations emerged, which point at the issue of demand connected to the workforce. When asked to describe the barriers that are present in their organisation (Q6) and in the construction sector (Q7), 25.00 % and 25.00% people respectively replied with “the challenge of creating more demand for energy efficiency”. 19.23% and 21.15% of participants chose “inadequate understanding of the importance of a skilled workforce”, 15.38% and 25.00% highlighted the “lack of trained manpower/staff” as another barrier. “Differences in competences of trainees” also came up as barriers with 3.85% and 7.69% respectively. Lastly, to Q7 the barriers of “not enough experience and lack of expertise in energy efficiency technology” emerged with 25.00%, as well as the challenge of replacing a retiring workforce, with 11.54%. These observations,in accordance with the literature, show that training the workforce and issues of demand around it, isat the heart of the concerns at the moment, when it comes to energy efficiency. Some implications were linked with financial aspects of training, as presented in Q22 included such as “difficulty in finding and training the required workforce”, according to a large number of respondents suggested (50.00%).These data point towards a strong link between costs and the training of the workforce, which cannotbe ignored, and needs to be more closely looked into. Further to that, in Q27, Q28, Q29, and Q30 where issues of inclusion and integration of several vulnerable to exclusion groups were touched on, it became apparent how the reply of an “excellent” inclusion was consistently the option with less answers. This could be argued that shows that a more nuanced approach, which focuses more on theneeds of the workforce, is required. This could benefit, not only the workers but also the industry, in terms of demand for training, by securing a more appealing and comprehensive sectors that offers incentives for further training and facilitates this process. It could be therefore be argued that the focusneeds to be further intensified in this direction.

During the interviewing process, some similar observations emerged, with regards to demand. When asked about market challenges concerning economic changes and demand, 2 interviewees highlightedthe level of demand, as being significant. When asked about barriers (Q4), 2 interviewees again, highlighted lack of demand as one them. In Q5 (What can be done, in your opinion, to increase demandfor energy efficiency, in the construction sector?) most interviewees replied with some type of mentionto the importance of awareness and training, as well as the crucial role of legislations. However, and on a more positive note, when asked to provide their opinion on the level of demand for energy efficiency training (Q8), 10 of them replied with “insufficient”, yet 16 presented a positive picture. Thisreaction could point to different contexts, countries, and perhaps also to the fact that there is not a coherent landscape with regards to demand for skilled workforce overall in the industry. Participants also expressed their perception around the skills that are needed in the new energy efficiencytechnologies, in their field, with “awareness & knowledge of the worker” emerging as the most significant. On another note, when participants were asked to comment on whether energy efficiencyin the construction sector contributes to a vision of long-term employment, 22 out of 28 participants replied that it does, which could be argued to demonstrate the power of training in attracting more people in the field and establishing training for energy efficiency as a significant factor in the field.

During the workshop, some significant observations emerged as well. To begin with, as highlighted previously in the interviews, in some contexts there is a high demand of workforce. For example, in Finland, this happens to such a degree that high demand for workforce is overpowering the quality for workforce. However, this deemed to be counterproductive to producing energy efficient buildings. It was argued how companies should be shown the correlation between a skilled workforce and the quality of the building. Seeing that comparison could empower them to make more informed decisions. This could lead to employing more skilled workers or motivating workers to undertake moretraining/development. Companies need to value the importance of upskilling workers, and to not see it as a drain on time/ finances. Another participant argued how when looking at entrepreneurs, the abundance of work and viscosity of workforce has led to companies doing the same things, instead ofinnovating and adapting to tackle new markets. This will not change until the clients demand change.Until that point, companies will continue to do the same processes with the same workforce, as they do not have the capacity to invest in upskilling (at least until they are required/ pressured to do so). Itwas also argued how a skilled workforce is desirable but sometimes difficult to access. In addition to that, one participant argued how demand for skilled workforce and legislation are interlinked. Lookingat Italy, it appears that the introduction of energy incentives has created a demand for energy efficiency in domestic buildings. This demand will inevitably lead to the requirement for skilled workersin energy efficiency. Financial/tax incentives appear to be successful motivators for increasing the demand of energy efficiency in the construction sector. Another participant highlighted how the workforce in Serbia is practicing outdated processes and this must change. A construction cluster in Serbia has designed a dual system of non-formal education that consists of vocational and education trainings. The training programme provides ICT tools that are relevant for that worker. The adoption of artificial intelligence, ICT tools etc. can be used as a contributor/ instrument to deliver a skilled workforce for energy efficiency. Further to that, it was highlighted that in Serbia, non-formal training would be a method worth exploring when considering new materials, energy efficiency, renewable energy sources etc. One point that did not rise from this, is whether non-formal training would lead toan accreditation. This last issue will be analysed further in the next theme/subchapter, concerning thequality and type of trainings.From the above observations, it seems that demand is a field dependent on many variables, and not an easy one to fully grasp or to untangle. The results from the data seem to confirm the initial statements and the evidence from the literature which suggest that demand for energy efficiency andenergy efficiency skills remains a crucial issue for the market and the sector. Some possible suggestionshave been proposed, as solutions, as analysed above and in the Results section of the study. However,as a general observation, it could be argued that demand is highly dependent not only on the context,fluctuating from geographical region to geographical region, but most importantly on the focus that isplaced on energy efficiency in the construction sector, which goes back to deeper and more structural issues of general awareness about the issue, and therefore is dependent on where priorities on all levels of stakeholders are set.

Lack of availability or inadequate training programmes (in terms of scope, quality, content, cost etc.)

The literature has pointed towards the importance of examining the quality of training programs and carefully reflect on the needs of the workforce, which are quite critical (Levine et al., 2012). The flexibility of programs, and the constant update of their potential and quality is recognised as significant in this endeavour (Milovanović et al., 2019). As highlighted by the BUILD UP Skills initiatives,it is quite urgent to place importance on the function of the worker, and not only their qualifications (European Commission, 2016). It has also been argued how the coordination and management of bestpractices plays a major role, and that successful initiatives offer a blueprint, in terms of precedents (Rezgui, 2020). Further to that studies have shown the importance of finetuning and constantly improving the content of the trainings, which sometimes end up being generic and fragmented. The BUILD UP Skills has also included characteristics of training, such as economic barriers, connected to lack of time for training and cost for training, as well as language, lack of facilities, and generally knowledge, as barriers which are at the centre of the challenges that are present in the development of training for energy efficiency in the field (European Commission, 2018). These barriers, which are highly dependent on the workforce and on the dynamics of communication between different stakeholders in the field will be discussed below.

The questionnaire has pointed towards several important findings, with regards to the adequacy of how the training are structured. In Q26, concerning the training of trainers and answering the question of whether it is considered sufficient, the vast majority of respondents argued that it is sufficient, whichis a positive outcome. Further to that, in

Q25, which asked respondents to elaborate on whether the training they had received was sufficient in terms of detail, duration, and other characteristics, the replies also presented a rather positive perspective, as the majority of respondents were satisfied withthe quality they had received. From Q24, that looked into the type of training material used, as it wasoverall suggested by the findings in the Results section, a vast majority of trainings combine different mediums of dissemination of the education, which is also a positive sign, and in the same direction- the update and constant development of the material.Other significant observations, in terms of barriers both within the organisation (Q6) and the industry (Q7) include respectively: “Cost of training for energy efficiency” (17.31%) & (23.08%) “Inadequate number and quality of training programs” (13.46%) & (11.54%) “Non-realistic & non-flexible timeframes for training” (11.54%) & (11.54%), as well “not enough time for training” (46.15%), (Q6) and “inadequate understanding of the importance of a skilled workforce (21.15%) (Q7). From these barriers, several barriers belong in the category of the quality and adequacy of training programs. Thisdata could be argued to point to a correlation and a suggestion that there is room for improvement, in this regard. As for some suggestions that were put forth to enhance training, as presented again within the context of the organisation, as well as within the context of the industry, the following are quite significant and common in both (Q15) & (Q16) respectively:

- “Training taking place in specific periods” (31.25%) & (31.91%)
- “Adequate promotion of training” (50.00) & (46.81%)
- “Make sure all parties and stakeholders involved are integrated in the process of developing trainingprograms, from the start” (41.67%) & (44.68)
- “Make sure training is flexible and adjusts to the needs of those who undertake it” (62.50%) &
- (53.19%)
- “Make sure training has a significant practical contribution for those involved” (43.75%) & (61.70%)
- “Raise awareness for the need for training in energy efficiency” (50.00%) & (53.19 %)
- “Make sure certain parts of training are made core elements of curricula” (22.92%) & (25.53%)
- “Make sure there is recognition/qualifications for the training undertaken” (31.25%) & (36.17%)
- “Establish support for funding initiatives that support training” (20.83%) & (29.79%)
- “Demand more ambitious results” (25.00%) & (25.53%)
- “Make sure there are mandatory courses for construction workers” (31.25%) & (34.04%) “Have a sense of responsibility for the future impact of the training” (16.67%) & (21.28%)
- “Build up a database of companies involved in training” (25.53%) for Q16-industry context
- “Make sure training and educational programs involved in energy efficiency are integrated in
- national frameworks” (34.04%) for Q16-industry context
- “Update relevant policies” (31.91%) for Q16-industry context.

From the above suggestions, it becomes evident how many layers of action need to be taken into consideration, to improve the quality of training. Raising awareness and the promotion of training, aswell as the flexibility of its structure to benefit those who undertake it, in combination with resulting in tangible benefits/practical contributions for them, are of utmost importance. The interviews also moved in a similar trajectory in terms of issues that were highlighted connected totraining for energy efficiency, and the efficiency of the relevant programs. As stated in the Results section, with regards to barriers, it could be argued that the data analysis points to the quality and breadth of training & education as being at the top of concerns. The majority of interviewees suggestedthat training as it is at the moment is not effective as it should, pointing at awareness issues, and lackof skills in the field and education. Lack of time also emerged as one of the most important barriers. To confirm that, Q10 (Is the focus placed on training for energy efficiency sufficient? Please elaborate on your opinion?) received an overwhelming number of negative responses (20 out of 28 interviewees). However, as demonstrated in the Results section, 21 out of 28 could give specific examples of successful trainings in the field. Furthermore, as demonstrated in the analysis for Q14 - which asked how comprehensive the training material they were familiar with is- a significant numberindicated they were satisfied (16 interviewees). These findings could point towards the fact that what is needed at the moment, is a careful documentation and study of successful cases, the barriers and suggestions, so as to come up with a framework of coordinated proposed action that tackles with all the different factors of these complex relations in the field. Also, interviewees were asked to commenton whether previous knowledge and informal learning and training are properly integrated (Q15). To this question, responses were split, with some suggesting that these two are independent, while in other cases arguing that they are quite significant, and in many cases suggesting that they are not integrated or taken into account as they should. It could be argued, once again, that aspects of traininglike this could be relevant based on the needs and contexts. As suggested in the previous subchapter,in the analysis of the workshop, in certain cases it could be a viable option and a valuable resource. Inany case, it is argued that such aspects could perhaps be examined and taken into account, by examining the positive and negative aspects and applying them to the appropriate context. Lastly, to the question of whether training programs develop synergies between academic and vocational training (Q18), the connection seem frail, with the majority of interviewees suggesting that there is not enough attention paid to the issue, but arguing that there should be. Insights from the workshop point to a similar direction. As argued by one participant, there seem to be a lot of training programmes available, however they are all very similar in content, quality, and theory. These trainings do not meet the needs of the workforce. In the Netherlands there is a lack of relevant trainings for construction workers. Whilst there are many training programmes available, the training must be less theory based and more practical for the craftsmen. Training for blue-collar workers should be on the job, to make that training as relevant as possible to that role. This opinion was shared by another participant as well, who, however, raised an issue around on the job training. Lack of time emerged as a major factor that must be considered. Could this be overcome by providingtraining on the construction site, during the working day? It was thought that this would be the best approach, as you have a captivated audience. Another question that arose was with regards to the manner that training is provided. Ultimately, the company director, site manager etc. must want theirworkforce to adapt and learn new skills for this method to work, because without their approval suchan initiative would never take off. Another participant suggested that suggested that a lack ofavailability or adequate training programmes is a European wide problem. Further to this, the first participant who commented on the conversation, said they are working on a project that addresses onthe job training and produces a task-based qualification. One challenge that arose from the research, is that workers were not rewarded for learning on the job. The research is looking at ways to reward workers for performing high quality work on the job. It was further elaborated by other participants, how incentive-based systems would be of value.

From the above correlations of data, the lack of availability or the inadequacy of training programs seems to emerge as a significant issue. On the positive side of things, it is significant that progress hasbeen made, and we are at a level of being able to assess the quality of training programs and their results within in a long-term framework. However, it could be argued that there is a long way ahead, and that there is a wide variety of factors and equilibriums that need to be looked into much more closely, and in detail, as suggested by the data collected.

Lack of shared vision and values for energy efficiency across the supply chain

The literature pointed at how the industry presents a rather fragmented nature, when it comes to shared values and vision (Rezgui & Miles, 2011), (Chaudhary et al. (2012). Furthermore, due to the many levels of stakeholders in the supply chain it was argued that there needs to be much more coordination (Richards et al., 2016) (Geros et al., 2006), (Bosch González et al., 2013).

The findings from the questionnaires seem to point in a similar direction. When describing the overallsituation with regards to the state of knowledge and experience sharing within the organisation that the participants worked in (Q8) and within the industry (Q9) there was a high contrast. When speakingabout their own organisation, most participants presented a positive outlook. However, when extending the argument towards the industry, less participants suggested that the level of knowledgeand experience sharing was at a very fully satisfactory level. This could be argued to be due to the much more complex nature of the industry as well as the many types or relations and conflicts that are at play within this broader context. Further to that, when participants were asked to comment on thelevel/scale that the results of training for energy efficiency were perceived (Q18), the majoritycommented on how the results were mostly let on national and local scale. Moreover, most participants highlighted and agreed on the fact training for energy efficiency can benefit the world onmultiple levels (environmental, societal, and economic level). Overall, these results could indicate that,on one hand there is an understanding and common agreement on the value of training for energy efficiency, however, on the other hand and in reality and practice, these values seem to get lost in themidst of conflicting interests and other factors, in the construction sector.

For example, when asked to comment on barriers, both on a organisational level (Q6) as well as the level of the industry (Q7), interesting relevant suggestions came up, respectively: "Financial/funding issues" (50.00%) & (42.31%), "financial concerns and insecurities about the future that hinder investments in the field" (19.23%) & (23.08%), "resistance to change" (21.15%) & (34.62%), "not enough interest in the field" (5.77%) & (30.77%), "incongruence of values between sectors and layers of stakeholders involved in theconstruction industry" (19.23%) for Q7, were among some of the factors that were highlighted, thus presenting a rather adversarial outlook of how the construction sector works. The financial factor seems to be at the forefront of concerns, and in addition to that, a resistance to change was also highlighted as a significant barrier in both contexts.

Similarly, the interviews pointed at the same tendencies. When asked to present barriers, the barrier regarding the "state of the industry and issuesof coordination between stakeholders" was suggested by 5 out of 28 interviewees. When answering to the questions with regards to the knowledge and experience sharing in the organisation and the industry respectively (Q6) & (Q7) a stark contrast emerged. Whilst within the context of organisations,22 out of 28 argued that the level was good, when extending the question to the industry, only 4 out of 28 thought the same. Several conflicts were analysed and proposed as well as solutions to improvethe situation, as argued in the Discussion section. However, what is significant to keep in mind is the shared discontent concerning the way that the construction sector is operating. On the other hand, when answering question Q3 (How does training and skill development in the construction sector contribute to the increasing need for environmental awareness, in our societies?) the vast majority ofinterviewees (25 out of 28) suggested that it does indeed contribute. This could be argued to show, beyond differences and conflicts, and the fragmented nature of the industry, that there is an underlying common value (environmental awareness) recognised by most.

Within the context of the workshop some similar observations emerged. According to one participant,all industries in Finland have recently formulated carbon neutral roadmaps for 2030 – 2050. The participant suggested that they were interested in looking into the roadmaps to see if they have considered energy efficiency at a workforce level, to ensure carbon neutrality throughout the whole value chain. Their argument was that in the construction industry, addressing low carbon and carbon neutrality must start with the workforce. Finland's low carbon targets have put pressure on all industries to operate more sustainably and so it will be interesting to see if this shared vision will havea positive impact on the adoption of energy efficiency in the construction sector, and whether it will bring about a change in training the workforce.

Furthermore, raising awareness was hailed as a priority. The more pressure and demand industries seefor energy efficiency, the more likely it is to be adopted across the supply chain. Serbia has introducedenergy passports as a step to achieve a shared vision for sustainability, carbon neutrality etc. However,it is felt that this is just a small step and much more needs to be done. The shared vision is not isolatedto just the construction sector. Other sectors are also involved throughout the supply chain. And so, to become truly energy efficient all the sectors involved must behave in the same way and share the same vision for energy efficiency. Whilst low carbon targets are well intended, they are also useless unless there are defined mechanisms/ responsible parties to put it in to practice. Comments from another participant also suggest that a common approach to energy efficiency must be adopted throughout the supply chain. There is a need to raise awareness, this can be done through communication campaigns. Lastly, one participant highlighted that there are some regulations in Italythat are increasing the demand for energy efficiency. Admittedly, whilst this is not at the level it shouldbe, it is still much better than it was 10 years ago. In Italy, a lot of companies are moving towards energy efficient processes as legislation is also moving in that direction.

Overall, there seems to be a common thread among all the data collected, which points towards the need to coordinate the industry in such a manner that the importance of training for energy efficiencybecomes a strong and shared value and a starting point of actions and initiatives.

Inadequate policy landscape, including lack of government incentives

The literature points to policies and legislations being a crucial element, for both envisioning and pushing forward changes with regards to future targets (Ministry of Energy, 2016), and also in terms of coordinating actions and creating the necessary and much needed legislative frameworks to make sure these goals are supported (Li and Yao, 2009). This element was particularly highlighted by the BUILD UP Skills initiative, and laid out as detailed suggestions to the European Commission (EuropeanCommission, 2018).

The questionnaire analysis of data has brought forth several issues around the policy landscape. For example, in Q13 with regards to the importance of energy efficiency training being taken into consideration in the EU, as much as it should, the responses demonstrated that the overall perceptionaround the matter do not create a coherent argument pointing in favour of either one or the other direction. To Q14 (which included the same question, but on a national level), most respondents (56.25%) stated that the importance of energy efficiency training is not being taken into considerationsufficiently. Further to that some suggestions related to ways of enhancing skills and training in the construction industry included: “Make sure training and educational programs involved in energy efficiency are integrated in national frameworks” (34.04%), and “update relevant policies” (31.91%). With regards to barriers that hinder training for energy efficiency, and are present in the organisations(Q6) and the construction industry (Q7), respectively, a number of relevant barriers concerning policiesand legislations was presented: “Procedural barriers” (9.62%) & (15.38%), “lack of government incentives” (23.08%) & (30.77%), “inadequate policies and legislations” (19.23%) for Q7. What becomes apparent from the above remarks is that the significance of legislation is being perceived byvarious levels of stakeholders in the industry.

In the interviews, legislation, policies and regulation issues emerged as one of the market challenges (Q19), while when interviewees were asked to comment on barriers for training for energy efficiency in the construction sector, legislation and regulation issues were among the most frequently mentioned barriers (5 out of 28 interviewees). Moreover, in Q17 interviewees were asked to commenton policies & legislation, and how effectively they believe they integrate training (e.g the European Green Deal, which focuses on making EU’s economy sustainable and EU climate neutral by 2050). Theresponses were quit revealing, in the sense that 16 interviewees argued that there is not an efficient link between the two, while arguing for its importance. Also, to Q20 (Have any aspects/insights of thetraining that you have been involved with been included into national strategies?), 9 respondents couldfind some aspect of the training being integrated, while 7 did not. Overall these replies indicate that the field of training for energy efficiency needs to be significantly improved in terms of legislative actions, assisting with the smooth implementation of common values, and contribution to a clearer vision/motivation for the education of the workforce, too. Further to that, and with regards to incentives and motivations, to Q16 (Does completing training result in any formal (e.g. accredited) qualification? Do these qualifications increase employability?) a significant number of interviewees argued that it does (16 out of 28) and 13 suggested they also increase employability. This is rather significant, as it could be argued that with the appropriate tools to motivate the professionals and provide a regulatory framework which supports the workforce, the landscape of training for energy efficiency in the construction sector could greatly improve.

The workshop provided relevant observations. The main message from this theme was that support from the government is a necessity in order for any real changes to happen. Whilst there are many initiatives for energy efficiency across Europe, it is rare that these will ever gain traction without political power behind it. Energy efficiency starts at the top, with the Government. This is a Europeanwide issue. The policy landscape varies depending on the countries priorities. There are some countries that might not advocate an energy efficiency agenda, and so we will see less of a push/demand for such policies. One participant argued that it is difficult to get anything considered within the political landscape. Government and policy are more likely to change when there is a pushfrom industry. For example, the National Digital Twin programme. It was suggested that ideally thereshould be something in the policy landscape that would allow for construction experts to mandate these things. It was also highlighted how energy efficiency is not considered widely enough in the UK. You often see energy efficiency training in terms of buildings and energy performance, but it is not considered with highway, rail schemes etc. even though they also contribute significantly to the energy efficiency of the country. Another participant stated that many initiatives/ projects have collected information on the policy landscape across Europe and their governmental initiatives. They suggested that the information should be shared amongst countries, to see if they can adopt any of the practices/initiatives/incentives from other countries. Finland has been given very stringent carbon neutral targets to reach by 2035 and so this has created more demand for energy efficiency across the supply chain. The country is developing its own national built environment digital twin. So,the policy landscape is not inadequate but there is still a lot more to be done. It seems that Finland islooking at what works well in other countries and evaluating how it can be adapted to their country, whilst achieving better results in a shorter timeframe. Maybe more communication amongst countries is required to share energy efficiency instruments, best practice etc. and to improve the policy landscape.

Overall, it could be argued that an inadequate policy landscape is a reality affecting the sector in various ways and on several levels. The data suggests that there is a need for further improvement ofthe efforts on both a European as well as a national levels and efficient strategies need to be found, towards this direction, as well as collaborative schemes.

8. Conclusion

To summarise the trajectory of this study, the research followed the steps as set out in the methodology section, in order to explore the connection between energy efficiency and training.

With regards to limitations, it needs to be stated that the sample of Questionnaires was smaller than initiallyplanned (33).

Overall, the two objectives that the study have been reached. These were:

A desk review to collect, organize and synthesize available evidence from authoritative sources across Europe and beyond. The review included both existing practices but also legislative frameworks.

The desk review fed into a series of consultations with key stakeholders, including BUILD UP Skills initiative key representatives across Europe, with a view of reinforcing the gathered evidence withfurther cases drawn from industry and practice.

The results section confirms that there is a thread running through the data collected as analysed in the five main areas of exploration, which highlights training for energy efficiency as a critical component. To conclude, based on the hypothesis that has been posited at the beginning of the studyand as elaborated in the Discussion section, it can be argued that the statement stands: Quality trainingcan, indeed, have a positive impact on energy efficiency in the construction sector and can contributeto sustainable interventions in the construction sector. The gathered evidence can be summarized bystages as elaborated below:

Inception Stage

Blue Collars

- Site geotechnics teams selected with the right skills and competencies, including from anenvironmental impact perspective.

White Collars

- Brief embeds energy performance targets.
- Consider interventions that best deliver energy performance targets.
- Site appraisal for environmental impact mitigation.
- Project Business case considers environmental impacts.
- Sustainability outcomes clearly articulated.
- Compliance with energy building regulation duly considered.
- Feasibility study environmentally proofed.
- Procurement strategy for recycling and re-use considered.
- Project information requirements embeds environmental considerations.
- Delivery of a performance-based brief.

Design Stage

White Collars

- Design options analysed through lifecycle impact assessment.
- Passive architectural design principles considered and retained.
- Integrated multi-disciplinary low carbon design considered.
- Adoption of a BIM-based information delivery approach.
- Specialist design options that best deliver energy performance targets retained.
- Continuous design review against Building Regulations.
- Lifecycle impact of structural design considered and optimized.
- Lifecycle impact of MEP (Mechanical, Electrical and Plumbing) interventions considered andoptimized.
- Material procurement strategy considered from an environmental impact perspective.

- Building Manuals clearly drafted highlighting environmental aspects.
- Detailed design complies with energy Building regulations and meets Low / Net-zero carbontargets.

Construction Stage

Blue Collars

- Construction site managers selected with the right skills and competencies.
- Blue collars selected with the right skills and competencies.
- Blue collars continuously briefed about best practice in relation to their project tasks.
- Building information accurate and widely available to blue collars.
- Building manuals widely accessible to all blue collars, including on portable devices.
- Interfaces between Work Packages rigorously managed.
- Compliance with design specification conducted systematically.
- Rectify defects as they occur and reported.

White Collars

- Site logistics and planning optimized to minimize environmental impacts.
- Low carbon materials and products procured.
- Rigorous compliance with construction planning conditions.
- Continuous quality site inspection.
- Commissioning strategy discussed and firmed-up.
- Review of project performance rigorously conducted and evidenced.
- Post occupancy evaluation strategy discussed and firmed-up.

In-use Stage

Blue Collars

- Monitor and inspect HVAC system components on a continuous basis.
- Detect and rectify malfunctions as soon as they occur.

White Collars

- Facility management strategy critically reviewed and agreed.
- Monitor the energy performance of the building on a continuous and real-time basis.
- Continuously reduce and eliminate the gap between predicted and actual energyperformance.
- Implement a continuous commissioning strategy to identify malfunctions and defects.
- Conduct actionable (dynamic and real-time) post occupancy evaluation.
- Review of project performance rigorously conducted and evidenced.

Finally, the results obtained through this study point to a number of policy measures, including theneed for adapted instruments to promote **mutual recognition of energy skills and qualifications** in the European construction sector. This is being addressed in follow-on work of the H2020 INSTRUCTproject.

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10. Appendix

10.1 Workshop Transcripts

INSTRUCT Workshop
30 October 2020

Workshop Discussions

Q1. Lack of access to useful information, knowledge, and best practice guides for energy efficient interventions.

Convenor – any opinions/ any ideas?

Participant 1 –If there is a lack of demand, there will invariably be a lack of access, because if something is not considered profitable no one will bother going after it. For example, in BIM if you started talking about it in 2006 in the academic sphere it would have had a lot of interest (as academia is always further ahead than industry is) but industry itself was only warming up to the idea of BIM. So, companies were not suggesting that they should develop technology spin outs, training programmes, university programmes, vocational programmes around it. Fast forward to today, and everybody is doing it. The access is almost in some cases too much, so you do not know what one to go to. And in some way, I feel this is almost true with energy efficiency; and appreciate that there's quite a heavy push to energy efficiency in specific areas of the construction sector (such as buildings, perhaps not so much in general infrastructure, such as transportation schemes) but because of the way clients – the amount of demand they have on keeping to programme, keeping to cost – because of the demand on that and less so on the efficiency for things outside of the building spaces, it can be quite an issue with regards to different groups wanting to set up or provide access to information. So there probably is a plethora of information that could be made available but, in my opinion, it's just not warranted because the people who should be pushing solutions, that should be energy efficient, are not pressing hard enough for it. And so perhaps as the policy landscape is changing in the coming months and years maybe that is due to change too, as well. So, I think in some way question one can be answered when question two and five are answered. I think everyone will do it when there is a demand for it. So, I would not be too worried about it from an excess perspective. I will give you an example again, I graduated from University in 2012 doing civil engineering, energy efficiency was very much pushed through what we were taught. However, once I went into industry it was a case of "that is very nice can you deliver to budget and cost"? And the whole life consideration and energy efficiency was not really (admittedly I was a highways engineer when I was doing engineering, so that weas perhaps one of the issues) but it was not considered a huge aspect. If you challenged a client on it, of course they would be willing to consider it, but it was never something they were pushing for.

Participant 2 – I would like to come in from another point of perspective. When you focus on lack of access, I think that should be underlined because, in my opinion, there is too much useful information, knowledge and best practice guides. So, the amount of knowledge and training materials, videos, and guidelines available for reaching energy efficient interventions is abundant. So, there is an abundancy of materials, but the problem is those materials are not accessed or digested. A good way forward is to guide people that need to have access to knowledge that is relevant to them and that they really access it. We must advise them on what is relevant for you as an investor, as a carpenter etc. from our professional perspective. Then you can nudge the market into accessing and digesting the knowledge and applying it.

Participant 3 – I agree with Participant 2 that there is quite a lot of information available on the supply side. The point is that we seem not to be able to stimulate the demand, whatever we try. To share our experience with our latest course that we are organising now, and is intended for end users. Our courses generate a lot of interest and we had 120 participants register for an online course on energy efficiency, however, the actual turnout on a free course is probably somewhere between 1/3 and ½ of the registered participants. So, we are not hitting the right point. We are not hitting the motivation of the different stakeholders in order to access these materials. One thing I am curious about, if this is not the case of not sharing actual examples, building examples locally, not having enough quality buildings that are open and visible to everybody locally and if we can relate that to the training experience. The fact is that one thing we need is a comparison between what happens with qualified workers involved in the best practice cases and what happens without qualified workers working on site. That kind of example I think must be brought into the picture. Looking at public authorities and public buildings project, particularly new buildings and renovations, if some good examples of the involvement of public authorities in the developing of awareness of different professional end user groups could be pointed out that would be really great.

Q2. Lack of demand for skilled workforce in energy efficiency.

Convenor – is there anything we can do to create a demand or emphasise having a skilled workforce would contribute to the overall effort of tackling energy efficiency. What would this skilled workforce mean in this context? Any contributors?

Participant 4 – I was thinking (even in the previous question) I was thinking about the situation with the workforce for construction in general, at least in Finland. Its more that the demand for workforce is high. So, you kind of go from you can't be a chooser, if you want a skilled workforce, you're overlooking the fact that you then don't get enough people working for you. The high demand for workforce is overpowering the quality of the workforce, in a way. I also think one thing that could then affect the amount of skilled workforce that companies would look for is the fact that you need to show them the correlation between skilled workforce and the quality of the building. For instance, health wise (which is one of the questions we are tackling in Finland) is showing the results of building failures or mistakes and those affecting the building health and indoor air quality etc. to show that skilled workforce will build better and healthier homes/ buildings that are also energy efficient. So, making those correlations visible, would be one thing.

Participant 2 – I would like to add something from the entrepreneur's perspective. What we see is that there is a viscosity regarding workforce and there is an abundance of work, and that means water flows to the lowest point available. And that means, as there is an abundance of work and viscosity of workforce companies keep doing the same things, instead of innovating and adapting new business processes in order to tackle new markets. And that is kind of a vicious circle, as long as the demand of clients is not forcibly changed the companies will keep delivering the same services with the same level of quality with the same workforce, because they simply do not have the capacity to invest in doing other things.

Convenor- I think that the conclusion is skilled workforce is desirable but sometimes it's difficult to access. Maybe an opinion from a different part of Europe would be good? Would anyone like to give an opinion?

Participant 5 – Something that this needs, in my opinion, is legislation. For example, in Italy and in my region, there is a high demand of people that want to improve the energy efficiency of their houses because of legislation and incentives that are available for people in my country. I think it is something very linked with legislation, investors and stakeholders can save money through tax incentives etc. I think the lack of demand, and skilled workforce is very linked with legislation.

Participant 6 – I am from Serbia. we have, as you have previously said, also a problem with the lack of skilled workforce, and it was a big problem and we have to do something about it. So, we tried as a cluster an initiative for a duo system of non-formal education. We have prepared a series of vocational and education trainings for the most highly-demanded roles in the workforce. But this is non-formal education. We did encounter some obstacles (from the side where we should have received support) from state institutions as they felt it was only them that should change and be asked about those educations. But you can see, we are facing that engineers (not just common workforce) they are not experienced they are not familiar with more than construction materials with the introduction to ICT tools, with a lot of things. That is a space where we see the non-formal education has to do something. I think that European funds must see this and we need some support from them. If we don't get support from our own country. The point is, in our country we should look to the direction of non-formal education to get skilled workforce, particularly in light of new materials, new ways of building, energy efficiency, ecological materials, renewable energy sources etc. Our workforce is a little bit out of date and we are here to help them. But someone must help us to help them.

Convenor – I think that is very useful. I think a conclusion form the contributions, I think it v interesting that some people suggest that adoption of new technologies such as ICT, Artificial Intelligence, IoT can be identified as a contributor or accelerator or methods and instruments do deliver this skilled workforce for energy efficiency.

Q3. Lack of availability or inadequate training programmes (in terms of scope, quality, content, cost etc.)

Convenor – In your country's do you see a lack of availability or inadequate training programmes, if so, how do you think we can tackle that?

Participant 2 – I would like to jump in directly. We see a lack of availability of well balanced and to the point training programmes. What we see is that many programmes are the same, same content, quality, same theoretical point of view. What the craftsmen need are less theory-based trainings and more practical trainings with a direct link to the work that they have to do. I really advocate that for blue-collar workers it should be as practical and "on the job" as possible. Such trainings are not widely available, in the Netherlands especially.

Participant 4 – I really agree with Participant 2. I also think that one of the problems with having on the job and practical training is how do the people doing the work get to access this training. The lackof time is really a factor that comes in to force. When you are working, you do not have the time or the possibility to access training even if you are seen to be needing it. How do we bring the training tothe people on the construction site and make sure that they are receiving the training on hand at theirplace of work? Because that is the best place for them to receive it. So how do we go in to the companies and do this?

Participant 3 – If you allow one more voice from this direction. I do believe it is a common issue around Europe. Ireland is the only place that I am aware of actually having some good practices of onsite training and that is based on a lot of interesting general build up skills initiatives and its continuation for many years. The fact is that we are still not able to integrate the requirements for qualifications of both white- and blue-collar workers in the procurement procedures at public and private level. For those that are not involved/ aware of INSTRUCT it may be on interest to know that we will be tackling this issue also on INSTRUCT and from our side we are really putting a lot of hopes on that. The way that we will be able to integrate the requirements for qualification of specialised training on site after winning the procurement for the construction companies, hopefully that can be developed as good practice and spread around.

Participant 3 – I can bring a small solution to the table. We are focusing on the use of task-based qualifications where we detail the tasks that are involved in making a building energy efficient to make task-based recognition of skills possible. One of the things lacking when learning on the job, is that you are not rewarded by anybody. We are trying to find out if there are mechanisms if you are performing high quality work on the job, can you be rewarded for it by recognition for that specific task. So, making the non-formal more formal.

Convenor - In other domains/ sectors there are reward systems where people can store points or even registering that into a blockchain environment where users can get the incentives when they accumulate a particular threshold in relation to their training. This can work well for institutions, or originations, but also for blue and white collars as an incentive. So, incentive-based systems would be very interesting.

Q4. Lack of shared vision and values for energy efficiency across the supply chain

Convenor – do we really understand the values/vision around energy efficiency? Is there a strategy in place to address this?

Participant 4 – I think some of this starts from a very high level. What we are really interested in following here in Finland, is that our industries have formulated their low carbon road maps that investigate the 2030 – 2050 axel, to see whether their roadmaps break it down even to the workforce level in a way that's how low carbon or carbon neutrality can be affected in the construction industry (in Finland) and how that trickles down into the other sectors. Maybe seeing just how much energy efficiency/carbon neutrality is considered on the industry strategic level is something to investigate. We are interested in following the strain here in Finland to see if this will actually bring about change also in training of workforce.

Participant 6 – here in Serbia we have made some steps towards. We have introduced energy passports, that is one step. There are energy passports, that is one step. There are steps before that that must be done. Lots of measurements must be taken and then we can have the broader picture, because when we are talking about a shared vision, we are not talking about just the construction sector. There are other sectors involved. And they all need to behave in the same way. For example, if you put some bags for paper/plastic waste you need to raise awareness in peoples head where to put such waste. You can make a lot of good rules and regulations but if you do not have mechanisms to put it in practice then there will not be results. As a task in Serbia, the first place we should start is raising awareness.

Convenor – I agree, that is important. I would like one more option on this item before moving to the next. Does anyone have an argument for vision/ value around energy efficiency?

Participant 3 – It is a matter of establishing common societal vision of the virus that we share as a community and how Environmntal responsibility and energy options are fitted among them. For that we need stronger awareness raising communication campaigns at various levels of an organisation. Here is where we can establish the common vision, that will resonate in different sectors. Developing the demand of quality efficiency and sustainable buildings will heavily impact the value switch in the supply chain and motivate the different sectors in the supply chain to develop and invest in more sustainable decisions. Also, in our communication strategies we are moving in that direction trying to steer the communication around common balance, which will help us to develop the market and stimulate the market for the end product. Without demand for the end product, the buildings in our part there would be hardly any demand for training so that is a basic connection that we are trying to follow.

Participant 5– I want to add something. In Italy, there are regulations. It is compulsory to achieve a certain level of efficiency. The level is not massive, but it is something very efficient when compared to 10 years ago. Also, the stakeholders understand what energy efficiency is, and are equipped with the skills. There is rooms for improvement, of course. But at the moment a lot of companies are moving in that direction as legislation is also moving in that direction. The traditional construction is not a good fit for this kind of approach but we are moving towards better construction.

Q5. Inadequate policy landscape, including lack of government incentivesConvenor– this is a major issue, I acknowledge that. The floor is open?

Participant 6– I think this is the central question. Without inadequate policy landscape, government initiatives or a government that is capable to understand what is needed, there is not much that we can do in particular parts of the construction sector, as well as other sectors. That is the first step, support from the government. In our country we simply do not have a triple helix – a triple helix is something that should be a basic nod, from that nod all the directions are then visible and everything is in a different light. We as a cluster has just made some initiatives, but it has hardly moved much beyond the initiative, because we do not have a political power and again, we are talking about policy not about skills, experts. This is common for many countries in Europe. We need European support to keep pace with development

Convenor- so i guess policy landscape is very much depending on the country priorities and some countries may not put forward this energy efficiency agenda. If you look at an energy efficiency map, where different courtiers have different energy sources and different energy strategies, I guess this is dependant from country to country. There are different parts of Europe where this is developing or under development, getting opinion from different countries would be much appreciated.

Participant 1- I would just like to add. Typically, in the UK it is quite difficult to get anything considered (ignoring the fact that were going through Brexit as a potential reason for that) it is very difficult to get things within the political landscape, regardless. Sometimes there is a bit of a halfway house to that, where there is a push from the industry. For example, there is a programme called the national digital twin programme, which has involved a level of government support and is fundamentally around trying to digitise the infrastructure sector in the form a digital twin for the UK. There was never necessarily a direct correlation to – well it has got to achieve the following targets for government to be able to warrant it standing up but it was almost a pet project for one of the government departments that was being pushed out to a university, some contractors and consultants. Through a little bit of development, we have seen recently (I've just been recently in discussions with the department of energy and industrial strategies) one of their particular interests is understanding how they can change their reposting cycles for supply and demand of energy and at the same time to find ways to decarbonise our economy and improve the efficiency of energy as well. But that is through the fact that there's an enabler, or a trojan horse, which is digital twins. I would say that the holy grail would be to have something in policy landscape that would allow for us to mandate these things.

it is also pertinent to consider at least from my perspective that ee (and I don't know whether these were the terms that this study was done) ee transcends beyond buildings and energy performance of the building but also the embedded energy required to build that infrastructure. I have noticed in the UK there is a plethora of training in relation to building and ee of said building and perhaps even some codes of practice in and around that, when it comes to highway or rail schemes there's very little you don't see an equivalent green/ need to those. Or you don't see anyone apply those to those techniques at all, but those do contribute significantly to the ee overall for our country as well. Policy landscape is important but I think there's a halfway house to be able to creep towards it in the UK we're starting to see the consideration of that through digital twins I guess, and other areas.

Convenor - another opinion on this from different country?

Participant 4 – I know that a lot of initiatives/ projects have collected information about the policy landscape overall in the EU countries and about the governmental incentives within. But I think those are something that could be shared (through the instruct project and in general) whether there are things that are being done in other countries that can be useful in yours. I know that a lot of things are happing right now in Finland due to our very stringent carbon neutrality targets of 2035, so we need to do a lot. For instance, Finland is developing its own national built environment digital twin. So, the policy landscape is not inadequate, but a lot has to be done so all these actions are being put through the chain within the different sectors. I think we are still looking at different instruments, incentives, what is being done in other countries to make these things happen and to have better results in a shorter timeframe

10.2 Use Cases

1	Use-case title	Use-case type	Funding source	Project title
2	14	Reduce the Gap Between Predicted and Actual Energy Consumption in Buildings	R&D	EU / FP7 Knohol
3	25	Minimizing operational costs and carbon emissions through matching supply with demand of heat and electricity production.	R&D	The European Cc
4	26	Innovative Information and Communication Technologies (ICT) platform able to support the optimization of water networks and to enable change in consumer behavior	R&D	The European Cc
5	27	Intelligent management and control of HVAC system	R&D	EU-FP7 funded p
6	28	Rural Regeneration Centre, Hadlow College	Real-world applic	Hadlow College
7	29	Sustainable Design and Building Information Modelling: Case study Energy Plus House, Hieron's Wood, Derbyshire UK	Real-world applic	Derek Latham (H
8	30	Friendly and Affordable Sustainable Urban Districts Retrofitting (FASUDIR) - Heinrich-Lubke housing area, Frankfurt, Germany	R&D	EU / FP7
9	31	Friendly and Affordable Sustainable Urban Districts Retrofitting (FASUDIR) - Budapest Residential District	R&D	EU / FP7
10	32	An innovative integrated concept for monitoring and evaluating building energy performance (the gap between predicted and actual building energy performance is addre	R&D	7th Framework P
11	50	BIM-based Parametric Building Energy Performance Multi- Objective Optimization	R&D	Autodesk Resea
12	51	Parametric design of a shelter roof in urban context	Real-world applic	Private (Swire Pr
13	52	Introducing the innovative tool of the Building Sector	BIM guideline	null
14	53	Intelligent Services For Energy-Efficient Design and Life Cycle Simulation	R&D	EU - 7TH FRAME
15	54	Collaborative optimisation of building performance during concept design phase	Real world applic	Senate Propertie
16	55	Robust decision making around building efficiency and occupant comfort	Real-world applic	Interserve
17	56	Delivering highly energy efficient hospital centre	Real-world applic	Walton Centre NI
18	57	Design for future climate change- Developing an adaptation strategy	Real-world applic	Admiral Insuranc
19	58	Parametric modeling for architectural form finding	R&D	LIST funded PhD
20	59	Shopping Center using around half the energy of a typical developement	Real-world applic	Renor Oy propert
21	60	Use of BIM in design and construction phase to achieve sustainability goals of an office building	Real-world applic	Skanska Comme
21	60	Use of BIM in design and construction phase to achieve sustainability goals of an office building	Real-world applic	Skanska Comme
22	61	Design of energy-efficient library with high architectural goals	Real-world applic	Helsinki City
23	62	Use of Optimization tool to compare hundreds of concepts energy efficiency before actual design	Real-world applic	YIT, Etera, Onve
24	63	Improving Energy Performance of Office Buildings Based on Light Building Information Model (BIM)	R&D; Master The	PRE-program; G
25	64	Retrofit alternatives based on energy simulations	R&D; Master The	Grandlund Oy;Ne
26	65	Energy properties of solar shading devices and their impact on the visual comfort of occupants	R&D	Wallonia - Belgiu
27	68	Collaborative Holistic Design Laboratory and Methodology for Energy-Efficient EMBEDDED Building	R&D	EU - 7TH FRAME
28	69	Semantic Web for Information Modelling in Energy Efficient Buildings	R&D	Horizon 2020
29	71	Occupant Aware, Intelligent and Adaptive Enterprises	R&D	EU - 7TH FRAME
30	72	Building As A Service	R&D	EU - 7TH FRAME
31	76	De Lacy Row	Real world (proto	Plus Dane (RSL)
32	77	Use of BIM for ESD Analysis of BCA Academic Tower	Real world projec	Building Constru
33	78	CMP_01	Project	CGI
34	79	eeEmbedded Pilot Demonstrators	Real-world applic	The European Co
35	80	EFFESUS Glasgow Case Study	Real-world applic	The European Co
36	81	HESMOS Pilot Projects	Real-world applic	The European Co
37	82	Towards the development of a virtual city model, using a 3D mode of Dundalk city	Real-world applic	The European Co
38	83	Modelling, assessment and Sankey diagrams of integrated electricity-heat-gas networks in multi-vector district energy systems	Real-world applic	The European Co
39	84	Eebers ICT Clusters	Real-world applic	The European Co
40	85	GreenOValley buildings by Schneider Electric in Grenoble	Real-world applic	Schneider Electri
41	86	Improving indoor climates in retrofitted buildings	R&D	FP7-ENVIRONM
42	87	Strategies for a nearly Zero-Energy Building market transition in the European Union	R&D	European Union
43	88	Best practice creating analytic model for energy simulation via gbXML (from Revit)	BIM guideline	EU FP7 Project
44	89	Common BIM requirements 2020, COBIM	BIM guideline	Group of Finnish
45	90	A zero energy house in Finnish climate (BLOK)	Real-world appl	-
46	91	RATINA shopping center	Real-world appl	-
47	92	BIM application to building energy performance visualisation and management	Real-world appl	EPSRC funding
48	93	Continuous-time Bayesian calibration of energy models using BIM and energy data	5 test cases an	Singapore�s N
49	94	Integrated BIM-GIS based design for high energy efficiency hospital buildings	R&D	EU (7th Framew
50	95	BIM for energy efficiency in housing refurbishments	R&D, Real-worl	UK Government
51	96	Optimising energy consumption in building designs using BIM	R&D, real-world	Client
52	97	Harmonised Building Information Speedway for Energy-Efficient Renovation	R&D	European Unior
53	98	Integrating BIM and energy analysis tools with green building certification system to conceptually design sustainable buildings	Real world appli	Client
54	99	Energy aware BIM Cloud Platform in a Cost-effective Building Renovation Context	BIM tools	EU- Horizon
55	100	Capacitation of skilled workforce for the design of new nZEB buildings or in the rehabilitation of existing buildings towards nZEB concept	R&D	Horizon 2020 - E
56	101	Energy Performance Certificates supported by BIM Scanning	R&D	European Comr
57	102	Train-to-nZEB	R&D, Real-worl	Horizon2020
58	103	Fit-to-nZEB	R&D, Real-worl	Horizon2020
59	104	Professional High-school of Construction and Architecture, Pazardzhik	Real-world Appl	Ministry of Educa
60	105	BIM supporting solar architecture	R&D and real-w	European Comr
61	106	nZEB Roadshow	Other	Horizon 2020
62	107	BUSLeague	Other	Horizon 2020
63	108	HIT2GAP & ZUTEC - Integrating BMS & BIM	R&D & real-worl	European Comr
64	109	BIM based tools for fast & efficient renovation (BIM4REN)	R&D	European Comr
65	110	3D Scanning services (R2M Solution & Matterport)	Real-world appl	Industrial consu
66	111	OptEEmAL - Optimised Energy Efficient Design Platform	R&D	European Unior
67	112	Smart Living Technologies	R&D	MIUR - Ministry c
68	113	Transparense - Increasing Transparency of Energy Service Markets	R&d	European Unior
69	114	Renew School	R&D	European Unior
70	115	Design of the largest hospital in the south of Luxembourg	Real-world appl	Centre Hospitali
71	116	Building Information Modeling (BIM) for green buildings: A critical review and future directions	R&D	This study is fin

10.1. Use Case details

Use case 1:

Use-case id*	1
Use-case title*	Reduce the Gap Between Predicted and Actual Energy Consumption in Buildings
Use-case type*	R&D
Funding source*	EU / FP7 KnoholEM project
Project title*	Knowledge-based energy management for public buildings through holistic information modeling and 3D visualization
Web link*	http://www.knoholem.eu/page.jsp?id=2
Targeted discipline*	Facility Management
Building type*	Public
Project type*	Existing
Lifecycle applicability*	In Use
Brief description of 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*	1-The Building BIM model is used to generate a calibrated energy model. 2- An enhanced BIM model is then developed in the form of a knowledge base augmented with energy saving rules. 3- The rules are regularity adapted to changing environmental conditions through a training capability. 4- The system supports a user-in-the-loop approach as the energy manager can ultimately actuate energy saving plans based on a wide range of factors, including comfort conditions.
Supporting case-study*	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.
Scenario definition*	This scenario provides a negotiation based energy management solution to the FORUM building. The ATRIUM zone, by minimising energy consumption while maintaining required comfort conditions.
Control variables*	Heating temperature set point: [16-24]C, (incremental size=1)
Objective*	* 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
Environment variables*	The most effective variables will be determined after sensitivity analysis.
Control rules*	Legislation regarding required internal temperature will need to be adhered to all times regardless of radiator optimization scheme implement.
Actors*	BC5, Occupancy sensor, light automation system, automation system, facility manager, technician, TRV, actuators, temperature sensors, weather station, window actuator, shade actuator.
When applicable*	The scenario is applicable to optimise energy and comfort in the Atrium Zone of the FORUM building.
Learning outcomes*	The use of BIM has helped achieve a reduction of 25% energy compared to baseline figures.
Supporting resources*	http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7317804&tag=1

Use case 2:

Use-case id*	1
Use-case title*	Minimizing operational costs and carbon emissions through matching supply with demand of heat and electricity production.
Use-case type*	R&D
Funding source*	The European Commission under FP7
Project title*	Resilient
Web link*	http://www.resilient-project.eu/
Targeted discipline*	Facility Management
Building type*	Public
Project type*	New Build
Lifecycle applicability*	Operational Stage
Brief description of 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 CO2 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.
Environment variables*	Carbon emissions
Control rules*	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.
Actors*	CHP, Biomass Boilers, Gas Boilers, National Grid
When applicable*	This scenario is applicable in optimising energy supply for a district area.
Learning outcomes*	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.
Supporting resources*	http://www.ijmo.org/vol6/521-SC006.pdf

Use case 3:

INSTRUCT Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Innovative Information and Communication Technologies (ICT) platform able to support the optimization of water networks and to enable change in consumer behavior
Use-case type*	R&D
Funding source*	The European Commission under FP7
Project title*	Water analytics and Intelligent Sensing for Demand Optimised Management (WISDOM)
Web link*	http://www.wisdom-project.eu/home
Targeted discipline*	Facility Management
Building type*	Domestic
Project type*	Existing
Lifecycle applicability*	In Use
Brief description of 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 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.
Scenario definition*	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.
Control variables*	Water demand, Users behaviors
Objective*	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).
Environment variables*	Water resource
Control rules*	The interaction between control room staff, the water network itself and local controllers are the key interactions.
Actors*	Water consumers, water network operators, local authorities, water management, water products, ICT.
When applicable*	This scenario is applicable
Learning outcomes*	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
Supporting resources*	http://www.wisdom-project.eu/documents/84944/90565/WDSA+July+2014+Bari/b827fe2c-5c43-4b98-89cc-662270ab99bc

Use case 4:

INSTRUCT Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Intelligent management and control of HVAC system
Use-case type*	R&D
Funding source*	EU-FP7 funded project
Project title*	SPORTE2
Web link*	http://www.sporte2.eu/
Targeted discipline*	Facility Management
Building type*	Public
Project type*	Existing
Lifecycle applicability*	Not In Use
Brief description of case-study*	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.
Key highlights*	To increase the knowledge base of sport facilities with respect to energy and energy efficiency To develop 4 scalable energy savings modules specific Objectives 3 to Sport Facilities To validate the system at three pilots To promote energy efficiency at sport facilities 30% Energy and CO2 reduction
Supporting case-study*	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.
Scenario definition*	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
Control variables*	Air temp. inlet Supplied air flow into room
Objective*	Minimization of energy consumption; maximize of the comfort
Environment variables*	Occupancy, Indoor relative humidity, Indoor room temperature, Water temperature.
Control rules*	Relative humidity < 70% 24 ?C < water temp. < 30 ?C 24 ?C < room temp. < 27 ?C CL in air >3.4 ppm
Actors*	BMS, automation server, facility technician, sensor, actuator
When applicable*	This scenario is applicable
Learning outcomes*	Up to 30% of Energy Saving Up to 30% Emission reduction
Supporting resources*	http://www.sciencedirect.com/science/article/pii/S0378778814003788

Use case 5:

INSTRUCT | Back to homepage | A+ | A- | R

Use-case id*	1
Use-case title*	Rural Regeneration Centre, Hadlow College
Use-case type*	Real-world application
Funding source*	Hadlow College
Project title*	Hadlow College
Web link*	non
Targeted discipline*	Architectural Design
Building type*	Public
Project type*	Renovation
Lifecycle applicability*	Design
Brief description of 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
Supporting case-study*	This case study is an extension to an existing building with the aim of meeting PassivHaus requirements.
Scenario definition*	This scenario provides a solution that is PassivHaus certified through various sustainable design choices for the Rural Regeneration Centre
Control variables*	Window opening/closing set point
Objective*	Reduction in energy consumption, carbon emissions and operational costs
Environment variables*	Solar gain, fresh air rates
Environment variables*	Solar gain, fresh air rates
Control rules*	Temperature to be maintained between 19 - 22C
Actors*	Mechanical ventilation 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
When applicable*	The scenario is applicable for use of the Rural Regeneration Centre in Hadlow College
Learning outcomes*	BIM technologies used predominantly for integrated building design at the design phase to achieve PassivHaus certification.
Supporting resources*	http://www.graphisoft.com/ftp/marketing/case_studies/Hadlow_GRAPHISOFT_CaseStudy.pdf

Use case 6:

INSTRUCT | Back to homepage | A+ | A- | R

Use-case id*	1
Use-case 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*	non
Targeted discipline*	Architectural Design
Building type*	Domestic
Project type*	New Build
Lifecycle applicability*	Design
Brief description of 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 materials
Supporting case-study*	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.
Scenario definition*	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.
Control variables*	passive stack and earth tube ventilation
Objective*	Low impact building
Environment variables*	Energy consumption, water usage, solar gain and carbon emissions
Control rules*	Predetermined specifications such as estimated energy use and emissions
Actors*	sycamore, passive stack and earth tube ventilation
When applicable*	The scenario is applicable for use of the Rural Regeneration Centre in Hadlow College
Learning outcomes*	Successful integration of sustainable design analysis with building information modelling using integrated design technologies as well as simulation software.
Supporting resources*	https://ac.els-cdn.com/S1876610215028283/1-s2.0-S1876610215028283-main.pdf?_tid=f5c0889e-d392-11e7-a528-00000aacb362&acdnat=1511801560_7d8476ee574b2c69126c26a54b53faa2

Use case 7:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Friendly and Affordable Sustainable Urban Districts Retrofitting (FASUDIR) - Heinrich-Lubke housing area, Frankfurt, Germany
Use-case type*	R&D
Funding source*	EU / FP7
Project title*	FASUDIR
Web link*	http://cordis.europa.eu/project/rcn/110304_en.html
Targeted discipline*	Facility Management
Building type*	Public
Project type*	Existing
Lifecycle applicability*	Operational & Maintenance Stage
Brief description of 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.
Supporting case-study*	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.
Scenario definition*	This scenario provide an alternative approach to the traditional one considered for building retrofiring through the use of BIM system (FASUDIR IDST) in order to achieve higher goals in reducing energy demand and CO2 emission.
Control variables*	* Global Warming Potential (GWP) * Operational Energy Demand
Objective*	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
Environment variables*	Introduction of a biomass plant.
Control rules*	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
Actors*	users, owners, investors, building solution suppliers, urban managers and grants management
When applicable*	The scenario is applicable to optimise energy and increase sustainability
Learning outcomes*	GWP reduction of 60%. Operational energy consumption reduction of 35%
Supporting resources*	http://fasudir.eu/documents/FASUDIR_CaseStudies_booklet.pdf

Use case 8:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Friendly and Affordable Sustainable Urban Districts Retrofitting (FASUDIR) - Budapest Residential District
Use-case type*	R&D
Funding source*	EU / FP7
Project title*	FASUDIR
Web link*	http://cordis.europa.eu/project/rcn/110304_en.html
Targeted discipline*	Facility Management
Building type*	Public
Project type*	Existing
Lifecycle applicability*	Operational Stage
Brief description of 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
Supporting case-study*	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.
Scenario definition*	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.
Control variables*	* Operation Energy Running Costs * Operational Energy Demand
Objective*	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
Environment variables*	Introduction of renewable energy to the district
Control rules*	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)
Actors*	users, owners, investors, building solution suppliers, urban managers and grants management
When applicable*	The scenario is applicable to optimise energy and increase sustainability
Learning outcomes*	Operational energy reduced by 35% and energy running costs reduced by 35%
Supporting resources*	http://fasudir.eu/documents/FASUDIR_CaseStudies_booklet.pdf

Use case 9:

INSTRUCT | Back to homepage | A+ A- R

Use-case id*	1
Use-case title*	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).
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*	http://performerproject.eu
Targeted discipline*	Facility Management
Building type*	Public
Project type*	Existing
Lifecycle applicability*	In Use
Brief description of 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*	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. 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 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 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
Objective*	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.
Environment variables*	Solar- temperature
Control rules*	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.
Actors*	Unoccupied rooms, rooms have occasional use, staff/pupils, sensors, lighting, temperature, energy generation and solar PV. Awareness.
When applicable*	The scenario is applicable in School
Learning outcomes*	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.
Supporting resources*	http://www.sustainableplaces.eu/wp-content/uploads/2017/07/posterA0PERFORMER_final.pdf

Use case 10:

INSTRUCT | Back to homepage | A+ A- R

Use-case id*	1
Use-case 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*	https://autodeskresearch.com/publications/bimparametric
Targeted discipline*	Architectural Design
Building type*	Domestic
Project type*	New Build
Lifecycle applicability*	Construction, Design
Brief description of 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.
Supporting case-study*	Not Applicable
Scenario definition*	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 build- ing can enter via two fixed curtain walls that are not included as free parameters in the design space op- timization. These two curtain systems light the main living space in the first floor and the balcony in sec- ond 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.
Control variables*	Size and height of windows Angle of building orientation Overall building footprint Form of the roof Interior layout
Objective*	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.
Environment variables*	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 incre- ment of 0.1'.
Control rules*	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.
Actors*	Designers
When applicable*	null
Learning outcomes*	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.
Supporting resources*	null

Use case 11:

Use-case id*	1
Use-case 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*	null
Targeted discipline*	Architectural Design, Structural Design, Mechanical Engineering, Steel contractor
Building type*	Public
Project type*	New Build
Lifecycle applicability*	Construction, Design
Brief description of 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
Supporting case-study*	Using models for computer simulation: wind simulation, sun & daylight simulation, rain simulation, structursl simulation and material and steel fabric
Scenario definition*	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.
Control variables*	Inclination of blades Topography of roof surface Dimensioning of support columns
Objective*	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 behavior, resist to hurricane wind loads
Environment variables*	null
Control rules*	Wind forces on the whole surface Glass surfaces are calculated to withstand the maximal winds and tested for flying debris
Actors*	Architect, Designer, Engineers, Steel contractor
When applicable*	null
Learning outcomes*	Early BIM for parametric optimization through simulations
Supporting resources*	null

Use case 12:

Use-case id*	1
Use-case title*	Introducing the innovative tool of the Building Sector
Use-case type*	BIM guideline
Funding source*	null
Project title*	BIMclay
Web link*	https://ied.eu/bimclay-project-introducing-innovative/
Targeted discipline*	workers in ceramic sector
Building type*	Other
Project type*	Existing
Lifecycle applicability*	null
Brief description of case-study*	the project aims to the enhancement of the technical knowledge related to the Building Information Modeling and to the Life Cycle Analysis of a building, product or process.
Key highlights*	1) interactive platform 2) courses and tools
Supporting case-study*	null
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.
Objective*	null
Environment variables*	null
Control rules*	null
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*	null

Use case 13:

Back to homepage A+ A- R

Use-case id*	1
Use-case 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*	http://ises.eu-project.info/about.php
Targeted discipline*	All
Building type*	Public
Project type*	Existing
Lifecycle applicability*	In Use
Brief description of 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*	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.
Supporting case-study*	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)
Scenario definition*	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 has been developed to deal with the random nature of energy profiles and consumption through the product life-cycle
Control variables*	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.
Objective*	null
Environment variables*	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 a combination of energy profiles for stochastic life-cycle consideration.
Control rules*	null
Actors*	Partner, National Observatory of Athens, Group Energy Conversation, Nyskopunarmidstod Islands, SOFiSTiK Hellas S.A., University of Ljubljana, Granlund Oy, Technische Universita?t Dresden,
When applicable*	2011-2014
Learning outcomes*	The combination of energy profile models with product development STEP models and building and facility BIM models
Supporting resources*	null

Use case 14:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Collaborative optimisation of building performance during concept design phase
Use-case type*	Real world application involving R&D aspect
Funding source*	Senate Properties (client) and Finnish Funding agency for Innovation, Tekes (R&D)
Project title*	Onerva Maki school
Web link*	http://www.granlund.fi/en/news/knotworking-undoes-knots/
Targeted discipline*	All
Building type*	Public
Project type*	New Build
Lifecycle applicability*	Concept design
Brief description of case-study*	This study presents a BIM-based and project team colaaboration based approach to building performance assessment. Target is to understand dependencies and impacts of design changes into different targetted 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.
Key highlights*	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) All necessary project participants were included in the facilitated workshop. Results to produce in the workshop were clarified to the team.
Supporting case-study*	The case study is a school building located in Jyvskyl, FInland. A new building was developed for a special school for visually imparaired 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
Scenario definition*	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.
Control variables*	Architects space model was well suited for energy consumption analysis but not detailed enough for accurate cost estimation and indoor condition simulation
Objective*	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)
Environment 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 asessment of suitability and performance of design proposals. Also visualisation of results help all participants to understand and 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

Use case 15:

Back to homepage A+ A- R

Use-case id*	1
Use-case 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*	http://constructingexcellence.org.uk/ingenuity-house/
Targeted discipline*	Facility Management
Building type*	Public
Project type*	New Build
Lifecycle applicability*	In Use
Brief description of 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.
Supporting case-study*	Ingenuity House
Scenario definition*	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.
Control variables*	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.
Objective*	To define a new asset classification system and how these can be linked these to product data sheets. To see a practical session using the BIM model to see how to navigate around the building a make the connection with FM.
Environment variables*	Not Provided
Control rules*	Not Provided
Actors*	Not Provided
When applicable*	Not Provided
Learning outcomes*	Delivery of SMART building to be established once it is completed
Supporting resources*	Not Provided

Use case 16:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Delivering highly energy efficient hospital centre
Use-case type*	Real-world application
Funding source*	Walton Centre NHS Foundation Trust
Project title*	Not Provided
Web link*	http://www.interserve.com/case-studies/2014/delivering-outstanding-environments-at-the-walton-centre
Targeted discipline*	Facility Management
Building type*	Public
Project type*	New Build
Lifecycle applicability*	Technical Design
Brief description of 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 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.
Scenario definition*	The use of BIM and 3D modelling how our design and construction innovation could give the Trust a third storey to the centre
Control variables*	Not Provided
Objective*	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
Environment variables*	Not Provided
Control rules*	Not Provided
Actors*	Not Provided
When applicable*	Not Provided
Learning outcomes*	- 41% reduction in fabric loss heat, generating 95,745 Pound 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 CO2 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*	Not Provided

Use case 17:

INSTRUCT Back to homepage A+ A- R

Use-case id*	1
Use-case 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 Provided
Web link*	Not Applicable
Targeted discipline*	Architectural Design
Building type*	Public
Project type*	New Build
Lifecycle applicability*	Technical Design
Brief description of 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 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
Scenario definition*	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 Pound.
Control variables*	Not Provided
Objective*	- 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
Environment variables*	Not Provided
Control rules*	Not Provided
Actors*	Not Provided
When applicable*	Not Provided
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

Use case 18:

INSTRUCT Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Parametric modeling for architectural form finding
Use-case type*	R&D
Funding source*	LIST funded PhD project
Project title*	Method and toolset for data-driven optimization of design solutions in parametric modeling systems
Web link*	NC
Targeted discipline*	Architectural Design
Building type*	Public
Project type*	New Build
Lifecycle applicability*	Construction, Design
Brief description of case-study*	Not Provided
Key highlights*	Not Provided
Supporting case-study*	Not Provided
Scenario definition*	Not Provided
Control variables*	Not Provided
Objective*	Not Provided
Environment variables*	Not Provided
Control rules*	Not Provided
Actors*	Not Provided
Learning outcomes*	Not Provided
Supporting resources*	Not Provided

Use case 19:

INSTRUCT | Back to homepage | A+ | A- | R

Use-case id*	1
Use-case title*	Shopping Center using around half the energy of a typical developement
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*	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
Building type*	Other
Project type*	Renovation
Lifecycle applicability*	Preparation and Brief, Concept Design, Developed Design, Technical Design, Construction, In Use
Brief description of 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.
Supporting case-study*	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 percentage 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).
Scenario definition*	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.
Control variables*	Ventilation system optimized by CO2-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 CO2 and carbon monoxide sensors to properly ventilate the spaces.
Objective*	Not applicable
Environment variables*	Not applicable
Control rules*	Not applicable
Actors*	Not applicable
When applicable*	Not applicable
Learning outcomes*	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 heatpumps and gains of free energy for heating and cooling have exceeded expectations.
Supporting resources*	http://www.skanska-sustainability-case-studies.com/index.php/latest-case-studies/item/download/276_bb182b7f47e1114b65458859014e1606

Use case 20:

INSTRUCT | Back to homepage | A+ | A- | R

Use-case id*	1
Use-case 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 phaze, BIM also used in designing and carbon analyses of structures for benchmarking an office building
Web link*	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 /
Building type*	Public
Project type*	New Build
Lifecycle applicability*	Concept Design, Developed Design, Technical Design, Construction
Brief description of 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 throug 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.
Supporting case-study*	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.
Scenario definition*	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.
Control variables*	Not applicable
Objective*	Not applicable
Environment variables*	Not applicable
Control rules*	Not applicable
Actors*	Not applicable
When applicable*	Not applicable
Learning outcomes*	Holistically BIM-based project achieved LEED Core & Shell Platinum Certificate.
Supporting resources*	http://www.skanska-sustainability-case-studies.com/index.php/latest-case-studies/item/download/110_e5719b55648a979d25e5f3929dc2412d

Use case 21:

INSTRUCT Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Design of energy-efficient library with high architectural goals
Use-case type*	Real-world application
Funding source*	Helsinki City
Project title*	Dynamic energy simulations part of whole design process. BIM helped designing and executiong a structurally complex building and hiding visually unpleasant HVAC-systems
Web link*	http://keskustakirjasto.fi/en/
Targeted discipline*	Architectural design / Structural engineering / HVAC engineering / Electrical engineering / Builders / Construction companies / Suppliers
Building type*	Public
Project type*	New Build
Lifecycle applicability*	Preparation and Brief, Concept Design, Developed Design, Technical Design, Construction
Brief description of case-study*	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 phaze 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.
Key highlights*	Holistic use of 3D BIM throug project. Dynamic energy-simulation model (Ida Ice) was in active use and frequently updated throughout the design process from the earliest stages. In pre-design the model was used in goal assessing (energy efficiency, indoor climate quality etc.) for the further and more developed design stages.
Supporting case-study*	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.
Scenario definition*	Demand based ventilation. Several different cooling strategies to keep indoor climate comfortable in the multiple use-cases of the building.
Control variables*	Not applicable
Objective*	Not applicable
Environment variables*	Not applicable
Control rules*	Not applicable
Actors*	Not applicable
When applicable*	Not applicable
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*	Karkkanen, Minna. 2016. Uuden aikakauden kirjasto. Talotekniikka -magazine 5/2016, p. 18-21.

Use case 22:

INSTRUCT Back to homepage A+ A- R

Use-case id*	1
Use-case 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*	https://tripla.yit.fi/en
Targeted discipline*	Architectural
Building type*	Public
Project type*	New Build
Lifecycle applicability*	RIBA Stage 2
Brief description of 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 decicionmakers and designers before design phaze. 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 over all 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 adabtable indoorspaces by calculating directly their effects on energy demand, indoor air quality, investment and energy cots. Two day workshop (called Solmu) had architect, HVAC-engineer, electic 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 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 decicion makers and found very useful. Without the tool only a couple of options whould had been able to analyze as deeply from the almost infinite number of alternatives.
Scenario definition*	Not applicable
Control variables*	Not applicable
Objective*	Not applicable
Environment variables*	Not applicable
Control rules*	Not applicable
Actors*	Not applicable
When applicable*	Not applicable
Learning outcomes*	Compared to busines as usual where a only few alternatives/building concepts might be studied more deeply for decicion 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 23:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Improving Energy Performance of Office Buildings Based on Light Building Information Model (BIM)
Use-case type*	R&D; Master Thesis
Funding source*	PRE-program; Grandlund Oy
Project title*	Improving Energy Performance of Office Buildings Based on Light Building Information Model (BIM)
Web link*	https://aaltodoc.aalto.fi/handle/123456789/11442
Targeted discipline*	Energy Modeler
Building type*	Public
Project type*	Existing
Lifecycle applicability*	In Use
Brief description of case-study*	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 possibilites 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.
Key highlights*	The different energy efficiency measures were simulated to demonstrate if the requirements of the decree of renovations (2013/4) were achieved. 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). Tenant based energy performance simulation for about 2500sq m area shows the difference of 0.9% between realised heating counsumption.
Supporting case-study*	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 tenatnt.
Scenario definition*	Not applicable
Control variables*	Not applicable
Objective*	Not applicable
Environment variables*	Not applicable
Control rules*	Not applicable
Actors*	Not applicable
When applicable*	Not applicable
Learning outcomes*	Minimal information requirements for energy simulation is highlighted in the study.
Supporting resources*	Not applicable

Use case 24:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Retrofit alternatives based on energy simulations
Use-case type*	R&D; Master Thesis
Funding source*	Grandlund Oy; NewTREND EU Projec
Project title*	New energy analysis process for the design of building retrofits
Web link*	https://aaltodoc.aalto.fi/handle/123456789/23259
Targeted discipline*	Architectural Design, HVAC Engineering
Building type*	Public
Project type*	Existing
Lifecycle applicability*	In Use
Brief description of case-study*	The pilot project neighborhood is located in the city of Seinajoki, Finland. The neighborhood consists of four buildings that were originally built in 1930 to serve as county hospital of Seinajoki, but since the 1980s the hospital moved elsewhere. The buildings are owned by the City of Seinajoki and are being used for multiple different purposes.
Key highlights*	BIM is the more accurate simulation results, since all the rooms and envelope elements can be modeled 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. 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.
Supporting case-study*	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.
Scenario definition*	Not applicable
Control variables*	Not applicable
Objective*	Not applicable
Environment variables*	Not applicable
Control rules*	Not applicable
Actors*	Not applicable
When applicable*	Not applicable
Learning outcomes*	BIM model used for sensitivity analysis simulations as well as AHU groups, room specific internal loads and ventilation rates need were model based input.
Supporting resources*	Not applicable

Use case 25:

INSTRUCT Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Energy properties of solar shading devices and their impact on the visual comfort of occupants
Use-case type*	R&D
Funding source*	Wallonia - Belgium
Project title*	PROSOLIS
Web link*	www.prosolis.be
Targeted discipline*	Architectural Design
Building type*	Public
Project type*	Existing
Lifecycle applicability*	Design
Brief description of case-study*	Energy properties of solar shading devices and their impact on the visual comfort of occupants
Key highlights*	Solar shading. Energy Consumption. Daylight supply.
Supporting case-study*	Not applicable
Scenario definition*	Representative rooms Belgian climate
Control variables*	Energy Consumption; Visual Comfort; Thermal Comfort
Objective*	Comparison of energy properties of solar shading devices and their impact on the visual comfort of occupants
Environment variables*	Orientation, glazing, solar shading
Control rules*	Solar radiation
Actors*	NA
When applicable*	NA
Learning outcomes*	Integration of multidisciplinary approach for the choice of solar shading
Supporting resources*	www.prosolis.be

Use case 26:

INSTRUCT Back to homepage A+ A- R

Use-case id*	1
Use-case 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*	http://eeembedded.eu/
Targeted discipline*	Engineering
Building type*	Public
Project type*	Existing
Lifecycle applicability*	Not applicable
Brief description of 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
Supporting case-study*	The project develops a platform which is composed of several simulators covering multiple physical and mathematical models as well as information models.
Scenario definition*	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.
Control variables*	To validate the eeEmbedded technologies, two real buildings of different types and its embedding into the neighbourhood were used as a test bench. The validation period was whole year to allow for a pre-market validation of the system.
Objective*	Not applicable
Environment variables*	Not applicable
Control rules*	Not applicable
Actors*	Technische Universitat Dresden, Institute of Contruction Informatics/ Technische Universitat 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/
When applicable*	2013- 17
Learning outcomes*	Not applicable
Supporting resources*	http://eeembedded.eu/wp-content/uploads/2017/09/20170917_eeE_Final_Report_V2.0.pdf

Use case 27:

Back to homepage A+ A- R

Use-case id*	1
Use-case 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*	http://swiming-project.eu/
Targeted discipline*	All
Building type*	Other
Project type*	Existing
Lifecycle applicability*	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 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.
Supporting case-study*	Not applicable
Scenario definition*	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.
Control variables*	Not applicable
Objective*	Not applicable
Environment variables*	Not applicable
Control rules*	Not applicable
Actors*	Trinity College Dublin - KIT (Karlsruhe institute of technology)- AEC3 - CERTH (Information of Technologies Institute- GR)- Tyndall
When applicable*	2015-17
Learning outcomes*	Not applicable
Supporting resources*	Not applicable

Use case 28:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Occupant Aware, Intelligent and Adaptive Enterprises
Use-case type*	R&D
Funding source*	EU - 7TH FRAMEWORK PROGRAMME
Project title*	Adapt4EE
Web link*	http://www.adapt4ee.eu/adapt4ee/
Targeted discipline*	Architectural
Building type*	Other
Project type*	Existing
Lifecycle applicability*	All aspects of construction products (assets and facilities, occupants and processes, environmental conditions)
Brief description of 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
Supporting case-study*	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.
Scenario definition*	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.
Control variables*	Modeling, 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).
Objective*	Not Applicable
Environment variables*	Environmental VS Occupancy Data/ Energy Consumption VS Occupancy Data
Control rules*	Not Applicable
Actors*	Centre for Research and Technology Hellas /Informatics and Telematics Institute (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)
When applicable*	Not Applicable
Learning outcomes*	Not Applicable
Supporting resources*	Models available at: http://www.adapt4ee.eu/adapt4ee/results/orm.html

Use case 29:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Building As A Service
Use-case type*	R&D
Funding source*	EU - 7TH FRAMEWORK PROGRAMME
Project title*	BaaS Project
Web link*	www.baas-project.eu
Targeted discipline*	Engineering
Building type*	Public
Project type*	Existing
Lifecycle applicability*	Not provider
Brief description of 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
Supporting case-study*	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.
Scenario definition*	Not provider
Control variables*	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.
Objective*	Not provider
Environment variables*	Not provider
Control rules*	End-user acceptance will be accomplished by analyzing the replication potential in tandem with the results of a sensibility study.
Actors*	Fundacion CARTIF - Technology Centre, Dalkia Energy Servicios, Fraunhofer IBP, Honeywell Prague Laboratory, NEC Laboratories Europe, Technical University of Crete, University College of Cork - IRUSE
When applicable*	2012-16
Learning outcomes*	Not provider
Supporting resources*	Project's deliverables available at: https://www.baas-project.eu/index.php/public/publicdocs

Use case 30:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	De Lacy Row
Use-case type*	Real world (prototype)
Funding source*	Plus Dane (RSL)
Project title*	De Lacy Row
Web link*	http://www.johnmccall.co.uk/portfolio_page/ni-smartbuild/
Targeted discipline*	Architecture
Building type*	Domestic
Project type*	New Build
Lifecycle applicability*	Stages 0-6 with 7 operations and maintenance considered by client
Brief description of case-study*	See https://www.youtube.com/watch?v=aJcYVZMJCHs&feature=youtu.be
Key highlights*	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 clients in-house team. Passive ventilation system type 2. Timber frame inner leaf. Radiators designed out (with provision for future installation if the client decide to add). 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.
Supporting case-study*	Not Applicable.
Scenario definition*	Option Appraisals
Control variables*	Other similar projects in the same area
Objective*	To provide housing without using contractors and subcontractors but instead using the client's own workforce.
Environment variables*	Passive ventilation instead of mechanical.
Control rules*	Not Applicable.
Actors*	Tenants, RSLs, Project Manager, Architects, Timber frame contractor, ground works contractors
When applicable*	Not Applicable.
Learning outcomes*	It achieved the timberframe design co-ordination, the trades 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.
Supporting resources*	Not Applicable.

Use case 31:

INSTRUCT Back to homepage A+ A- R

Use-case id*	1
Use-case 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*	http://www.rsp.com.sg/project/show?id=224
Targeted discipline*	Architectural, Mechanical & Structural
Building type*	Public
Project type*	New Build
Lifecycle applicability*	RIBA Stage 2 and Stage 3
Brief description of 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. To 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 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 definition*	Not applicable
Control variables*	Not applicable
Objective*	Not applicable
Environment variables*	Not applicable
Control rules*	Not applicable
Actors*	Not applicable
When applicable*	Not 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

Use case 32:

INSTRUCT Back to homepage A+ A- R

Use-case id*	1
Use-case title*	CMP_01
Use-case type*	Project
Funding source*	CGI
Project title*	CMP
Web link*	-
Targeted discipline*	Architectural Design / Energy Simulations
Building type*	Public
Project type*	New Build
Lifecycle applicability*	Stage 3 Developed Design
Brief description of case-study*	School project for 700 students
Key highlights*	BIM SCHOOL PROJECT
Supporting case-study*	Design the BIM workflow between the architects and the energy engineer.
Scenario definition*	Put de architectural design model into a energy simulation software.
Control variables*	-
Objective*	To do a Thermo dynamic simulation of the building.
Environment variables*	-
Control rules*	Evaluation of visual similitude of the model on the architectural design software and on the energy simulation software.
Actors*	Architectects and energy engineer.
Actors*	Architectects and energy engineer.
When applicable*	At the stages of concept design and developed design
Learning outcomes*	-
Supporting resources*	-

Use case 33:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	eeEmbedded Pilot Demonstrators
Use-case type*	Real-world application
Funding source*	The European Commission under FP7
Project title*	eeEmbedded
Web link*	http://eeembedded.eu/
Targeted discipline*	Architectural Design
Building type*	Public
Project type*	Existing
Lifecycle applicability*	Design
Brief description of 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 finalization of previous tasks with relevant links to necessary data.
Supporting case-study*	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.
Scenario definition*	This scenario provides analysis performed in 3 separate design phases through the virtual lab platform.
Control variables*	Varies with each design phase (Material U-values, building shape and orientation, materials of construction, weather conditions)
Objective*	Evaluate the capabilities of the virtual lab platform in various stages of design
Environment variables*	Wind, Temperature, Solar gains
Control rules*	Varies with design stage
Control rules*	Varies with design stage
Actors*	Building geometries and relevant components of construction
When applicable*	This is applicable for the design phase of a project.
Learning outcomes*	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.
Supporting resources*	http://eeembedded.eu/wp-content/uploads/2017/09/20170917_eeE_Final_Report_V2.0.pdf

Use case 34:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	EFFESUS Glasgow Case Study
Use-case type*	Real-world application
Funding source*	The European Commission under FP7
Project title*	EFFESUS
Web link*	http://www.effesus.eu/about-effesus/case-studies/glasgow
Targeted discipline*	Construction Enineegering
Building type*	Public
Project type*	Renovation
Lifecycle applicability*	In Use
Brief description of 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 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 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.
Objective*	Evaluate the capabilities of the virtual lab platform in various stages of design
Environment variables*	historical hertiage, maritime climate conditions: percipitation, wind, solar gains and humidity
Control rules*	2 separate rooms monitored over a 10 month period for comparison
Actors*	Aerogel fiber 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 35:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	HESMOS Pilot Projects
Use-case type*	Real-world application
Funding source*	The European Commission under FP7
Project title*	HESMOS
Web link*	http://hesmos.eu/
Targeted discipline*	Design
Building type*	Public
Project type*	Existing
Lifecycle applicability*	Designers
Brief description of 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, CO2 emissions, energy costs can be simulated and estimated with new primary energy library development.
Supporting 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 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 relevent environmental variables
Objective*	Evaluate the capabilities of the virtual lab platform in various stages of design
Environment variables*	Outdoor and indoor temperature, room and outdoor seasonal humidity and CO2 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 relevent 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 36:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Towards the development of a virtual city model, using a 3D mode of Dundalk city
Use-case type*	Real-world application
Funding source*	The European Commission under FP7
Project title*	INDICATE
Web link*	http://indicate-smartcities.eu/
Targeted discipline*	Design
Building type*	Public
Project type*	Existing
Lifecycle applicability*	Design
Brief description of case-study*	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.
Key highlights*	Results demonstrate the potential impact of energy consumption within the modelled buildings along with the implemented retrofits. Shows an effective measure of the positive impacts of modelling and simulating at the early stage of analysis. Annual energy need, purchased, CO2 emissions, energy costs can be simulated and estimated with new primary energy library development.
Supporting case-study*	This case study involves a select number of buildings in Dundalk through the development of 3D models that need to be ready for simulation. This was done through ordinance survey mapping coupled with LiDAR information to ensure the correct dimensions.
Scenario definition*	This scenario provides a method of modelling and simulating at the early stage of analysis for urban systems.
Control variables*	Not Applicable.
Objective*	Improving the efficiency and effectiveness of urban system.
Environment variables*	Temperature, solar gain.
Control rules*	Geometry of existing BIM model.
Actors*	HVAC systems, building components and materials.
When applicable*	This scenario is applicable for urban systems.
Learning outcomes*	Building Information Models developed of select buildings and subsequently used to simulate retrofits.
Supporting resources*	https://infoscience.epfl.ch/record/213431/files/9_MELIA.pdf

Use case 37:

Back to homepage	A+ A- R
Use-case id*	1
Use-case 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*	www.dimmerproject.eu/
Targeted discipline*	Facility Management
Building type*	Public
Project type*	Existing
Lifecycle applicability*	Operational Stage
Brief description of case-study*	This case study explores the potential of advances in 3D modelling, visualisation, and interactive technologies enabling user profiling and real-time feeback 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.
Supporting case-study*	This case study takes place in the campus of the University of Manchester.
Scenario definition*	This investigation explores 6 scenarios of varying supply technologies and levels of a district multi-energy system
Control variables*	6 scenarios of various conversion components at different levels
Objective*	Minimise carbon emissions and operational costs
Environment variables*	Carbon emissions
Control rules*	Energy Prices: Grid electricity (50/6 Pound/MWh), Electrcity (export) (80% of grid price), Natural gas (23.6 Pound/MWh) Carbon content: Natural gas (0.204 kgCO2/kWh), Grid electricity (0.027-0.45 kgCO2/kWh)
Actors*	District level and building level: gas boilers, CHP, heat pumps
When applicable*	The scenario is applicable for district multi-energy systems
Learning outcomes*	Integration of Building Information Modelling with real-time data and feedback, successfully extending to district level, leading to District Information Models
Supporting resources*	https://ac.els-cdn.com/S0306261915010259/1-s2.0-S0306261915010259-main.pdf?_tid=5f3f7896-0838-11e8-b007-00000aacb361&acdnat=1517590065_aa53cc639ad2d0fa08d89605a4fadc91

Use case 38:

Back to homepage	A+ A- R
Use-case id*	1
Use-case title*	Eebers ICT Clusters
Use-case type*	Real-world application
Funding source*	The European Commission under H2020
Project title*	Eebers
Web link*	http://www.fabiodisconzi.com/open-h2020/projects/193414/index.html
Targeted discipline*	Facility Management
Building type*	Other
Project type*	Existing
Lifecycle applicability*	Operational Stage
Brief description of 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 case-study*	Not Applicable.
Scenario definition*	Not Applicable.
Control variables*	Not Applicable.
Objective*	Not Applicable.
Environment variables*	Not Applicable.
Control rules*	Not Applicable.
Objective*	Not Applicable.
Environment variables*	Not Applicable.
Control rules*	Not Applicable.
Actors*	Not Applicable.
When applicable*	Not Applicable.
Learning outcomes*	Not Applicable.
Supporting resources*	http://eebers.eu/static/img/Eebers_d1%201%20projects%20mapping_public%20deliverable.pdf

Use case 39:

INSTRUCT Back to homepage	A+ A- R
Use-case id*	1
Use-case title*	GreenOValley buildings by Schneider Electric in Grenoble
Use-case type*	Real-world application
Funding source*	Schneider Electric
Project title*	GreenOValley
Web link*	https://www.autodesk.fr/redshift/schneider-electric-grenoble/
Targeted discipline*	Facility Management
Building type*	Industrial
Project type*	New Build
Lifecycle applicability*	In Use
Brief description of case-study*	The project aims to link static building (BIM) models of the buildings to the dynamic flows of data managed by automation systems during building operations (BMS).
Key highlights*	There is a lack of information in-between design BIM models and FM BIM models, limiting the actual use of design-BIM data during operations. It is required to enhance design models with construction data in order to make FM BIM models usable and linked to BMS systems. The goal is to obtain the digital twice of the building really built. No additional costs. Organisational break in-between actors creates a lot of difficulties in the actual management of buildings. BIM helps reducing it.
Supporting case-study*	not explained
Scenario definition*	45 kWh/m2 / year
Control variables*	not explained
Objective*	not explained
Environment variables*	Facility Managers, Building Energy Managers
Control rules*	Adding construction related data to the BIM to make it usable in operations. Filtering data really useful (from big data to smart data)
Actors*	SKubicki
When applicable*	740194b9c7264dbab41042584c90abcc
Learning outcomes*	null
Supporting resources*	null
Learning outcomes*	null
Supporting resources*	null

Use case 40:

Use case 41:

INSTRUCT Back to homepage	A+ A- R
Use-case id*	1
Use-case title*	Strategies for a nearly Zero-Energy Building market transition in the European Union
Use-case type*	R&D
Funding source*	European Union
Project title*	Nearly Zero-Energy Building Strategy 2020 (nZEB)
Web link*	http://zebra2020.eu
Targeted discipline*	Building energy
Building type*	Public
Project type*	Existing
Lifecycle applicability*	In use
Brief description of case-study*	Large-scale uptake of nZEB construction and renovation will be a big challenge for all market actors and stakeholders involved. A substantial gap in reliable data on current market activities makes it difficult for policy-makers to evaluate the success of their policies and measures. Therefore, ZEBRA2020 monitors the market uptake of nZEBs across Europe and provides data on how to reach the nZEB standard. This information gathered was structured and analysed to derive recommendations and strategies.
Key highlights*	Zero-energy building; CO2 emission; Renewable energy; Building retrofit
Supporting case-study*	Two tools are developed in this project. The first one, energy efficiency trends in buildings, presents an overview of the current building stock including renovation and construction and monitors Energy Performance Certificates (EPC) activities by country (focusing on 17 target countries). The second tool, selected nearly zero-energy building (nZEB) buildings, displays relevant indicators of nZEB buildings in selected European countries. It aims to provide information of selected best cases in Europe, thereby showing most recurrent technologies, materials and strategies towards the nZEB target.
Scenario definition*	Building codes for new buildings and building renovation; Financial and fiscal support policies/programmes; Increase of renovation rate in public buildings; Obligation to install renewable heating systems; Compliance with regulatory policies; Other instruments like CO2 taxes, mandatory thermal retrofitting in case of fa�ade maintenance or/and during real estate transaction, prohibition of oil boilers or in general all fossil fuel boilers.
Control variables*	http://zebra2020.eu/website/wp-content/uploads/2014/08/ZEBRA2020_Strategies-for-nZEB_07_LQ_single-pages-1.pdf
Objective*	Monitor building performance market data in Europe through developed on-line tools. Discuss the role of more ambitious policies play in nZEB strategy.
Environment variables*	CO2 emission
Control rules*	hodoroga
Actors*	e8e3c998cee4443c8a93ac95d7f2670a
When applicable*	null
Learning outcomes*	null
Supporting resources*	null

Use case 42:

INSTRUCT | Back to homepage | A+ A- R

Use-case id*	1
Use-case title*	Best practice creating analytic model for energy simulation via gbXML (from Revit)
Use-case type*	BIM guideline
Funding source*	EU FP7 Project
Project title*	Design4Energy
Web link*	http://www.design4energy.eu/SmartPerformanceIntegration.html
Targeted discipline*	Architectural Desing
Building type*	Public
Project type*	Existing
Lifecycle applicability*	Pre-design to final design
Brief description of case-study*	Tutorial video and guide for best practice in preparing CAD models for energy simulation. Can be found in D4E portal http://www.design4energy.eu/SmartPerformanceIntegration.html 0> Topic 2. The developer is Dr. Vanda Dimitriou, Loughborough University, UK
Key highlights*	TarjaM
Supporting case-study*	4944205ad9dd4bd58b69b4b9efcd7f88
Scenario definition*	null
Control variables*	null
Objective*	null
Environment variables*	null
Control rules*	null
Actors*	null
When applicable*	null
Learning outcomes*	null
Supporting resources*	null

Use case 43:

INSTRUCT | Back to homepage | A+ A- R

Use-case id*	1
Use-case title*	Common BIM requirements 2020, COBIM
Use-case type*	BIM guideline
Funding source*	Group of Finnish companies via buildingSMART Finland
Project title*	COBIM
Web link*	https://buildingsmart.fi/en/common-bim-requirements-2012/
Targeted discipline*	all main domains in builidng process
Building type*	Public
Project type*	New Build
Lifecycle applicability*	Programming, design, analyses, construction, maintanance
Brief description of case-study*	Common BIM Requirement 2012, COBIM, is based on the BIM Requirements published by Senate Properties in 2007. The update project was funded by Senate Properties in addition to several other real estate owners and developers, construction companies and software vendors. BuildingSMART Finland participated also in the financing of the project. As a result, the updated Series 1-9 and new Series 10-13 were released in Finnish on March 27th 2012.
Key highlights*	series 4: MEP design, Series 9: Use of models in MEP analyses, Series 10: Energy Analyses
Supporting case-study*	TarjaM
Scenario definition*	4944205ad9dd4bd58b69b4b9efcd7f88
Control variables*	null
Objective*	null
Environment variables*	null
Control rules*	null
Actors*	null
When applicable*	null
Learning outcomes*	null
Supporting resources*	null

Use case 44:

INSTRUCT Back to homepage A+ A- R

Use-case id*	1
Use-case title*	A zero energy house in Finnish climate (BLOK)
Use-case type*	Real-world application
Funding source*	-
Project title*	A zero energy house in Finnish climate (BLOK)
Web link*	https://www.rehva.eu/rehva-journal/chapter/a-net-zero-energy-building-in-finlanda-net-zero-energy-building-in-finland
Targeted discipline*	Architectural design/HVAC engineering
Building type*	Domestic
Project type*	New Build
Lifecycle applicability*	Design, construction, in use
Brief description of case-study*	The building was designed based on architecture competition organised by Saint-Gobain ISOVER in co-operation with Finnish Association of Architects SAFA, Rakennuslehti Building and construction magazine, VTT Finnish Technical Reseach Centre and WWF World Wide Fund for Nature. The competition was big and all together 81 proposals were achieved. The selection of the winning proposal was hard due to many very good solutions. The winning proposal was named as BLOK and it was designed by architects Tiina Antinoja Olli Metso from Muuan Studio.
Key highlights*	Air tightness: 0, 4 m3/m2h with 50 Pa G-value glass: 0, 49 U-value Exterior wall: 0, 09 W/m2K U-value Roof: 0, 06 W/m2K U-value Base floor: 0, 09 W/m2K U-value Window: 0, 75 W/m2K U-value Door: 0,6-0,75 W/m2K Energy demand: 53 kWh/m2 Building year: 2014 Renewable energy sources: photovoltaic and heat solar panels.
Supporting case-study*	The cornerstone in design was to first minimise the energy demand for heating, cooling and electricity use, and then to cover the energy use by building integrated energy production at the yearly balance level. The main heating source was ground source heat pump but also solar heat can serve a share of heating use. In addition the building was equipped with a fire place capable to store some heat in its massive structures. The space heating was distributed with a floor heating maximising the use of solar heat (low exergy system). The ground source heat pump efficiency SPF (seasonal) was 3.5 for space heating and 2.5 for domestic hot water heating. The solar thermal collector system was faced towards south with an angle of 15-30 degree from horizontal and the collector surfaces area was 6 m2. (text source: Airaksinen M., Shemeikka J., Jokinen J., 2014 Reheva Journal) The surface area of the photovoltaic system was 80 m2. Also the PV system was installed in the southern facade of the roof at the same angle as the solar thermal collectors. The PV system consists of 72 CIS-type thin film modules. The system is has 3 inverters each rated for 3 kW power. The structures were designed for high thermal resistance, corresponding very low energy building structures in Finnish climate. The window solar heat transmission factor (g-value) was 0.49 except for the west facade 0.34. The air tightness of the envelope at 50 Pa was 0.4 m3/m2h (measured value). (text source: Airaksinen M., Shemeikka J., Jokinen J., 2014 Reheva Journal) The efficiency of the heat recovery unit in the ventilation system is designed for 80% and the set point temperature for heat exchange surface freezing is -10°C, corresponding a yearly heat recovery efficiency rate of 76% for the ventilation system. The calculated delivered energy is 8200 kWh yearly corresponding 53 kWh/-living-m2. Roughly 60% of the energy is used for heating and ventilation. The cooling system was integrated in the ventilation system to cool the supplied air. (text source:Emeric Ryckaert, 2017)
Scenario definition*	-
Control variables*	-
Objective*	-
Environment variables*	-
Control rules*	-
Actors*	-
When applicable*	-
Learning outcomes*	-
Supporting resources*	https://www.rehva.eu/rehva-journal/chapter/a-net-zero-energy-building-in-finlanda-net-zero-energy-building-in-finland https://www.theseus.fi/bitstream/handle/10024/132631/Thesis_Emeric_Ryckaert.pdf?sequence=1&isAllowed=y

Use case 45:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	RATINA shopping center
Use-case type*	Real-world application
Funding source*	-
Project title*	RATINA shopping center
Web link*	https://www.ratina.fi/en/info/
Targeted discipline*	Architectural design/ Structural engineering/ Mechanical engineering
Building type*	Public
Project type*	New Build
Lifecycle applicability*	Design, construction, In use
Brief description of case-study*	Ratina, the largest shopping centre in Tampere. Ratina is the largest shopping centre in Tampere. The shopping centre consists of three buildings: the newly constructed Ratina building and the renovated 1930s functionalist buildings Ranta-Ratina (formerly known as the Autotuonti building) and Ratinan Kulma (formerly known as the Vuoltsu building). There is interior access between the three buildings.
Key highlights*	At Ratina, environmental responsibility and energy efficiency were taken into account starting from the shopping centre�s design phase. The shopping centre was designed to meet the requirements for BREEAM� Very Good environmental certification. Ratina features several technical solutions that promote ecofriendliness and energy efficiency: - The cooling systems utilise the cold water masses that flow through Ratina Bay. - This has a significant impact on the shopping centre�s energy efficiency: the use of cold water from the bay reduces the consumption of electricity for the shopping centre�s cooling by an estimated 75% compared to typical cooling systems that use air condensers. - The heat generated by the refrigeration equipment of shops will be used for heating the property. - The air that circulates through the shopping centre will be used to heat the parking facilities. - There are a total of 26 charging stations for electric cars on both levels of Ratina�s indoor car park. The charging stations are intended for hybrid and electric cars. - The general lighting of the shopping centre and its shops is based on energy-efficient LED lights. - In addition to technical solutions, the choices of equipment and materials at Ratina were made with the aim of maximising responsibility. - The shopping centre will collect, sort and recycle waste as efficiently as possible. The shopping centre has a recycling station that is available to its customers. - Ratina is committed to using electricity generated from renewable sources. The shopping centre has acquired guarantees of origin for Nordic EKOenergy certified wind power production to cover all of the electricity consumed by the property itself. EKOenergy is an international ecolabel developed by the Finnish Association for Nature Conservation. - Ratina shopping center recovers 70,000 m3/h of clean hot air. This grease-reduced air makes it possible to recover heat energy over 2 TWh annually, corresponding to savings up to MEUR 2 in energy costs, and over 800 tons of reduced CO2 emissions.
Supporting case-study*	-
Scenario definition*	-
Control variables*	-
Objective*	-
Environment variables*	-
Control rules*	-
Actors*	-
When applicable*	-
Learning outcomes*	-
Supporting resources*	https://www.epressi.com/media/userfiles/110643/1524025483/ratina_shopping_centre_facts.pdf https://www.ozonetech.com/de/node/917

Use case 46:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	BIM application to building energy performance visualisation and management
Use-case type*	Real-world application
Funding source*	EPSRC funding (EP/G037272/1)
Project title*	Industrial Doctorate Centre: Innovative and Collaborative Construction Engineering
Web link*	https://www.sciencedirect.com/science/article/pii/S0378778817308770
Targeted discipline*	Energy engineering
Building type*	Public
Project type*	Existing
Lifecycle applicability*	In use
Brief description of case-study*	The case study was based on a 30,500 m2, 3000 person non-domestic office building completed in 2013. It aimed for extensive monitoring and environmental control for energy use reduction, in conjunction with high-resolution measurement of space, system and equipment performance. Monitoring was achieved using a BMS, recording information from thousands of sensors throughout the building, storing results in a Structured Query Language (SQL) database. Practice-led research was used to identify the barriers in-place for widespread BIM application to building performance monitoring, through development of as-built models for simulation, creation of a performance attributable and accessible BIM model and an interface between these environments and monitored performance information.
Key highlights*	BIM model for building energy performance visualisation and Information management
Supporting case-study*	BIM model for building energy performance visualisation and Information management
Scenario definition*	IES-VE: Modelling and simulation of building performance Autodesk Revit: Modelling and attribution of descriptive performance meta-data to objects &spaces within the BIM model Autodesk Dynamo: Attribution of simulated performance output to Autodesk Revit model Extraction of geometry and meta-data from Autodesk Revit into a lightweight data-interchange format Python (Pandas, Matplotlib, ipywidgets):Extraction of data from BMS SQL Server; Cleaning of extracted data; Code interlinking JSON file with query-able performance data
Control variables*	The case study evaluates the potential for use of building information modelling (BIM) as a tool to support the visualisation and management of a building's performance; demonstrating a method for the capture, collation and linking of data stored across the currently disparate BIM and building management system (BMS) data environments. Its intention is to identify the barriers facing implementation of BIM for building designers and operators as a performance optimisation tool. The method developed links design documentation and metered building performance to identify the technological requirements for BIM and building performance connection in a real-world example.
Objective*	BIM for building energy performance visualisation and management
Environment variables*	It recognises the need for more effective data management in both design and operation to support interlinking of these data-rich environments. Requirements for linking these environments are proposed in conjunction with feedback from building designers and operators, providing guidance for the production and sourcing of data to support building performance management using BIM.
Control rules*	https://www.sciencedirect.com/science/article/pii/S0378778817308770#bib0045
Actors*	Yu
When applicable*	4f6abbfc560f447f838f2ac8f15dcfba
Learning outcomes*	null
Supporting resources*	null

Use case 47:

Back to homepage | A+ | A- | R

Use-case id*	1
Use-case title*	Continuous-time Bayesian calibration of energy models using BIM and energy data
Use-case type*	5 test cases and 1 real-world application
Funding source*	Singapore�s National Research Foundation (NRF) [grant number BCA RID 94.17.2.6]
Project title*	Lifecycle BIM Integration with Energy MM&V for Net Zero Energy Building
Web link*	https://ideaslab.io/project/lifecycle-bim/
Targeted discipline*	Energy engineering
Building type*	Public
Project type*	Existing
Lifecycle applicability*	In use
Brief description of case-study*	The five geometric benchmark test-cases were created based on ASHRAE Research Project 1468, and are used to ensure compliance of the BIM to BES translation with gbXML�s standards for geometry accuracy and information integrity. The real case study building is an office building located on the campus of the National University ofSingapore (NUS) in Singapore. The building consists of 3 blocks each 3-story high with a total gross floor area of 5445 m2. The air-conditioning and mechanical ventilation (ACMV) system is a variable air volume system served by a central district cooling system. Given Singapore�s tropical climate, no heating is required and the ACMV system is required to operate throughout the year to maintain thermal comfort within the building. The BIM was created using Revit and contains both the actual construction layers and material properties. 3 years of electrical energy consumption data at a monthly resolution from 1 January 2014 to 31 December 2016 were collected and used to evaluate the proposed framework as illustrated in Fig. 1. The weather file used for calibration is the Actual Meteorological Year (AMY) weather data from the Singapore Changi airport weather station (WMO #486980).
Key highlights*	Continuous calibrationBayesian calibrationUncertainty analysis
Supporting case-study*	The study proposed a framework for the continuous-time Bayesian calibration of building energy simulation (BES) models using data from building information models (BIM), as well as energy data from the building energy management system (BEMS). To extract useful information from a BIM, a BIM to �ready-to-simulate� BES framework was proposed by integrating user-defined information and data from standards and references into the translation process. The proposed continuous Bayesian calibration method extends Kennedy and O�Hagan�s Bayesian calibration approach into a continuous calibration framework by integrating the principles of a receding horizon or model predictive control.
Scenario definition*	CVRMSE (root mean square error) and NMBE (normalized mean biased error) are compared to ensure calibration accuracy
Control variables*	Through an actual building calibration case study, its BIM and three years of its monthly electrical energy consumption, the proposed framework could maintain prediction accuracy while reducing parameter posterior uncertainties
Objective*	BIM facilitated building energy calibration
Environment variables*	https://download.schneider-electric.com/files?p_enDocType=White+Paper&p_File_Name=998-20501257_WP-Bridging+BIM+and+BEM.pdf&p_Doc_Ref=998-20501257_WP
Control rules*	Yu
Actors*	4f6abbfc560f447f838f2ac8f15dcfba
When applicable*	null
Learning outcomes*	null
Supporting resources*	null

Use case 48:

Back to homepage | A+ | A- | R

Use-case id*	1
Use-case title*	Integrated BIM-GIS based design for high energy efficiency hospital buildings
Use-case type*	R&D
Funding source*	EU (7th Framework)
Project title*	Integrated BIM-GIS based design for high energy efficiency hospital buildings
Web link*	http://www.fupress.net/index.php/techne/article/view/19728
Targeted discipline*	Architectural Design
Building type*	Public
Project type*	New Build
Lifecycle applicability*	Design
Brief description of case-study*	The interoperability of the tools for managing and controlling the design process is one of the themes on which research and innovations are focussed in the field of BIM (Building Information Modelling) systems. A strategic objective of the STREAMER research, co-funded by the European Union within the context of the Seventh Framework Programme, that of defining the tools and methods of designing hospital buildings that allow for a reduction in energy consumption and emissions in large healthcare districts. Contributing to the achievement of this result is the creation of integrated tools, based on BIM and GIS systems, capable of providing an effective backup to the decisions of the various subjects involved in the project and the management of hospital complexes.
Key highlights*	The experimentation of the tools perfected in the STREAMER project in the procedures and management systems of the enlarging and retrofitting interventions in the hospital district of Careggi is still in progress. The results obtained so far have highlighted the potential of STREAMER, not only in terms of upgrading and refining the functions foreseen in the research project, but also in terms of their substantial expansion. This possibility depends however on the alignment, and where necessary, also on upgrading the software used to the most widely used standards. The same SACS system requires continuous updates which however, thanks to the rapid development of the ICTS, give rise to a constant expansion process of the platform. The progressive improvement of the levels of compatibility of the data and the interoperability of the two systems nevertheless allow for glimpsing interesting prospects for development and innovation. Moreover, the challenge of standardising the methods of access, interpretation and exchange of data, as well as the defining of a semantic ontology that could be shared by all the countries involved in the project, has already been envisaged during the phase of developing the research programme. The project has therefore had to tackle the difficulties and limits of the data exchange among the different type of software used in the tool set of the Dashboard. Although the IFC is by a consolidated standard for importing and exporting data in the BIM environments, the format has not yet assumed the dissemination standard (as in the case of the CAD formats) necessary for making the software that has to reprocess the information of the BIM models really interoperable and reliable in the results.
Supporting case-study*	The strategic objectives of the STREAMER project concern: � the development of a semantic model based on the classification and identification, by means of technical and performance specifications, of the "objects" on which to base the BIM modelling of a hospital building; � the drawing up of innovative plan of the design process based on the co-ordination, co-operation and active participation by all the categories of stakeholders involved; � the defining of parameters, indicators (KPIs - Key Performance Indicators) and threshold values of the relative performance relating to energy efficiency, costs and quality; � the creation of back-up tools for the decision-making, concentrated during the initial phases of the design process, capable of managing, processing and comparing the data coming from functional modelling software and from calculation instruments of the levels of energy efficiency.
Scenario definition*	A strategic objective of the project is the perfecting of tools and methods for the design of interventions allowing for a 50% reduction of energy consumption and emissions of carbon dioxide by the large healthcare districts, notoriously among the most energy-intensive and polluting users. The achievement of this result passes through the creation of advanced and integrated design tools based on BIM and GIS systems that are capable of guiding the choices of all the subjects involved in the project and in the management of hospital complexes, towards optimisation and energy efficiency. Tools that only concern the first phase of the design process, from the definition of the strategic objectives up to the preliminary project.
Control variables*	Publication
Objective*	Richard
Environment variables*	1c9b9413ce4b4ad59a5e8bb4eab3ecf2
Control rules*	null
Actors*	null
When applicable*	null
Learning outcomes*	null

Use case 49:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	BIM for energy efficiency in housing refurbishments
Use-case type*	R&D, Real-world application
Funding source*	UK Government (Innovate UK)
Project title*	BIM for energy efficiency in housing refurbishments
Web link*	http://eprints.hud.ac.uk/id/eprint/25689/
Targeted discipline*	Design, Surveying
Building type*	Domestic
Project type*	Renovation
Lifecycle applicability*	In-use
Brief description of case-study*	Building Information modelling offers potential process and delivery improvements throughout the lifecycle of built assets. However, there is limited research in the use of BIM for energy efficiency in housing refurbishments. The UK has over 300,000 solid wall homes with very poor energy efficiency. A BIM based solution for the retrofit of solid wall housing using lean and collaborative improvement techniques will offer a cost effective, comprehensive solution that is less disruptive, reduces waste and increases accuracy, leading to high quality outcomes. The aim of this research is to develop a BIM based protocol supporting development of 'what if' scenarios in housing retrofits for high efficiency thermal improvements, aiming to reduce costs and disruption for users. The paper presents a literature review on the topic and discusses the research method for the research project (S-IMPLER).
Key highlights*	The Solid Wall Innovative Insulation and Monitoring Processes uses Lean Energy Efficient Retrofit (S-IMPLER) research project, with a focus on the BIM implementation for retrofit of No Fines Concrete (NFC) solid wall housing. S-IMPLER, in receipt of funding from Innovate UK aims to investigate the retrofit of solid wall housing, to achieve a 60% reduction in monitored energy costs, with less disruption, at least 10% faster, without reductions in quality & safety. The research is a joint activity working with a housing association, two SMEs, a contractor, academic institutions, a lean consultant and a construction research organisation. Several innovations from the research will be combined into a single attractive commercial proposition: � an innovative surveying tool; � a BIM tool to allow client modelling of different options with costs and benefits; � a whole house monitoring system to assess real energy performance; � a new solid wall retrofit Certification scheme to transfer knowledge and assure quality.
Supporting case-study*	The expected BIM outputs for the SIMPLER research are improved multidisciplinary work flows and communication, reduced coordination issues, improved productivity, creative solutions, cost reductions to meet the SIMPLER research aims. The BIM development for the project is supported through the selection of BIM authoring software, a BIM Object library concept and the development of BIM process and protocols. Energy modelling based on a 3D BIM model will inform design and specification decisions through the iterative refinement cycles. The predictive performance modelling to calculate the building�s expected energy demand and the projected running costs and CO2 emissions will be evaluated and compared against actual performance measurements derived from whole house monitoring.
Scenario definition*	Publication
Control variables*	Richard
Objective*	1c9b9413ce4b4ad59a5e8bb4eab3ecf2
Environment variables*	null
Control rules*	null
Actors*	null
When applicable*	null
Learning outcomes*	null
Supporting resources*	null

Use case 50:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Optimising energy consumption in building designs using BIM
Use-case type*	R&D, real-world application
Funding source*	Client
Project title*	Optimising energy consumption in building designs using BIM
Web link*	https://www.degruyter.com/downloadpdf/j/sjce.2016.24.issue-3/sjce-2016-0013/sjce-2016-0013.pdf
Targeted discipline*	Architectural design
Building type*	Public
Project type*	New Build
Lifecycle applicability*	Design
Brief description of case-study*	Given the ability of a Building Information Model (BIM) to serve as a multi-disciplinary data repository, this paper seeks to explore and exploit the sustainability value of Building Information Modelling/models in delivering buildings that require less energy for their operation, emit less CO2 and at the same time provide a comfortable living environment for their occupants. This objective was achieved by a critical and extensive review of the literature covering: (1) building energy consumption, (2) building energy performance and analysis, and (3) building information modeling and energy assessment.
Key highlights*	The literature cited in this paper showed that linking an energy analysis tool with a BIM model helped project design teams to predict and create optimized energy consumption. To validate this finding, an in-depth analysis was carried out on a completed BIM integrated construction project using the Arboleda Project in the Dominican Republic. The findings showed that the BIM-based energy analysis helped the design team achieve the world's first 103% positive energy building. From the research findings, the paper concludes that linking an energy analysis tool with a BIM model helps to expedite the energy analysis process, provide more detailed and accurate results as well as delivering energy-efficient buildings. The study further recommends that the adoption of a level 2 BIM and the integration of BIM in energy optimization analysis should be made compulsory for all projects irrespective of the method of procurement (government-funded or otherwise) or its size.
Supporting case-study*	Publication
Scenario definition*	Richard
Control variables*	1c9b9413ce4b4ad59a5e8bb4eab3ecf2
Objective*	null
Environment variables*	null
Control rules*	null
Actors*	null
When applicable*	null
Learning outcomes*	null
Supporting resources*	null

Use case 51:

Back to homepage | A+ | A- | R

Use-case id*	1
Use-case title*	Harmonised Building Information Speedway for Energy-Efficient Renovation
Use-case type*	R&D
Funding source*	European Union
Project title*	BIM-SPEED
Web link*	https://www.bim-speed.eu/en
Targeted discipline*	architects, HVAC engineers and construction firms
Building type*	Domestic
Project type*	Renovation
Lifecycle applicability*	In Use
Brief description of case-study*	The project aims to enable all stakeholders to adopt BIM to reduce the time of deep renovation projects by at least 30% by providing them with: 1) an affordable BIM cloud platform, 2) a set of inter-operable BIM tools, and 3) standardised procedures for As-Built data acquisition, modelling, simulation, implementation and maintenance of renovation solutions
Key highlights*	Building renovation; energy saving; modelling; simulation
Supporting case-study*	The project relies on a trans-disciplinary approach comprising (i) process, (ii) ICT, and (iii) social innovation with a special attention to the stakeholders as a key success factor for BIM adoption. The developped tools for renovation will be available free-of-charge and the holistic solution will be tested on the demonstration cases.
Scenario definition*	BIM-SPEED demonstrates the holistic solution in 13 real demonstration cases, where are performed the following activities: (1) As-Built data acquisition and BIM modelling, (2) Renovation design, (3) BEM and performance simulations, (4) Renovation execution (off-site and on-site construction), (5) Post-renovation evaluation and long-term maintenance planning.
Control variables*	Testing the KROQI Cloud platform integration architecture with the demonstration cases, as a tool/ solution for the project's objectives. Other potential tools examined are the integration of GIS into renovation project, the development of a BIM passport, 3D Scan to BIM, comfort eye tool and the AR/VR technology.
Objective*	?o take �BIM for renovation� to a deep renovation level for at least 60% energy saving, and to accelerate the market uptake across the EU
Environment variables*	CO2 emissions, annual energy consumption.
Control rules*	The results of the developed tools to the demonstration cases, which cover all Europe�s climatic geo-clusters and varying levels of BIM experience in different countries.
Actors*	8 SMEs, 3 large industries, 2 research organisations, 3 higher education establishment, 1 public body, 4 non-profit organisations of EU professional associations (9 EU countries)
When applicable*	October 2022
Learning outcomes*	The project will engineer the integration and quick installation of building and HVAC products for renovation into the existing buildings, aiming at achieving energy efficiency in existing buildings with overall time reduction.
Supporting resources*	not available yet

Use case 52:

Back to homepage | A+ | A- | R

Use-case id*	1
Use-case title*	Integrating BIM and energy analysis tools with green building certification system to conceptually design sustainable buildings
Use-case type*	Real world application
Funding source*	Client
Project title*	Integrating BIM and energy analysis tools with green building certification system to conceptually design sustainable buildings
Web link*	https://www.itcon.org/papers/2014_29.content.06700.pdf
Targeted discipline*	Architectural design
Building type*	Public
Project type*	New Build
Lifecycle applicability*	Design
Brief description of case-study*	The main objective of this paper is to propose an integrated methodology that links BIM and energy analysis tools with green building certification systems. This methodology will be applied at the early design stage of a project's life. It will help designers measure and identify potential loss or gain of energy for different design alternatives and calculate the potential LEED points they may accumulate and gain and accordingly select the best one. An actual building project will be used to illustrate the workability and capability of the proposed methodology.
Key highlights*	The development of the model described in this paper focuses on automating the process of connecting the output of the BIM module with other different modules, (energy analysis and day lighting simulation, embodied energy of the building's components and Green Certification System and associated costs). The model is an integrated tool that helps owners and designers share a variety of information at the conceptual design stage of sustainable buildings. It assists designers in comparing and evaluating each design family and its associated components that are selected during the conceptual design taking into consideration the materials' selection criteria.
Supporting case-study*	� Investigate the feasibility of creating full integration between BIM, Energy and lighting analysis tools, � Collect, create and store series of design families that incorporate sustainably certified components in a database in an attempt to improve the workability and capability of the BIM tool used to do sustainable design at the conceptual stage. � Create and develop an efficient framework for this Integration that takes into consideration the sustainable design requirements and the functionality of the BIM tool � Develop a BIM sustainable design model that incorporates the five previously mentioned modules, � Analyze the data and information associated with the proposed building's model, which is transmitted during the transformation process from one file format to another to identify how much of this data was retained and how much was lost
Scenario definition*	Publication
Control variables*	Richard
Objective*	1c9b9413ce4b4ad59a5e8bb4eab3ecf2
Environment variables*	null
Control rules*	null
Actors*	null
When applicable*	null
Learning outcomes*	null
Supporting resources*	null

Use case 53:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Energy aware BIM Cloud Platform in a Cost-effective Building Renovation Context
Use-case type*	BIM tools
Funding source*	EU- Horizon
Project title*	ENCORE
Web link*	http://encorebim.eu/
Targeted discipline*	architecture studios, designers, constructors, tenants, or public administration
Building type*	Domestic
Project type*	Renovation
Lifecycle applicability*	In Use
Brief description of case-study*	ENCORE project will create a system that integrates services for data acquisition from the buildings like Static LiDAR setups and LiDAR or photgrammetry equipment embarked in UAVs. It will also involve dwellers in the process by providing them with mobile tools to capture images or other in-doors information.
Key highlights*	energy efficiency gains; renovation alternatives; mobile tools
Supporting case-study*	It provides support to architects and designers in the creation of the 3D models from the acquired data, automatically identifying and classifying the constructive elements, and allowing them to complete the model with existing BIM resources. They will be able to modify the model, presenting the energy efficiency gains of different renovation alternatives, including the impact in the overall budget.
Scenario definition*	The developpment of a BIM Cloud-based solution that will offer several services to all the stakeholders in the renovation life-cycle: data acquisition/surveying of the properties/buildings (interior and envelop), supported generation of BIM Models from Point Clouds or Photogrammetry, semantic classification of components, manipulation of BIM models to perform energy efficiency simulations, use of Augmented Reality/Mixed Reality techniques to provide quick feedback, automatic generation of tasks for the construction crews
Control variables*	ENCORE will be valided in real life conditions, for the renovation of social buildings (demonstration dwellers).
Objective*	To boost renovation industry and to increase the share of renovated stock in Europe by providing effective and affordable BIM tools that cover the whole renovation life-cycle for achieving higher energy efficiency
Environment variables*	The use of the model in real dwellers in real renovation will link energy efficiency to comfort parameters, which are measurable.
Control rules*	There are two demonstrator housings ("Pattern" and "Experimental") available, the "Pattern" housing is used as a reference and the "Experimental" housing is used to evaluate different renovation strategies and measure their effectiveness.
Actors*	INSTITUT FOR ANGEWANDTE SYSTEMTECHNIK BREMEN GMBH, RTD TALOS LIMITED,UNIVERSITA POLITECNICA DELLE MARCHE, UNIVERSIDAD DE LA LAGUNA, SVEUCILISTE U ZAGREBU FAKULTET ELEKTROTEHNIKE I RACUNARSTVA,BIM EQUITY A/S, LAURENTIA TECHNOLOGIES SLL, SUPERACAO-CONSULTORIA, PROJECTOS, ESTUDOS E ACCESSORIAS LDA, EIDGENOESSISCHE TECHNISCHE HOCHSCHULE ZUERICH, CONSEJERIA DE SANIDAD Y POLITICAS SOCIALES - JUNTA DE EXTREMADURA, CONSIGLIO NAZIONALE DELLE RICERCHE,SMARTGATEWAYS LTD
When applicable*	By Feb 2022.
Learning outcomes*	BIM tools will cover the renovation from data collection to project execution, and commissioning/delivery, tackling energy efficiency and comfort parameters.
Supporting resources*	Not available yet

Use case 54:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Energy Performance Certificates supported by BIM Scanning
Use-case type*	R&D
Funding source*	European Commission
Project title*	EPC RECAST
Web link*	https://cordis.europa.eu/project/id/893118
Targeted discipline*	EPC assessors
Building type*	Domestic
Project type*	Existing
Lifecycle applicability*	Use
Brief description of case-study*	EPC RECAST works on the development of the next-generation of Energy Performance Certificates (EPCs). The concept includes the use of BIM scanning technology to facilitate the overall EPC assessment process.
Key highlights*	In the context of EPCs, the exploitation of image recognition technologies linked to BIM modelling will support both accuracy and simplicity of buildings / dwellings� geometry measurements and data collection.
Supporting case-study*	The EPC RECAST new generation EPC will be delivered for at least 70 buildings / covering over 150 dwellings in 6 EU countries (France, Germany, Spain, Italy, Slovakia, and Luxembourg)
Scenario definition*	Supporting EP assessors for a robust, modern and user-friendly data collection process, favoring comparable good quality
Control variables*	Geometrical data required to deliver an EPC (Energy Performance Certificate)
Objective*	In order to perform the EPC RECAST certification process, inputs regarding the building characteristics and energy-related measured data (for existing buildings) are required. Strongly relying on a user-centric perspective (here professional EPC assessor), the data model (DM) of the building will be created by collecting all building features in a simple BIM model (IFC format) generated semi-automatically with low user action, using BIMEO�s AR2BUILD technology to provide geometrical information (facilitation and reliability of the on-site data collection). Additionally, in countries or situations where EPCs are delivered for entire buildings (multifamily), infra-red camera equipped drones might be used to obtain 2D and 3D mapping of building envelopes (technology brought by ENGIE). Furthermore, the EPC assessors will be driven through a structured interface to collect all semantic data needed to calculate the KPIs and produce the EPC RECAST certificate . These geometry and semantic models will be converted to BEM (Building Energy Modelling) models34 compliant with the energy performance assessment according to the ISO/CEN standards developed under Commission mandate M/480, which will be used to fed energy simulation modules. Energy-related measured data will be obtained from smart meters or directly from the energy providers, from connected devices (including thermostats and heating controls) and IoT devices available in the dwellings. Alongside energy consumption and building�s semantic data, the certifier is asked � from a structured supporting interface � to adjust the existing input parameters (ex. for the material thermal conductivity which remains difficult to characterize and may deteriorate over years) and several input parameters, such as materials information or regular usage of the rooms to improve the certification process; a survey methodology to obtain such information will also be present in the input layer. In the end, public or accessible datasets will also be exploited to enrich and facilitate data collection (ex. description of the surrounding built environment and topography).
Environment variables*	AR2BUILD technology allows obtaining BIM-IFC digital models from dwellings/rooms visit and image capture with smartphone technologies (camera)
Control rules*	AR2BUILD technology makes it possible to scan a room, including floor, ceiling, wall, openings (doors and windows) with little user interaction. After scanning the room AR2BUILD offers the possibility to edit the capture annotating components of the room, enriching the semantics. The final output is an open-standard IFC digital model.
Actors*	In EPC RECAST the BIM scanning technology (AR2BUILD) is brought by BIMEO, a French SME - https://www.bimeo.fr
When applicable*	Residential buildings that want to get an updated EPC (e.g. EPC required for a real-estate transaction)
Learning outcomes*	An innovative use of BIM scanning technology in the context of Energy Performance Certificates which is currently rather / mostly based on theoretical calculations, not on actual measurements
Supporting resources*	BIMEO website presenting their technology : https://www.bimeo.fr EPC RECAST deliverables not available yet (project started in September 2020 and finishing December 2023)

Use case 55:

Use-case id*	1
Use-case title*	Train-to-nZEB
Use-case type*	R&D, Real-world application
Funding source*	Horizon2020
Project title*	Train-to-nZEB The Building Knowledge Hubs
Web link*	http://www.train-to-nzeb.com/
Targeted discipline*	Architectural Design, Building Construction, Energy Performance, HVAC
Building type*	Other
Project type*	New Build
Lifecycle applicability*	Design and Construction
Brief description of case-study*	The Train-to-NZEB project provides world-class training on energy efficiency and RES in buildings, based on new training programmes, business plans and up-to-date training equipment for five training and consultation centers around Europe. Along with the new training programmes on energy efficiency and RES in buildings, that were developed and the dozens of training courses that were conducted, invaluable asset of Train-to-nZEB is the web application created, that helps learning tips and tricks to make our homes energy efficient with key learning material and quizzes.
Key highlights*	Development of training programmes and materials on energy efficiency and RES in buildings. Conduction of trainings. Web/Google Play Store Application development with key information and learning material.
Supporting case-study*	Not-applicable
Scenario definition*	Not-applicable
Control variables*	Not-applicable
Objective*	Not-applicable
Environment variables*	Not-applicable
Control rules*	Not-applicable
Actors*	Not-applicable
When applicable*	Not-applicable
Learning outcomes*	Not-applicable
Supporting resources*	Project's deliverables available at: http://www.train-to-nzeb.com/what-weve-delivered.html

Use case 56:

Use-case id*	1
Use-case title*	Fit-to-nZEB
Use-case type*	R&D, Real-world application
Funding source*	Horizon2020
Project title*	Fit-to-nZEB Innovative Training Schemes for retrofitting to nZEB levels
Web link*	http://www.fit-to-nzeb.com/
Targeted discipline*	Architectural Design, Building Construction, Energy Performance, HVAC
Building type*	Other
Project type*	Renovation
Lifecycle applicability*	Renovation and retrofitting
Brief description of case-study*	The project is designed to increase competence and skills of the building professionals in the field of retrofitting to NZEB-levels in Czech Republic, Romania, Bulgaria, Italy, Croatia, Ireland, Austria and Greece through the unique educational programmes developed which will contribute to both the quality and the scale of the deep energy building renovations.
Key highlights*	Thoroughly developed web Catalogue of learning outcomes consisting of new knowledge, skills and responsibility needed for the different qualification levels, divided in 17 topics on retrofitting to nZEB levels. Design of demonstration and training models. Training programmes for: higher education establishments; professional colleges and high schools; specialization of adult workers. Scheme for validating of knowledge, skills and competences acquired at the workplace. Thoroughly and meticulously developed educational content on building renovation all available online and free to download on the project website: http://www.fit-to-nzeb.com/objectives--results.html
Supporting case-study*	Not-applicable
Scenario definition*	Not-applicable
Control variables*	Not-applicable
Objective*	Not-applicable
Environment variables*	Not-applicable
Control rules*	Not-applicable
Actors*	Not-applicable
When applicable*	Not-applicable
Learning outcomes*	Not-applicable
Supporting resources*	Project's deliverables available at: http://www.fit-to-nzeb.com/objectives--results.html

Use case 57:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Professional High-school of Construction and Architecture, Pazardzhik
Use-case type*	Real-world Application
Funding source*	Ministry of Education, Bulgaria
Project title*	nZEB Laboratory: Professional High-school of Construction and Architecture, Pazardzhik
Web link*	Not-applicable
Targeted discipline*	Architectural Design, Building Construction, Energy Performance, HVAC
Building type*	Other
Project type*	New Build
Lifecycle applicability*	Design and Construction
Brief description of case-study*	The project establishes a building knowledge hub on nZEB in the existing building of the Professional High-school of Construction and Architecture in Pazardzhik, Bulgaria.
Key highlights*	The actual establishment of the building knowledge hub on nZEB is supplemented by the development of ? handbook on energy efficient and ecological construction in whose development the high-school staff took participation. The handbook itself is used in the newly adopted by the high-school subject on energy efficient and ecological construction that takes place in the building knowledge hub. To complete the process the teacher staff was trained to use Thermal Bridge Calculation Software in order to spread the knowledge to the students and plan and conduct any future renovations in the school more precisely in terms of energy consumption and energy performance of building components.
Supporting case-study*	Not-applicable
Scenario definition*	Not-applicable
Control variables*	Not-applicable
Objective*	Not-applicable
Environment variables*	Not-applicable
Control rules*	Not-applicable
Actors*	Not-applicable
When applicable*	Not-applicable
Learning outcomes*	Not-applicable
Supporting resources*	Not-applicable

Use case 58:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	BIM supporting solar architecture
Use-case type*	R&D and real-world application
Funding source*	European Commission
Project title*	BIMSolar & PV-SITES
Web link*	https://www.pvsites.eu/software/
Targeted discipline*	Solar architecture
Building type*	Public
Project type*	New Build
Lifecycle applicability*	Concept Design
Brief description of case-study*	BimSolar is Digital BIM platform dedicated to Solar Energy coupled with Architectural design, Engineering and Construction
Key highlights*	The platform provides : 1) Decision support, feasibility studies, optimization for Building Applied and Integrated PhotoVoltaics (BAPV & BIPV) 2) Cell, module, transparency: a configurator for PV layouts, inverter and wiring 3) BIM prescription within the master project, expert collaboration in connected mode
Supporting case-study*	Software developed by EnerBIM / CADCAMation. The software embeds a library of innovative BIPV / BAPV materials from industrial manufacturers - in the context of the PVSITES H2020 project, the BIPV glass from the Spanish Onyx Solar manufacturer has been incrementally implemented into the software
Scenario definition*	BIMSOLAR works as a Software as a Service platform, providing support to every stakeholder involved in solar building design. eCatalogs feed in solar PV simulation with specific BIPV parameters, enriching virtual design facilities and improving thermal and visual performance. Showcasing BIPV products inside virtual workspaces supports supply chain actors and designers helping them to start a direct relationship with commercial commitment.
Control variables*	n.a.
Objective*	The PVSITES software suite is based on the BIMsolar platform developed by CADCAMation. It allows professional and academic users to easily model and evaluate BIPV projects in terms of: 1) Architectural design 2) Energy production Thermal impact 3) Light transmission
Environment variables*	A user-friendly interface guides you through iterative steps: Import of building 3D models from various formats, including BIM, such as .skp (SketchUp), .ifc (openBIM), .gbXML (Green Building) and .idf (EnergyPlus) Selection of project location and built-in download of corresponding weather data Visualization of irradiance on all surfaces of the 3D model Optional import of existing BIPV products in the software, or assisted self-design of products Easy, flexible layouting of BIPV modules and surfaces in various configurations (on roofs, facades, canopies, etc) Inverter selection and stringing of modules, either manual or automated Precise simulation of PV performance and including losses by shadowing and other factors Financial analysis to evaluate the project viability under different scenarios, including net-metering and self-consumption of electricity. Built-in database of all BIPV products developed within the PVSITES project Automated generation of project report Modelling of energy storage (batteries) and building energy management strategies Standardized optical simulation of glazing systems for skylights, ventilated facades etc Angular optical simulation of glazing systems for more accurate optical modelling of glazed products (tentative) Thermal simulation of glazing products (solar heat gain) and of modelled buildings (with EnergyPlus files)
Control rules*	n.a.
Actors*	Architects, Urban planners, BIPV / BAPV manufacturers, etc.
When applicable*	Primarily for new constructions that aim to reach an energy efficiency label / certification, but can also be used for energy efficient renovation
Learning outcomes*	In this case study, the BIM software platform is supporting the introduction of mature but still innovative construction materials (BIPV & BAPV) which are still rather rarely used in new constructions. It facilitates their introduction through an early visualisation of how the technology will look and impact the overall design
Supporting resources*	See reports and resources available at https://www.pvsites.eu/software/

Use case 59:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	nZEB Roadshow
Use-case type*	Other
Funding source*	Horizon 2020
Project title*	nZEB Roadshow
Web link*	www.mzebroadshow.eu
Targeted discipline*	Architectural Design / Mechanical Engineering / Blue collar construction workers / RES installers / Municipal energy managers
Building type*	Public
Project type*	Existing
Lifecycle applicability*	Design and Construction
Brief description of case-study*	The nZEB Roadshow will organize no less than 25 large-scale events for promotion of sustainable energy skills in Bulgaria, Croatia, Greece, Italy and Romania, featuring product exhibitions, job fairs, training courses, live demonstrations, games for children and media events. The initiative is open for external partnerships with potential hosts, exhibitors, training providers, employers, or project developers. It will feature BIM-assisted demonstrations, training sessions and real-time measurement and monitoring of building performance.
Key highlights*	Increasing demand for skilled construction services through involvement of end users and improving the understanding of the benefits of nZEBs
Supporting case-study*	n/a
Scenario definition*	n/a
Control variables*	n/a
Objective*	n/a
Environment variables*	n/a
Control rules*	n/a
Actors*	n/a
When applicable*	n/a
Learning outcomes*	n/a
Supporting resources*	n/a

Use case 60:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	BUSLeague
Use-case type*	Other
Funding source*	Horizon 2020
Project title*	BUSLeague
Web link*	n.a
Targeted discipline*	Architectural Design / Mechanical Engineering / Blue collar construction workers / RES installers / Municipal energy managers
Building type*	Domestic
Project type*	Existing
Lifecycle applicability*	Design and Construction
Brief description of case-study*	For sustainable stimulation of demand for energy skills, BUSLeague addresses five main challenges in an integrated approach: 1) Testing and Recognition of Skills, 2) Awareness by both the general public and workforce; 3) Lack of support of / request for the skilled professional by the public authorities; 4) Practical training & Lack of motivation and time; 5) Integration of new technologies and addressing new societal and technological trends
Key highlights*	Individual pilot actions to support the demand for skilled construction services involving practical training and demonstrations of digital technologies and improvement of the quality of the related training upply
Supporting case-study*	n/a
Scenario definition*	n/a
Control variables*	n/a
Objective*	n/a
Environment variables*	n/a
Control rules*	n/a
Actors*	n/a
When applicable*	n/a
Learning outcomes*	n/a
Supporting resources*	n/a

Use case 61:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	HIT2GAP & ZUTEC - Integrating BMS & BIM
Use-case type*	R&D & real-world application
Funding source*	European Commission (H2020)
Project title*	HIT2GAP & ZUTEC
Web link*	http://www.hit2gap.eu/blog/introducing-zutec-dimensions
Targeted discipline*	Facility management
Building type*	Public
Project type*	Existing
Lifecycle applicability*	In use
Brief description of case-study*	A real time connection between BMS and BIM, and a success story for the HIT2GAP project.
Key highlights*	Thanks to the work in HIT2GAP to develop ZUTEC Dimensions, real time connection between Building Information Models (BIM) and Building Management Systems (BMS) is now a reality: real time values from the installed data-points can be visualized in the 3-dimensional BIM environment
Supporting case-study*	Several pilots have been implemented in HIT2GAP including the Wilan�w City Town Hall building in Poland, and the engineering building of National University Galway
Scenario definition*	Rich visualization options facilitate facility management and allow measured values outside acceptable comfort and operation ranges to be easily visualized with different colors and alerts for fast and easy detection, thus reducing the energy performance gap.
Control variables*	BEM data (monitoring data, environmental data, etc.) are displayed on BIM models
Objective*	Zutec Dimensions provides one answer of how to valorize BIM models after construction is complete. Coupled to the Zutec construction management platform, it provides 3D virtual visualization of building and systems components, architectural and MEP parts of the BIM model both involved, real time visualization of the measured data from the BMS, technical information, documents, photos and other information materials directly accessible and integrated, snags list and asset lists for AHUs and other components in order to check needed actions and features of buildings zones, components and systems parts. Using it, stakeholders can view their project/building on their mobile device, tablet or desktop showing measurements in real or near real time.
Environment variables*	All type of data from sensors and meters can be displayed such as temperature, CO2, occupancy, windows opening, etc.
Environment variables*	All type of data from sensors and meters can be displayed such as temperature, CO2, occupancy, windows opening, etc.
Control rules*	n.a.
Actors*	Facility managers
When applicable*	Primarily for facility management, building management scenario, and for decision-support when looking at improving the overall energy efficiency of the building
Learning outcomes*	An illustration of the role of BIM combined with real-time building data to improve facility management
Supporting resources*	Watch the demo video of the Wilan�w and Alice Perry Buildings on the Zutec Youtube channel at https://www.youtube.com/watch?v=pitnxdaUfhl Success story factsheet : https://www.dropbox.com/s/eop8sbq2y1pbhvp/Succes%20story%20%235_Zutec%20Dimensions_V1.pdf?dl=0

Use case 62:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	BIM based tools for fast & efficient renovation (BIM4REN)
Use-case type*	R&D
Funding source*	European Commission (H2020)
Project title*	BIM4REN
Web link*	https://bim4ren.eu
Targeted discipline*	Building renovation
Building type*	Public
Project type*	Existing
Lifecycle applicability*	In use
Brief description of case-study*	Exploitation of BIM potential for the energy renovation of existing buildings for the whole construction value chain.
Key highlights*	Development of BIM based workflows dedicated to the renovation of residential buildings adapted to the complexity of targets of construction sector and put into a systematic and integrated workflows (IDDS).
Supporting case-study*	Real time testing in ongoing refurbishment operations allow project pilots to act as a user-centered, open-innovation ecosystem with co-creation, exploration, experimentation and evaluation of the deployed tools. BIM4REN includes pilots in Paris (Residential social housing), San Sebastian (Residential private), and Venice (Student dormitory)
Scenario definition*	BIM4Ren Tools & Digital Environment : Workflows are backboned by a novel, state of the art, open and decentralized environment, and BIM solutions on data collection, data management and data driven design are integrated into it.
Control variables*	n.a.
Objective*	On the basis of easy access, quick and straightforward operation, affordability and fast ROI with adapted business models, BIM4REN will be able to deliver an independent and collaborative service platform for all stakeholders to efficiently communicate and to optimize the management tasks and quality checks, during the supply or preparation phase, during the execution phase and further commissioning and operation.
Environment variables*	B4R digital ecosystem will be accessible via a web based One Stop Access Platform, where depending on each user profile and needs, orientation, best practice examples from a dedicated database and links to the different tools and services (from Top-grade to Entry-level) will be provided on differentiated access schemes underpinned by different business models.
Control rules*	n.a.
Actors*	Construction professionals, renovation specialists
When applicable*	Renovation of residential buildings
Learning outcomes*	BIM applied to renovation
Supporting resources*	BIM4REN deliverables available at https://bim4ren.eu/project-deliverables/

Use case 63:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	3D Scanning services (R2M Solution & Matterport)
Use-case type*	Real-world application
Funding source*	Industrial consultancy
Project title*	3D Scanning services
Web link*	https://www.r2msolution.com/innovative-products/digital-construction/
Targeted discipline*	Construction, Quality assurance
Building type*	Public
Project type*	Existing
Lifecycle applicability*	Design, in-use
Brief description of case-study*	Construction site progress and quality check can be offered through BIM-enabled services. The activity is based on the Matterport Pro2 3D camera that captures images and data from a real place for combining them into a complete 3D model. This service allows you to visually analyze a property, export the point cloud to generate an information model (BIM) and to shape the existing conditions to identify the differences with the project design.
Key highlights*	There are multiple benefits including : ONE MINUTE FOR SCANNING Each scan takes less than a minute: to scan 500 square meters, it takes only an hour. No leveling or registration marks are required because our powerful visualization pipeline aligns and combines your data on site. CLOUD DATA SYSTEM The scans are uploaded and then merged into a textured mesh in just a few hours. You can mark places and things with more information and share a link with stakeholders who can explore the model directly from their browser. MEASURE ANY DIMENSION WITH 99%* ACCURACY Scanning is not only fast, but also precise in order to generate point clouds for as built drawings, technical documentation and information models (BIM). You can export point clouds, 2D images, floor plans, mesh and much more.
Supporting case-study*	Several case studies implementing the Matterport technology available at : https://matterport.com/case-studies
Scenario definition*	n.a.
Control variables*	n.a.
Objective*	These are the services offered through such technology : FLOOR PLANS AND BIM MODELING Navigable 3D model, export floor plans and BIM development if not present CONSTRUCTION SITE PROGRESS Monitor your construction site and check the quality of your orders during the work phases DESIGNED � BUILT COMPARISON In yellow as compliant and in blue as it differs from the project design TAGS AND EXTRA CONTENT Use tags to attach data sheets, links and multimedia content to specific points in your 3D models 3D MEASUREMENTS Did you forget a size? Measure it on the 3D model � no return on the site
Environment variables*	n.a.
Control rules*	n.a.
Actors*	Construction workers, facility managers, building owners, etc.
When applicable*	Construction site progress monitoring, quality assurance scenarios
Learning outcomes*	How BIM can facilitate monitoring a construction site progress and check its quality, adherence to the initial design
Supporting resources*	Further information about the Matterport technology which is used for this service available at https://matterport.com

Use case 64:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Smart Living Technologies
Use-case type*	R&D
Funding source*	MIUR - Ministry of Education, University and Research (Italy)
Project title*	SHELL
Web link*	http://shell.smartlivingtech.it/en/
Targeted discipline*	N.A.
Building type*	Public
Project type*	Existing
Lifecycle applicability*	N.A.
Brief description of case-study*	N.A.
Key highlights*	N.A.
Supporting case-study*	N.A.
Scenario definition*	Today the communication between heterogeneous objects (electrical appliances, tablet, home automation system, home theatre) is possible thanks to the diffusion of electronic equipment, electrical appliances and personal devices. During years, devices are increasing their interconnection and integration, but in the real market, opportunities promoted by this interconnection are not so easy to achieve.
Control variables*	N.A.
Objective*	The first objective is to pass from potentiality to actualization, starting from market�s products, to promote business and develop research activities into new solutions, innovative business models, new opportunities. For this reason, the project proposes an interoperability, open, free, accessible framework; it is the crucial structure and the enabling tool for vertical solutions in different and multifunctional fields (energy, security, comfort). In this inls -Iterconnected way, the complete openness and accessibility to technologic infrastructures will encourage innovation. The model will be open, win to win, based on open innovation paradigms, and on cooperation actions between manufacturing enterprises and not, small, medium and large enterprises, to improve traditional business and create new opportunities. The programme also will analyse how to transform technological interoperability in commercial/business interoperability, through the creation of new professional profiles. The project boosts interoperability between home and automation devices on it; this interoperability grows energetic efficiency, safety and comfort. Home so is a functional and interoperable point, of a more widespread Smart Communities, open to new opportunities of Smart Cities.
Environment variables*	N.A.
Control rules*	N.A.
Actors*	energy manager, comfort manager, safety and security manager.
When applicable*	N.A.
Learning outcomes*	N.A.
Supporting resources*	N.A.

Use case 65:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Transparense - Increasing Transparency of Energy Service Markets
Use-case type*	R&d
Funding source*	European Union
Project title*	Transparense
Web link*	www.transparense.eu
Targeted discipline*	N.A.
Building type*	Public
Project type*	Existing
Lifecycle applicability*	N.A.
Brief description of case-study*	N.A.
Key highlights*	N.A.
Supporting case-study*	N.A.
Scenario definition*	N.A.
Control variables*	N.A.
Objective*	The objective of the project called Transparense was to increase the transparency and reliability of the Energy Performance Contracting (EPC) markets across Europe. Within the Transparense project, ESCOs will be offered high quality training programs and materials. Training programs are also planned in order to support the transfer of experience from more advanced EPC markets to less experienced ones. This transfer will also be supported by databases that provide an overview of the European EPC markets through specific information on existing ESCOs, associations, EPC models and initiatives promoting EPC, and will be made available to the public on the Transparense website.
Environment variables*	N.A.
Control rules*	N.A.
Control rules*	N.A.
Actors*	20 PARTNERS ACROSS EUROPE
When applicable*	N.A.
Learning outcomes*	N.A.
Supporting resources*	N.A.

Use case 66:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Renew School
Use-case type*	R&D
Funding source*	European Union
Project title*	Renew School
Web link*	www.renew-school.eu
Targeted discipline*	Architectural Design / Structural
Building type*	Public
Project type*	Existing
Lifecycle applicability*	n.a.
Brief description of case-study*	n.a.
Key highlights*	n.a.
Supporting case-study*	n.a.
Scenario definition*	School buildings are places of major public interest. Our children are educated in life�s basics, in some schools beyond that. Therefore not only the educational system itself, but also the conditions of these buildings are very important signals to the public, even to the pupils themselves. Schools were mostly built between 1950ies and 1980ies. Beside educational aspects the school buildings are presently in high need of renovation. Together with the discussions about future education the topic is on the political agenda. But even when the school buildings are in poor condition most of the school owners lack of financial resources to retrofit them in a comprehensive way.
Control variables*	n.a.
Objective*	The RENEW SCHOOL project aims at retrofitting a great amount of school buildings to highest nearly zero energy buildings (nZEB) standards. It will, by promoting appropriate tools and measures, help to downsize the energy use significantly as well as create and secure comfortable conditions for the pupils and teachers.
Environment variables*	n.a.
Control rules*	n.a.
Actors*	European partners and European schools
When applicable*	n.a.
Learning outcomes*	n.a.
Supporting resources*	n.a.

Use case 67:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Building Information Modeling (BIM) for green buildings: A critical review and future directions
Use-case type*	R&D
Funding source*	This study is financially supported by the National University of Singapore (Grant Number: R-296-000-151-133) and the National Natural Science Foundation of China (Grant Numbers: 71390523 and 71471136).
Project title*	Journal paper
Web link*	https://www.sciencedirect.com/science/article/abs/pii/S092658051730095X?via%3Dihub
Targeted discipline*	Architects / Engineers
Building type*	Other
Project type*	Existing
Lifecycle applicability*	Design
Brief description of case-study*	Although a large number of studies on Building Information Modeling (BIM) have been conducted in the past decade, a lack of consensus remains among researchers and practitioners regarding the applications of BIM for the development of green buildings, the activity of making buildings in a way that protects the natural environment. As the usefulness of BIM has been widely recognized in the building and construction industry, there is an urgent need to establish an up-to-date synthesis on the nexus between BIM and green buildings. After an in-depth review of hundreds of journal articles published from 1999 to 2016 and 12 widely used types of BIM software, this study provides a holistic understanding and critical reflection on the nexus between BIM and green buildings, which is systematically illustrated by a �Green BIM Triangle� taxonomy. The proposed taxonomy indicates that the nexus between BIM and green buildings needs to be understood based on three dimensions, namely project phases, green attributes and BIM attributes. Following the proposed taxonomy, this paper systematically illustrated 1) the applications of BIM in supporting the design, construction, operation, and retrofitting processes of green buildings; 2) the various functions of BIM for green building analyses such as energy, emissions, and ventilation analysis; 3) the applications of BIM in supporting green building assessments (GBA); and 4) research gaps and future research directions in this area. Through critical review and synthesis of BIM and green buildings based on evidence from both academic research and industrial practices, this paper provides important guidance for building researchers and practitioners to better align BIM development with green building development in the future.
Key highlights*	Reviewed over 400 research articles and 14 software programs on green BIM Proposed a taxonomy to demonstrate research landscape of green BIM Summarized the applications of BIM in supporting green building lifecycle process Discussed key BIM-supported functions for green building performance analysis Analyzed the use of BIM for green building assessments (GBA)
Supporting case-study*	Reviewed over 400 research articles and 14 software programs on green BIM
Scenario definition*	Energy performance, carbon emission, natural ventilation, solar radiation, water usage, acoustics, thermal comfort
Control variables*	Analysis of the use of BIM for green buildings
Objective*	Design/Construction/Operation/Renovation
Environment variables*	BIM-supported lifecycles of green buildings � Design, Construction, Operation, Renovation BIM supported functions for green issues � Energy performance analyses � Carbon emission analyses � Natural ventilation system analyses � Solar radiation and lighting analyses � Water usage analyses � Acoustics analyses � Thermal comfort analyses BIM-supported green building assessment (GBA)
Control rules*	See paper https://www.sciencedirect.com/science/article/abs/pii/S092658051730095X?via%3Dihub
Actors*	SKubicki
When applicable*	e938a235bc7e468189b6b8df92713c67
Learning outcomes*	null
Supporting resources*	null

Use case 68:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Capacitation of skilled workforce for the design of new nZEB buildings or in the rehabilitation of existing buildings towards nZEB concept
Use-case type*	R&D
Funding source*	Horizon 2020 - European Union funds
Project title*	SOUTHZEB
Web link*	http://www.southzeb.eu/
Targeted discipline*	Architects, Engineers, professionals
Building type*	Other
Project type*	Existing
Lifecycle applicability*	The target audience for the SouthZEB training modules were professionalsinvolved in the building sector, either in the design of new buildings or the rehabilitation of existing ones. The following list provides an overview of the target audience for the project:Building Professionals / developer companies is the largest target group, including all intermediate and senior professionals (engineers, architects, municipality employees) in the Southern European countries. They facilitate the construction of new buildings towards the nZEB targets;Authorities / decision makers will also benefit from training modules prepared to support the use of appropriate funding schemes and other incentives for the promotion of nZEB. Decision makers have been involved in the project course in order to better understand the legislation and regional roadmaps towards the application of the relevant EU directives;Property owners will benefit from the project effects as energy efficient buildings are less costly for the users. By facilitating the training of professionals in nZEB building, the local property value is raised in a long-term sustainable way; Vocational training / Certification bodies transfer the projects results to the community under a well European wide recognized educational framework.
Brief description of case-study*	The SouthZEB project aims to contribute towards the nZEB goals established in the EPBD directive recast through the capacitation of the skilled workforce involved in the design of new nZEB buildingsor in the rehabilitation of existing buildings towards nZEB concept.
Key highlights*	62c881a6338f471fa3e41e796817857b
Supporting case-study*	null
Scenario definition*	null
Control variables*	null
Objective*	null
Environment variables*	null
Control rules*	null
Actors*	null
When applicable*	null
Learning outcomes*	null
Supporting resources*	hodoroga

Use case 69:

Back to homepage A+ A- R

Use-case id*	1
Use-case title*	Design of the largest hospital in the south of Luxembourg
Use-case type*	Real-world application
Funding source*	Centre Hospitalier Emile Mayrisch / Luxembourg State
Project title*	S�dspidol Luxembourg
Web link*	https://www.sudspidol.lu
Targeted discipline*	Other
Building type*	New Build
Project type*	The case study hospital is located in Esch-sur-Alzette in the south of Luxembourg nearby other healthcare institutions and the university, creating a healthcare campus.The hospital complex of 110.000 m2 and around 600 beds consists of 4 main buildings and is composed of three circular rounded triangles and a prefixed rectangular functional building.The architecture follows the patient centered process-oriented design. The BT 100 functional building houses the emergency room, radiology, endoscopy, nuclear medicine, central sterilization and the surgical department with 16 rooms. The following building BT 300 houses the ambulant clinics, dialysis, obstetrics, IMC, intensive care, day clinic and nursing units on the upper floors.The BT 500 houses the radiotherapy, the ambulant chemo- and infusion therapy, the laboratory, and rooms for administration. Essentially, the nursing areas of oncology are located here. The BT 700 includes areas for palliative care, rehabilitative care, psychiatry and geriatrics.All building segments are connected by an underground supply and disposal structure. Logistic is provided by AGV (automated guided vehicles).One of two connecting bridges linking all the buildings is located on level 1 and is dedicated for visitors and staff only. The connecting bridge on floor 2 is exclusively for patients and medical personnel. This separates the different flows in the hospital, resulting in a significant improvement in logistical and healthcare processes.
Lifecycle applicability*	The maximum use of natural light has played a very important role in the design of the buildings.In addition, about 80% of all rooms are occupied with only one bed, which improves the quality and efficiency of care.All the important digitalisation aspects (i.e. IoT, FM, patient record, wearables, ...) are taken into account to a very high extent.Building Information Modeling is required as a standard for the design, construction management and eventually BIM will be delivered for Facility Management (CAFM).DGNB Certification (Gold) foreseen.
Brief description of case-study*	Today, there is still no uniform method for mapping all relevant material data in BIM. Therefore, additional databases are often used, which has a negative impact on data security. Considering the essential concept of �healing environment� developed by the CHEM project, a smooth and real-time process will be simulated to collect all product information during construction works. One of the goal is to use few critical chemical substances in the building as possible. Through the simulation in the BIM, the/all materials within the building are already known (link to BAMB) and the impact on health of the existing chemical products in a substance group can be precisely identified before installation.
Key highlights*	Number of product specification linked to as-built BIM, coverage of health parameters (VOC),
Supporting case-study*	Contractors, Project Manager, Architect
Scenario definition*	Extending BIM metadata to capture materials installed at the building stageSelection of system provider to ensure the continuous (automated or manual) collect of materials specifications and feed the BIM model
Control variables*	hodoroga
Objective*	62c881a6338f471fa3e41e796817857b
Environment variables*	null
Control rules*	null
Actors*	null
When applicable*	null
Learning outcomes*	null
Supporting resources*	null

Use case 70:

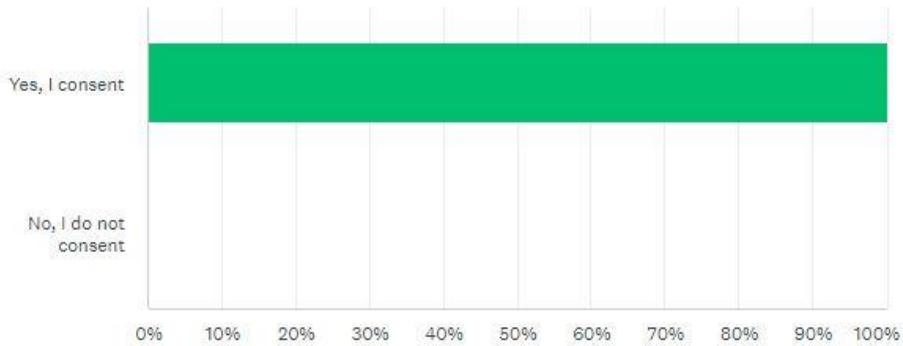
Back to homepage A+ A- R

Use-case id*	1
Use-case title*	OptEEmAL - Optimised Energy Efficient Design Platform
Use-case type*	R&D
Funding source*	European Union - Horizon 2020
Project title*	OptEEmAL
Web link*	https://www.opteemal-project.eu/
Targeted discipline*	Public
Building type*	Existing
Project type*	The developed platform will reduce time delivery and uncertainties and result in improved solutions when compared to business-as-usual practices. Under the coordination of CARTIF Technology Centre, 13 partners from 8 countries are working on delivering an optimised, integrated and systemic design tool based on an Integrated Project Delivery approach for building and district retrofitting projects.
Lifecycle applicability*	hodoroga
Brief description of case-study*	62c881a6338f471fa3e41e796817857b
Key highlights*	null
Supporting case-study*	null
Scenario definition*	null
Control variables*	null
Objective*	null
Environment variables*	null
Control rules*	null
Actors*	null
When applicable*	null
Learning outcomes*	null
Supporting resources*	null

10.3 Results - Questionnaires

Below we find the analysis of the data collected from the Questionnaire on SurveyMonkey. Thirty-three responses were collected, which are presented in the relevant graphs, with a commentary of how they related to the study and its aims. One observation is that not all respondents replied to all questions. However, all of the graphs clearly state the number of answers received, and the statistical data is based on the sum of the answers that were received on that particular question.

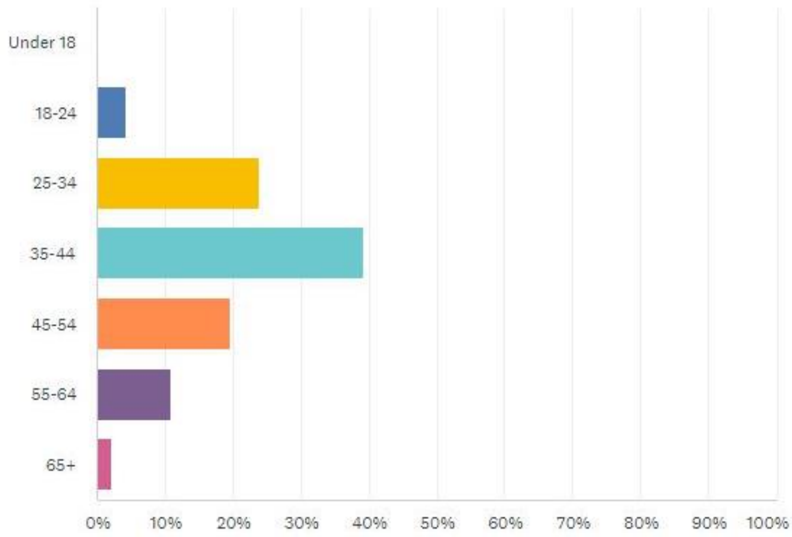
Answered: 46 Skipped: 6



ANSWER CHOICES	RESPONSES	
Yes, I consent	100.00%	46
No, I do not consent	0.00%	0
TOTAL		46

Figure 31.Responses received from survey question 1

Answered: 46   Skipped: 6

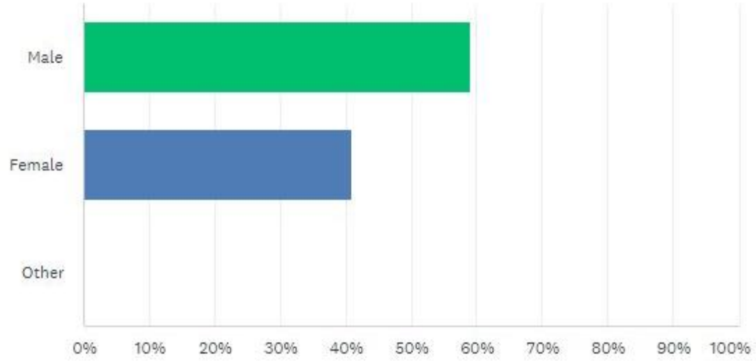


ANSWER CHOICES	RESPONSES	
Under 18	0.00%	0
18-24	4.35%	2
25-34	23.91%	11
35-44	39.13%	18
45-54	19.57%	9
55-64	10.87%	5
65+	2.17%	1
TOTAL		46

Figure 32. Responses received from survey Q2

Graphs (Q2) & (Q3), give us information about demographics. The first graph (Q2) shows that a significantly large sample of the participants belong in the age group of 35-44 (39.13 %), compared to other age groups. The second largest group of participants belongs in the age group of 25-34 (23.91 %). The smallest group of participants belongs in two groups, those of 65+, and 18-24, with a percentage of contribution of 3.03%. In the second graph (Q3), it can be seen how the sample is almost evenly spread among men and women, in terms of gender (59.09 % & 40.91 % in terms of percentages, respectively).

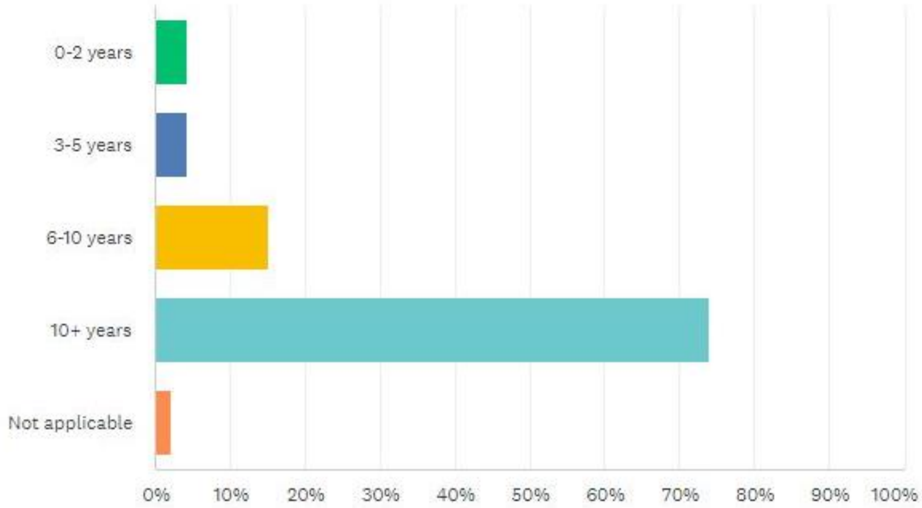
Answered: 44   Skipped: 8



ANSWER CHOICES		RESPONSES	
Male		59.09%	26
Female		40.91%	18
Other	Responses	0.00%	0
TOTAL			44

Figure 33. Responses received from survey Q3

Answered: 46 Skipped: 6



ANSWER CHOICES	RESPONSES	
0-2 years	4.35%	2
3-5 years	4.35%	2
6-10 years	15.22%	7
10+ years	73.91%	34
Not applicable	2.17%	1
TOTAL		46

Figure 34. Responses received from survey Q4

As seen in the above graph (Q4) the overwhelming majority (73.91 %) of the participants have a long experience, over 10 years, in their field. This is a positive element with regards to the rigour of the data collected, as it could be argued that it reflects a deeper understanding of the fields each respondent refers to.

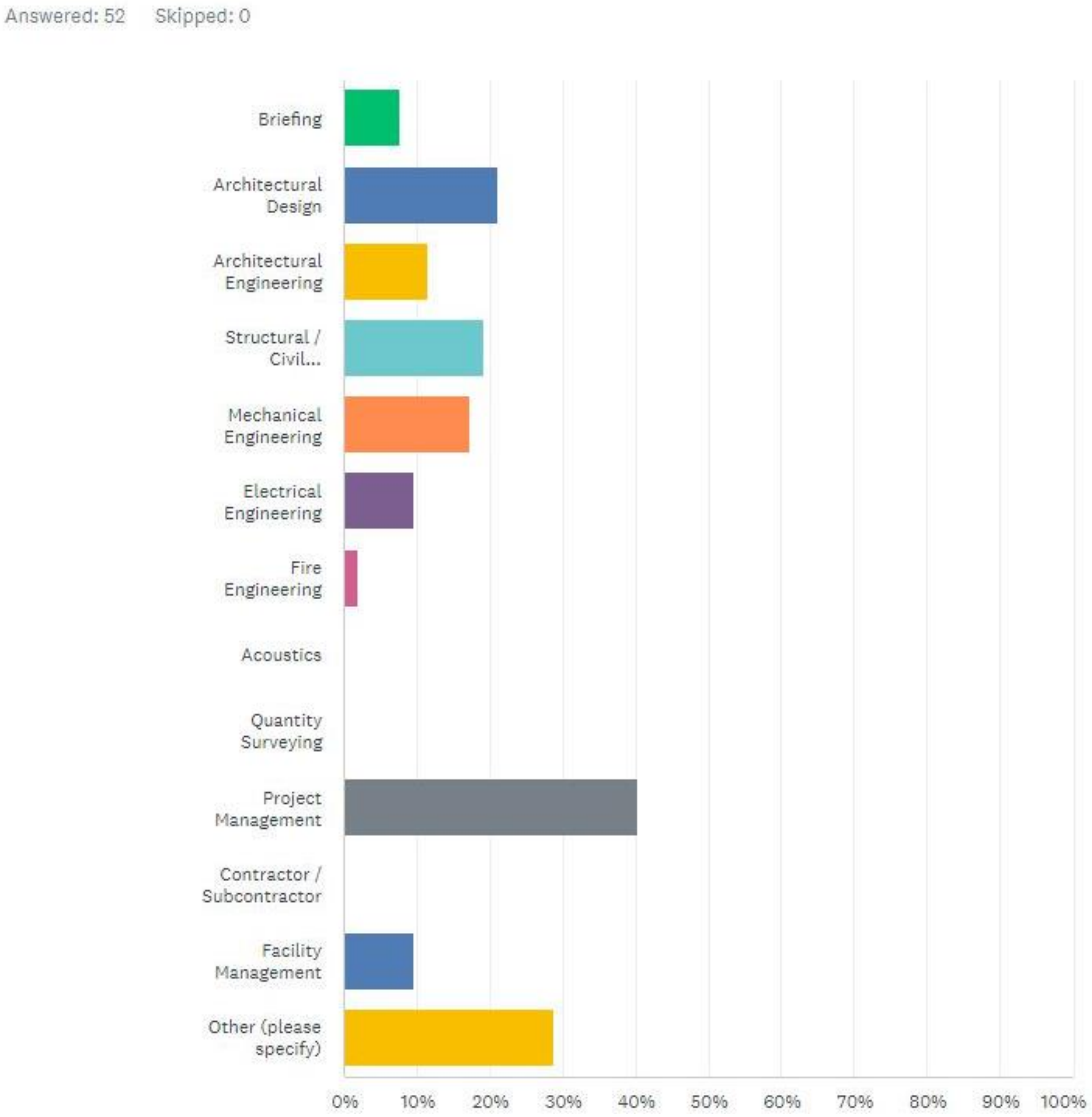


Figure 35. Responses received from survey Q5

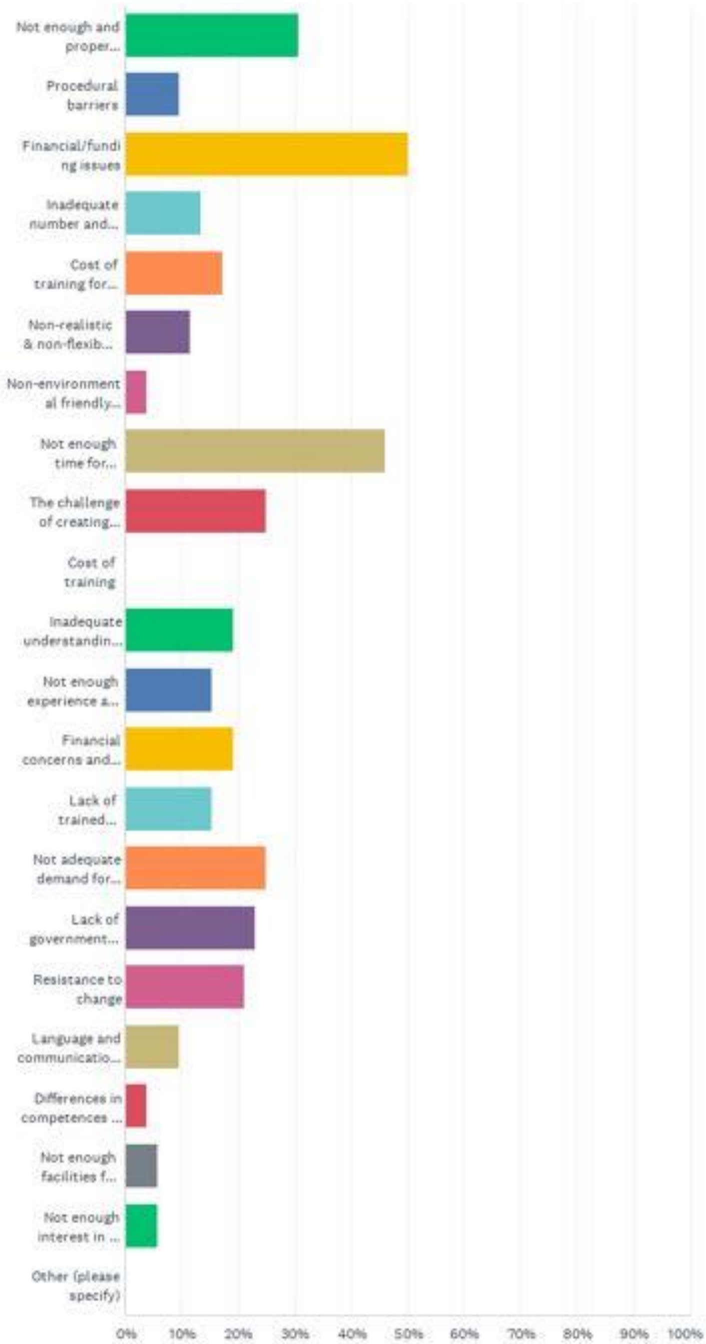
As seen above (Q5), more than half of the respondents (40.38 %) the majority of belong in the "Project Management" field. One observation that emerges from the Following that, the second largest sample belongs to "Other" (28.85 %) and Architectural Design (21.15 %). In the field of "other" the following 11 responses were collected, when asked to specify:

1. Teacher
2. Knowledge Institute
3. Service Design, Engineering and Innovation
4. Environmental Education
5. Training
6. Energy Systems
7. Education and Training specialist
8. Energy
9. Energy Process Engineering

10. Energy Sustainable Engineering
11. Teaching
12. Energy consultant
13. Software Development
14. Application of Computer Science to Engineering
15. Vocational Training

The fields that were not covered by the sample of respondents were the following: Fire Engineering, Acoustics, Quantity Surveying, Contractor/Subcontractor. Overall what becomes evident is that the majority of respondents are white-collar workers. This relates to the profile of the interviewers' participants, which will be examined in the next subchapter of the study.

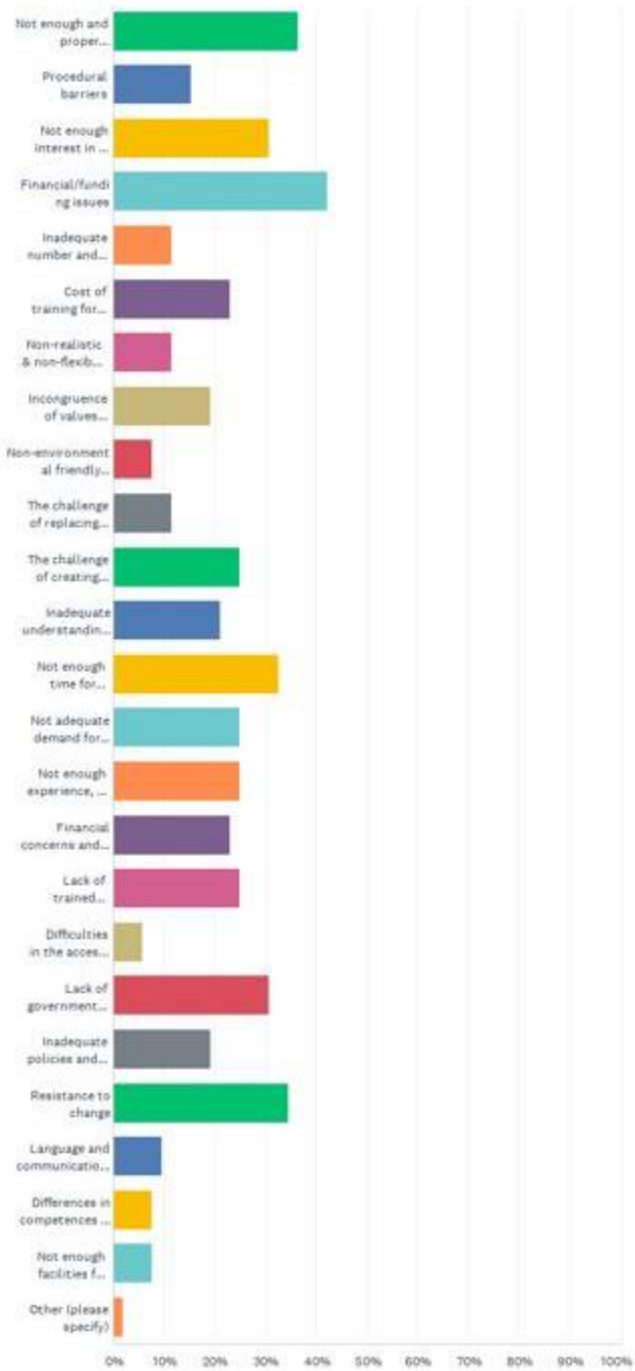
ANSWER CHOICES		RESPONSES	
Briefing		7.69%	4
Architectural Design		21.15%	11
Architectural Engineering		11.54%	6
Structural / Civil Engineering		19.23%	10
Mechanical Engineering		17.31%	9
Electrical Engineering		9.62%	5
Fire Engineering		1.92%	1
Acoustics		0.00%	0
Quantity Surveying		0.00%	0
Project Management		40.38%	21
Contractor / Subcontractor		0.00%	0
Facility Management		9.62%	5
Other (please specify)	Responses	28.85%	15


Not enough and proper...
Procedural barriers
Financial/funding issues
Inadequate number and...
Cost of training for...
Non-realistic & non-flexib...
Non-environmental friendly...
Not enough time for...
The challenge of creating...
Cost of training
Inadequate understandin...
Not enough experience a...
Financial concerns and...
Lack of trained...
Not adequate demand for...
Lack of government...
Resistance to change
Language and communicatio...
Differences in competences ...
Not enough facilities f...
Not enough interest in ...
Other (please specify)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

ANSWER CHOICES	RESPONSES	
Not enough and proper information & awareness	36.36%	12
Procedural barriers	12.12%	4
Financial/funding issues	45.45%	15
Inadequate number and quality of training programs	9.09%	3
Cost of training for energy efficiency	15.15%	5
Non-realistic & non-flexible timeframes for training	3.03%	1
Non-environmental friendly work procedures	6.06%	2
Not enough time for training	60.61%	20
The challenge of creating more demand for energy efficiency	27.27%	9
Cost of training	0.00%	0
Inadequate understanding of the importance of a skilled workforce	24.24%	8
Not enough experience and lack of expertise in energy efficiency technology	21.21%	7
Financial concerns and insecurities about the future that hinder investments in the field	18.18%	6
Lack of trained manpower/staff	18.18%	6
Not adequate demand for energy efficiency buildings	33.33%	11
Lack of government incentives	27.27%	9
Resistance to change	21.21%	7
Language and communication issues	6.06%	2
Differences in competences of trainees	6.06%	2
Not enough facilities for training	6.06%	2
Not enough interest in the field	6.06%	2
Other (please specify)	0.00%	0
Total Respondents: 33		

Figure 36. Responses received from survey Q6

The graph for (Q6) shows the barriers that are encountered in the organisation that the participants are working in, that some observations emerge. The barrier that has been chosen by the majority of participants (60.61%), is "financial/funding issues" (50.00%), followed by is the lack of time for training ("not enough time for training") (46.15%), then "not enough and proper information & awareness" (30.77 %) and "not adequate demand for energy efficient buildings" (25.00%).
As a general picture, and by looking at the data, it could be argued that training needs to be made as a priority within organisations, both on a structural level, in terms of priorities and funding, but also in terms of how employees are being given the opportunity and time to interact with training programs and education, in order to improve their skills.


Not enough and proper...
Procedural barriers
Not enough interest in ...
Financial/funding issues
Inadequate number and...
Cost of training for...
Non-realistic & non-flexib...
Incongruence of values...
Non-environmental friendly...
The challenge of replacing...
The challenge of creating...
Inadequate understandin...
Not enough time for...
Not adequate demand for...
Not enough experience, ...
Financial concerns and...
Lack of trained...
Difficulties in the acces...
Lack of government...
Inadequate policies and...
Resistance to change
Language and communicatio...
Differences in competences ...
Not enough facilities f...
Other (please specify)
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

ANSWER CHOICES		RESPONSES	
Not enough and proper information & awareness		36.54%	19
Procedural barriers		15.38%	8
Not enough interest in the field		30.77%	16
Financial/funding issues		42.31%	22
Inadequate number and quality of training programs		11.54%	6
Cost of training for energy efficiency		23.08%	12
Non-realistic & non-flexible timeframes for training		11.54%	6
Incongruence of values between sectors and layers of stakeholders involved in the construction industry		19.23%	10
Non-environmental friendly work procedures		7.69%	4
The challenge of replacing a retiring workforce		11.54%	6
The challenge of creating more demand for energy efficiency		25.00%	13
Inadequate understanding of the importance of a skilled workforce		21.15%	11
Not enough time for training		32.69%	17
Not adequate demand for energy efficiency buildings		25.00%	13
Not enough experience, and lack of expertise in energy efficiency technology		25.00%	13
Financial concerns and insecurities about the future that hinder investments in the field		23.08%	12
Lack of trained manpower/staff		25.00%	13
Difficulties in the access to capital		5.77%	3
Lack of government incentives		30.77%	16
Inadequate policies and legislations		19.23%	10
Resistance to change		34.62%	18
Language and communication issues		9.62%	5
Differences in competences of trainees		7.69%	4
Not enough facilities for training		7.69%	4
Other (please specify)	Responses	1.92%	1
Total Respondents: 52			

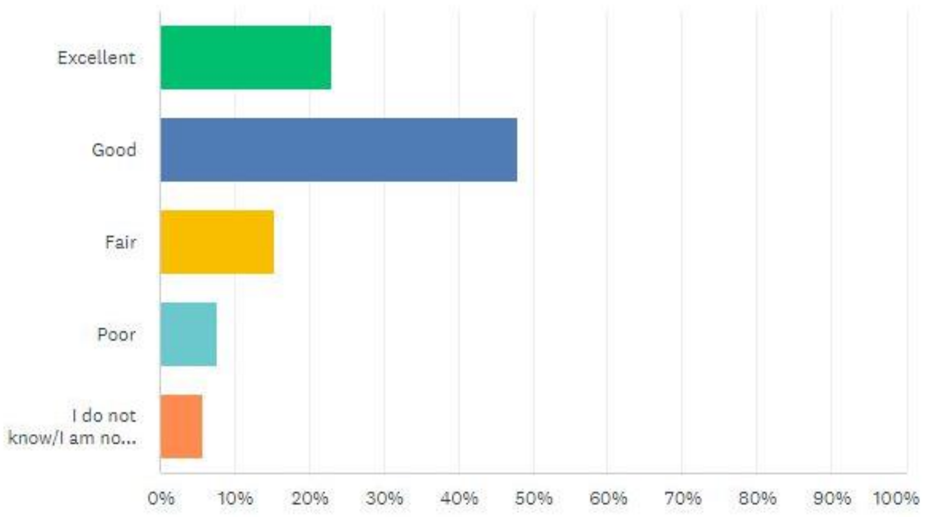
Figure 37. Responses received from survey Q7

The graph for (Q7) shows the barriers that are encountered in the industry that the participants are working in, that some observations emerge. The barriers that have been chosen by the majority of participants are “financial/funding issues” (42.31%), are “not enough and proper information and awareness” (36.54%.

Other significant barriers include “not enough time fortraining” (32.69%), “not enough interest in the field”(30.77%) a followed by “resistance to change”(34.62%).By looking at the tendencies that the data analysis shows, two interesting observations emerge. The barriers most often selected by the participants are common within the organisations as well as in theindustry, such as the lack of time for training, financial/funding issues, not enough and proper information, and awareness. This could be argued to reflect some common mentalities across stakeholders and different actors in the industry, and could potentially help identify the problem and narrow down the necessary action to be taken, if we are to increase training for energy efficiency. It seems more focus should be placed overall, in terms of how much capital investments are being placed

into training, as well as on raising awareness about the importance of education in this area and of improving skills.

Answered: 52 Skipped: 0



ANSWER CHOICES	RESPONSES	
Excellent	23.08%	12
Good	48.08%	25
Fair	15.38%	8
Poor	7.69%	4
I do not know/I am not sure	5.77%	3

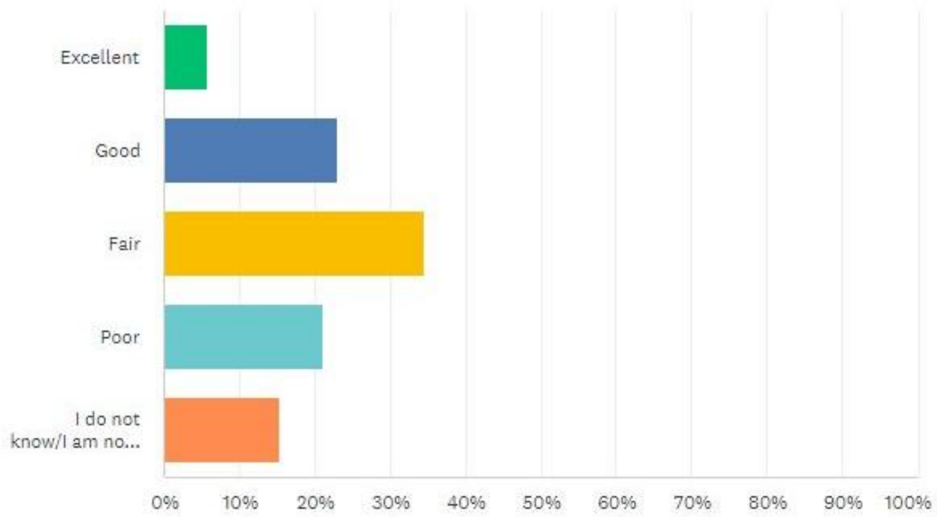
Figure 38. Responses received from survey Q8

The graph for (Q8) shows an overall very good level of knowledge and experience sharing in the companies and organisations, with only 7.69 % of participants suggesting it is in a poor state. This isan optimistic outcome, and could probably suggest that it is easier to coordinate actions, within a more limited context, such as a company (rather, for example, in the totality of the construction industry). Some relevant observations made by those who answered “good, fair, poor” are below:

1. “Due to time pressure, it is often difficult to take time to formalise experience from one project to another in my organisation”
2. “Lack of time”
3. “I work for the city. Everyone is familiar with energy efficiency but believe the payback might take long. They are not well aware or do not trust energy efficiency as a service -models. We are improving on that by increasing discussion between public and private sector and piloting new business / procurement models”
4. “As the number of topics is quite high, there is a lack of capacity in some of the fields of expertise”

5. ”Energy champions within organisations and some Government incentives are helping”
6. “We don't have to care about energy in our office, because we rent the offices”
7. “The state is different among organisation”.
8. “The team has access to good information but could have more experience in implementation”.
9. “There is no seriousness to reduce electricity bill since it’s paid by the government and there is no serious measures to reduce the cost and move to energy efficiency”.
10. “The amount of work and the lack of time hinder the experience sharing”.

Answered: 52 Skipped: 0



ANSWER CHOICES	RESPONSES	
Excellent	5.77%	3
Good	23.08%	12
Fair	34.62%	18
Poor	21.15%	11
I do not know/I am not sure	15.38%	8

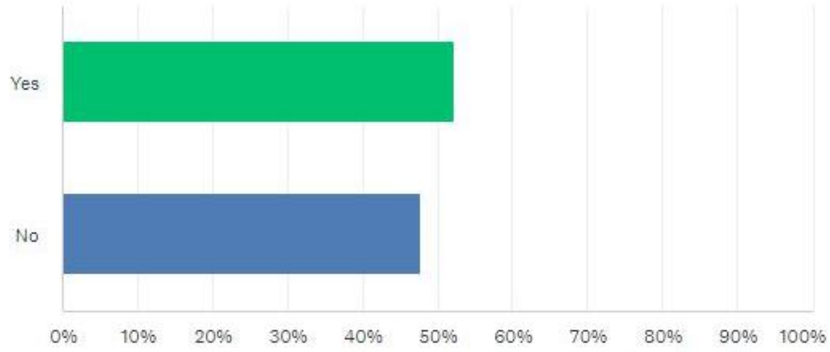
Figure 39. Responses received from survey Q9

The graph for (Q9) shows a fairly good level of knowledge and experience sharing in the industry, with only 21.15 % of participants suggesting it is in a poor state. In any case, however, those who replied with “excellent” are very limited (5.77%), which shows that there is clearly a lot of room for improvement in this regard. Some relevant observations made by those who answered “good, fair, poor” are below:

1. “The knowledge is divided uneven among employees”
2. “More and more case studies are described in professional newspapers and websites, but unfortunately they are often oriented towards wide marketing rather than providing technical information”
3. “Easy to share to the few who want to upskill, reaching clients and majority of others is the issue”

4. “Lack of time”
5. “Energy efficiency is a complex, fast-growing sector. Overall, there is a low to average awareness regarding the good practices in this field”
6. “A group of quite good frontrunners. But the mass is not properly upskilled”
7. “Lack of funds and awareness”
8. “Because interest is triggered by economic interest”
9. “Not adequate demand for energy efficiency buildings”
10. “Comparatively low price of energy and energy carriers leads to lack of motivation”
11. “Lots of good practice being shared”
12. “No demand for energy efficient projects leads to lack of interest”
13. “Mainly due to the industry culture: 1. No need to learn anything new. 2 The more I know, the better I am than the rest”.

Answered: 46 Skipped: 6

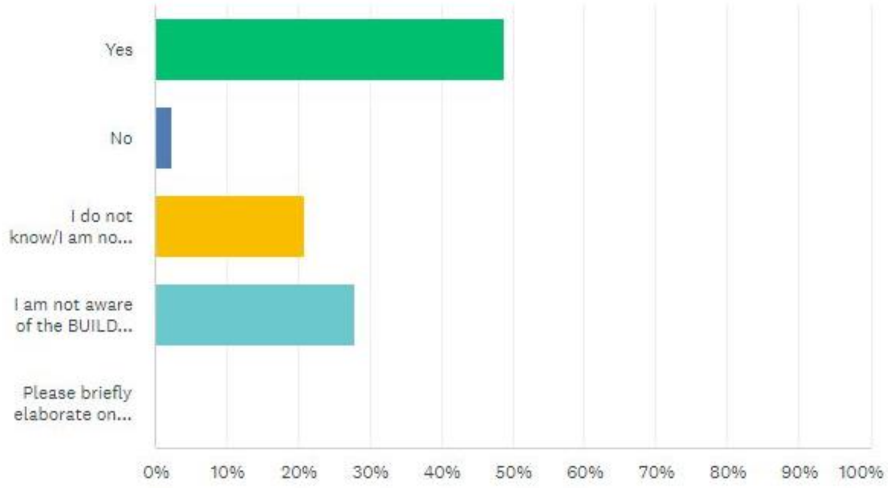


ANSWER CHOICES	RESPONSES	
Yes	52.17%	24
No	47.83%	22
TOTAL		46

Figure 40. Responses received from survey Q10

The graph for (Q10) shows an almost evenly spread of responses between “yes” and “no” to the question of whether they are aware of the BUILD UP Skills initiative. Although this in a good sign on one hand (with regards to those who are aware of it), it might also suggest that there is a long road ahead, in terms of coordinating efforts, properly educating professionals and updating them with regards to what is available in the field of training for energy efficiency in the construction sector.

Answered: 43 Skipped: 9

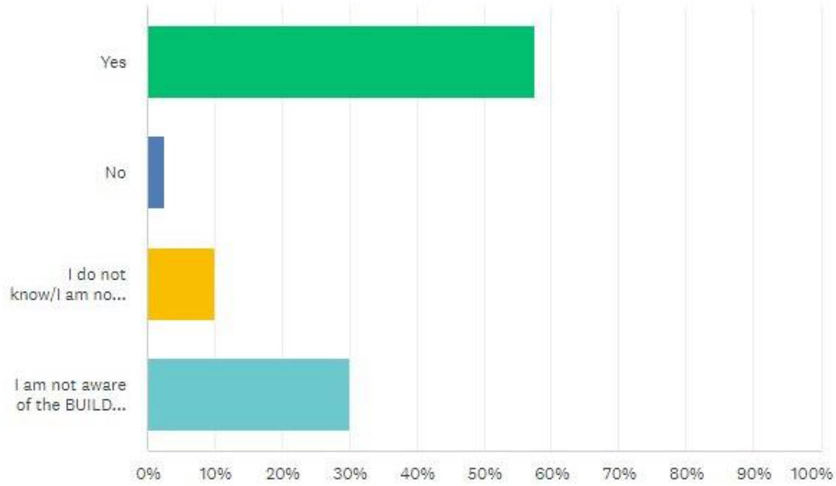


ANSWER CHOICES		RESPONSES	
Yes		48.84%	21
No		2.33%	1
I do not know/I am not sure		20.93%	9
I am not aware of the BUILD UP Skills initiative		27.91%	12
Please briefly elaborate on your opinion below	Responses	0.00%	0
Total Respondents: 43			

Figure 41. Responses received from survey Q11

Out of the 29 respondents who answered to Q11, the majority of those who knew about the initiative suggested it was successful. This is rather encouraging, as it shows that when the right initiatives are put forth and set in motion, and enough attention is being paid, people respond positively. It could also be argued to suggest that people feel that such initiatives are needed currently, in the construction field.

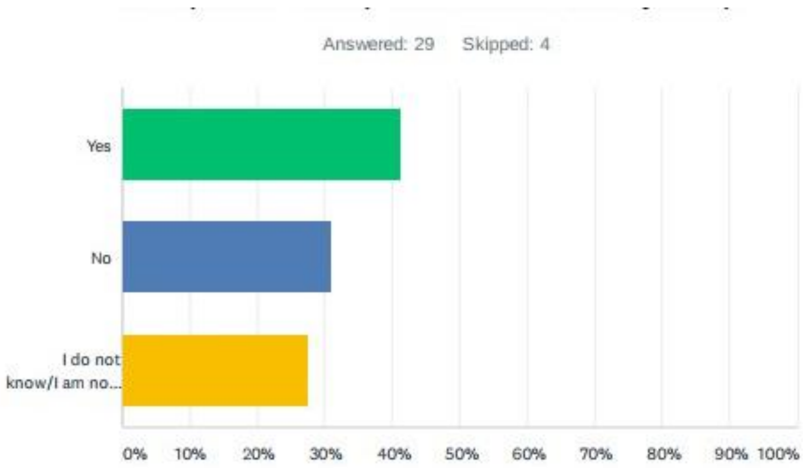
Answered: 40 Skipped: 12



ANSWER CHOICES	RESPONSES	
Yes	57.50%	23
No	2.50%	1
I do not know/I am not sure	10.00%	4
I am not aware of the BUILD UP Skills initiative	30.00%	12
TOTAL		40

Figure 42. Responses received from survey question 12

When asked on whether the demand for such initiatives is needed (Q12), out of those who replied, a sweeping majority replied with “yes”.

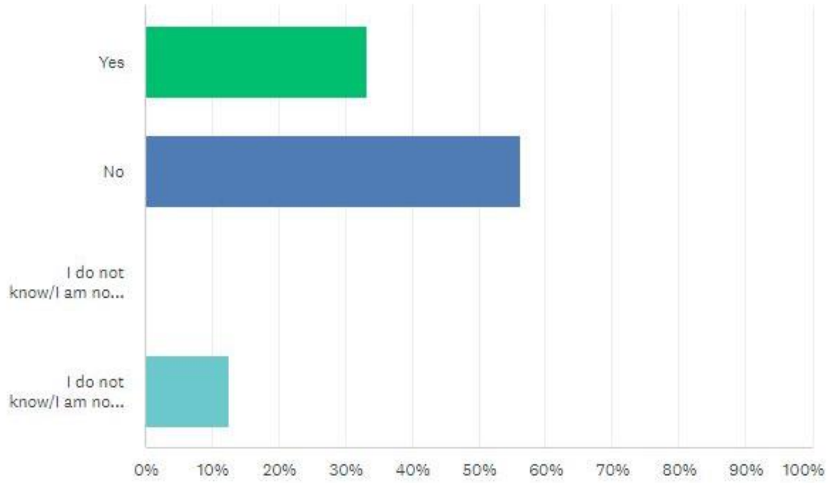


ANSWER CHOICES	RESPONSES	
Yes	41.38%	12
No	31.03%	9
I do not know/I am not sure	27.59%	8
Total Respondents: 29		

Figure 43. Responses received from survey Q13

What can be seen in the graph for (Q13), is that the responses vary, and there is a split in the perception of whether Europe takes energy efficiency training into consideration as much as it should. In any case, it could be argued that this indicates that some basis is already there, but much room for improvement exists, in this regard.

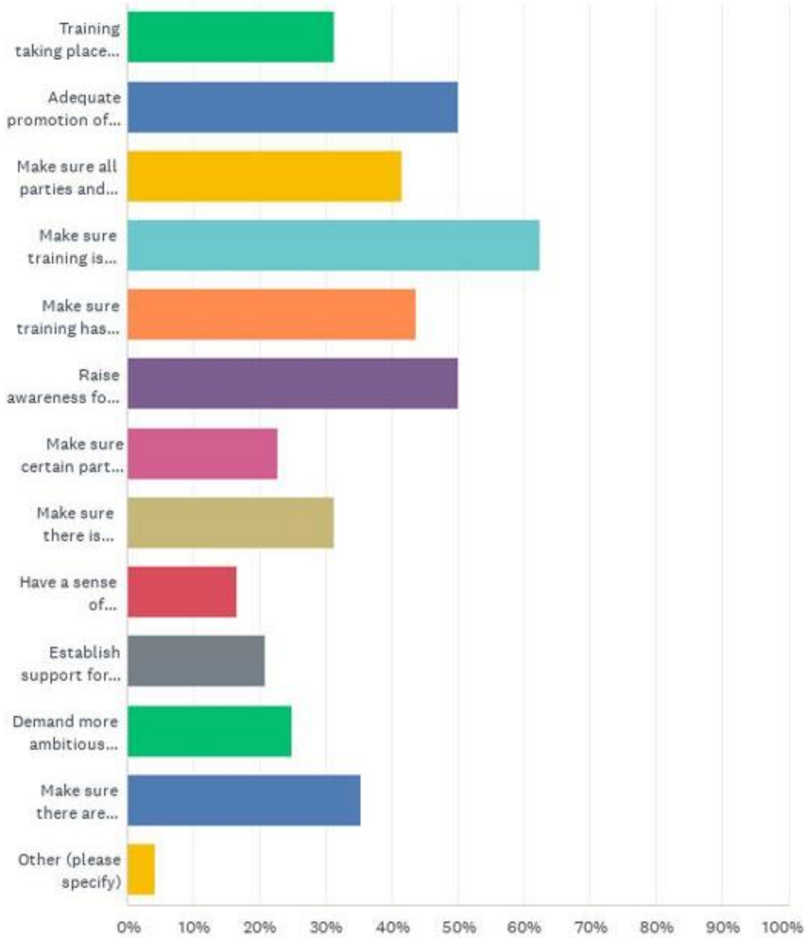
Answered: 48 Skipped: 4



ANSWER CHOICES	RESPONSES	
Yes	33.33%	16
No	56.25%	27
I do not know/I am not sure	0.00%	0
I do not know/I am not sure	12.50%	6
Total Respondents: 48		

Figure 44. Responses received from survey Q14

Interestingly, and further to the previous question, (Q14) shows a drop in positive responses when the question shifts to a national level, with a significantly larger number of participants (56.25%) suggesting the importance of energy efficiency training is not being taken into consideration adequately. This could indicate the importance of having a coordinated plan of action, perhaps stemming from a level of EU legislation, which helps level up the perception of training in the construction field. One participant commented: "No demand from the investors (incl. Governmental investors)."

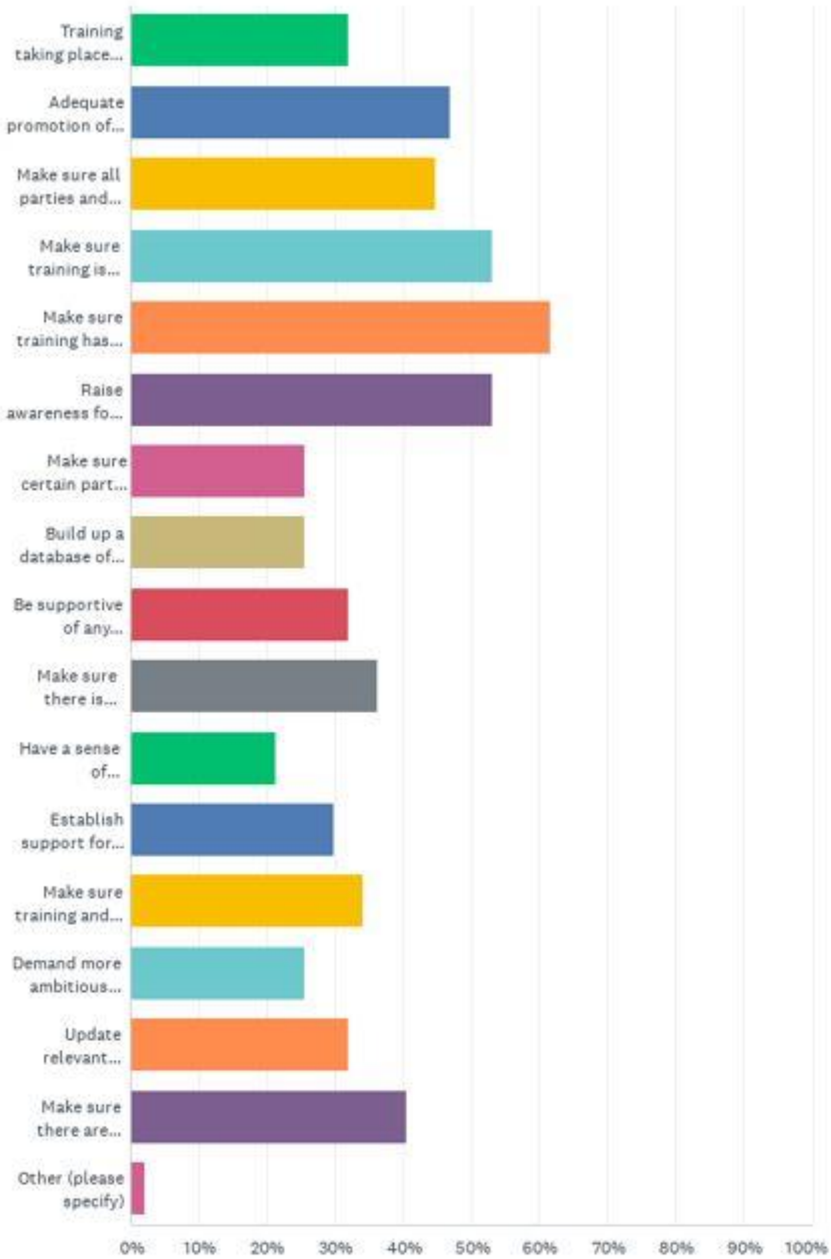


ANSWER CHOICES	RESPONSES	
Training taking place in specific periods	31.25%	15
Adequate promotion of training	50.00%	24
Make sure all parties and stakeholders involved are integrated in the process of developing training programs, from the start	41.67%	20
Make sure training is flexible and adjusts to the needs of those who undertake it	62.50%	30
Make sure training has a significant contribution for those involved	43.75%	21
Raise awareness for the need for training in energy efficiency	50.00%	24
Make sure certain parts of training are made core elements of curricula	22.92%	11
Make sure there is recognition/qualifications for the training undertaken	31.25%	15
Have a sense of responsibility for the future impact of the training	16.67%	8
Establish support for funding initiatives that support training	20.83%	10
Demand more ambitious results	25.00%	12
Make sure there are mandatory courses for construction workers	35.42%	17
Other (please specify) Responses	4.17%	2
Total Respondents: 48		

Figure 45. Responses received from survey Q15

The data from (Q15) with regards to recommendations in the relevant organisations show a focus on the importance of training being flexible and to adjust to the needs of those who undertake it (62.50%), as almost half of participants chose that. Other significant recommendations include "adequate promotion of training" (50.00%), "Raise awareness for the need for training in energy efficiency" (50.00%). These repliespoint to the importance of awareness and the proper structure of training taking place to be improved.They also indicate (and perhaps related to lack of time as indicated multiple times in previous questions), the importance of making sure training is a flexible and organic process which benefits theprofessional who undertakes it.

As "Other" the answer "the trainings should have the accreditation from the professional associations (e.g. engineers, architects)".

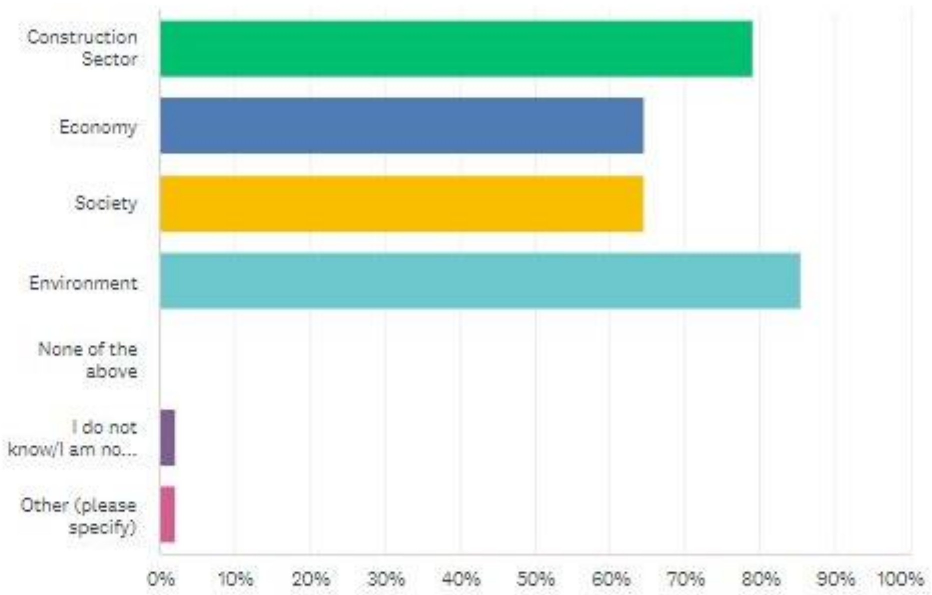


ANSWER CHOICES		RESPONSES	
Training taking place in specific periods		31.91%	15
Adequate promotion of training		46.81%	22
Make sure all parties and stakeholders involved are integrated in the process of developing training programs, from the start		44.68%	21
Make sure training is flexible and adjusts to the needs of those who undertake it		53.19%	25
Make sure training has a significant practical contribution for those involved		61.70%	29
Raise awareness for the need for training in energy efficiency		53.19%	25
Make sure certain parts of training are made core elements of curricula		25.53%	12
Build up a database of companies involved in training		25.53%	12
Be supportive of any initiative that promote awareness in the field		31.91%	15
Make sure there is recognition/qualifications for the training undertaken		36.17%	17
Have a sense of responsibility for the future impact of the training		21.28%	10
Establish support for funding initiatives that support training		29.79%	14
Make sure training and educational programs involved in energy efficiency are integrated in national frameworks		34.04%	16
Demand more ambitious results		25.53%	12
Update relevant policies		31.91%	15
Make sure there are mandatory courses for construction workers		40.43%	19
Other (please specify)	Responses	2.13%	1
Total Respondents: 47			

Figure 46. Responses received from survey Q16

The data from (Q16) with regards to recommendations in the industry shows a focus a lot of similar recommendations as (Q15) but with some additions. The most selected recommendations were "Make sure training has a significant practical contribution for those involved" (61.70%). "Makesure training is flexible and adjusts to the needs of those who undertake it" (53.19%) and "Raise awareness for the needfor training in energy efficiency" (53.19%). Other recommendations include "adequate promotion of training" (46.81%), "Make sure there are mandatory courses for construction workers" (40.43%). As with the previous question, what seems to emerge is that more attention and focus needs to be placed on the needs of professionals and those who undertake the training, as well as, once again, the importance of raising awareness in the field about training for energy efficiency.

Answered: 48 Skipped: 4

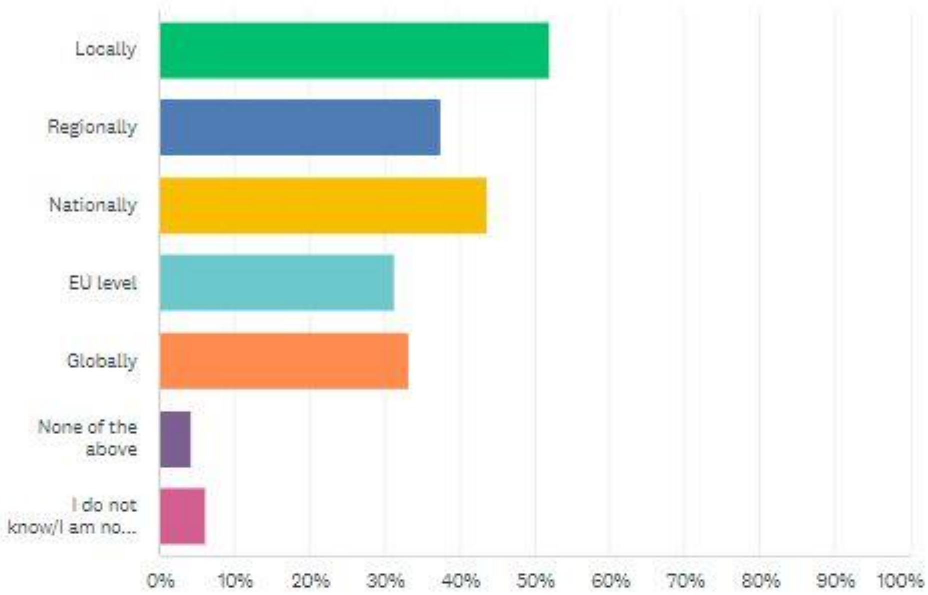


ANSWER CHOICES		RESPONSES	
Construction Sector		79.17%	38
Economy		64.58%	31
Society		64.58%	31
Environment		85.42%	41
None of the above		0.00%	0
I do not know/I am not sure		2.08%	1
Other (please specify)	Responses	2.08%	1
Total Respondents: 48			

Figure 47. Responses received from survey Q17

The high percentages of responses to (Q17) indicate that there is a high understanding of the value of training for energy efficiency, not solely in the construction sector, but on an environmental, societal, and economic level.

Answered: 48   Skipped: 4

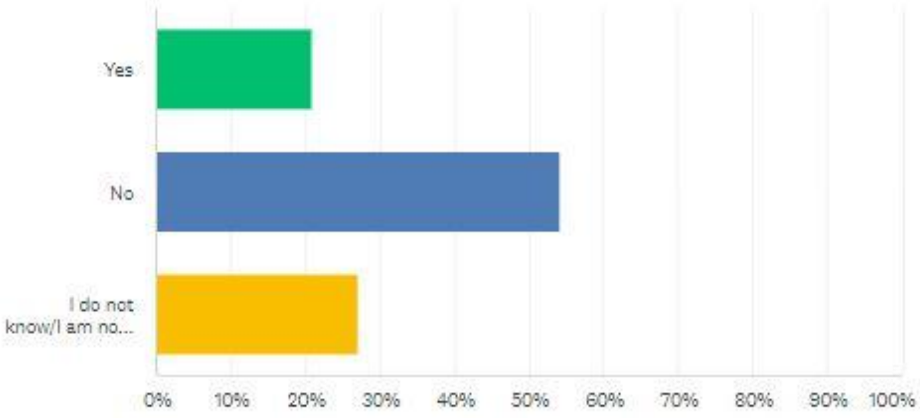


ANSWER CHOICES	RESPONSES	
Locally	52.08%	25
Regionally	37.50%	18
Nationally	43.75%	21
EU level	31.25%	15
Globally	33.33%	16
None of the above	4.17%	2
I do not know/I am not sure	6.25%	3
Total Respondents: 48		

Figure 48. Responses received from survey Q18

The answers to question (Q18) highlight how the results of training for energy efficiency are mostly perceived on a local and national level. This is a significant observation as it could be argued that there is interest, in a micro-scale, to develop further and improve the current state of training for energy efficiency.

Answered: 48 Skipped: 4



ANSWER CHOICES	RESPONSES	
Yes	20.83%	10
No	54.17%	26
I do not know/I am not sure	27.08%	13
Total Respondents: 48		

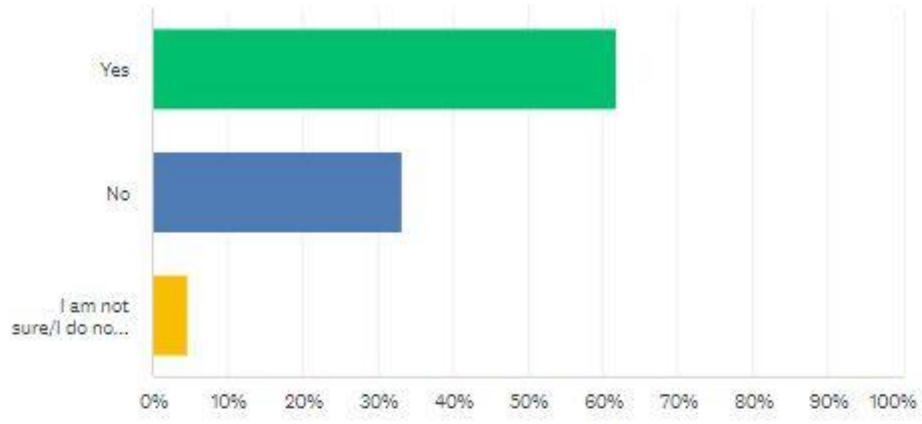
Figure 49. Responses received from survey Q19

To (Q19) very few respondents (20.69%) replied with a positive answer. The majority (54.17%) replied with "no". This could indicate that currently, there is a significant need for focusing even more on the training for energy efficiency, as several stakeholders in the industry point out a deficiency and gap, in that regard.

There were some other comments made by the respondents:

1. "There is no focus on training"
2. "Should be further strengthened"
3. "In Ireland yes because NZEB is mandatory, in other countries no"
4. "Awareness raising and a strong marketing campaign is needed"
5. "Construction companies do not put emphasis on energy efficiency on top of what is required in the legislation"
6. "People do not see the benefits yet, they see it more as time consuming"
7. "Still, more attention is paid to energy supply rather than to energy efficiency"
8. "Not adequate demand for energy efficiency buildings"
9. "It is still not reflected fully in national qualification frameworks, and demand for upskilling courses is limited"
10. "Lack of demand: still considered as something extra, something exotic and not that useful"

Answered: 42 Skipped: 10



ANSWER CHOICES	RESPONSES	
Yes	61.90%	26
No	33.33%	14
I am not sure/I do not know	4.76%	2
TOTAL		42

Comments (13)

Figure 50. Responses received from survey Q20

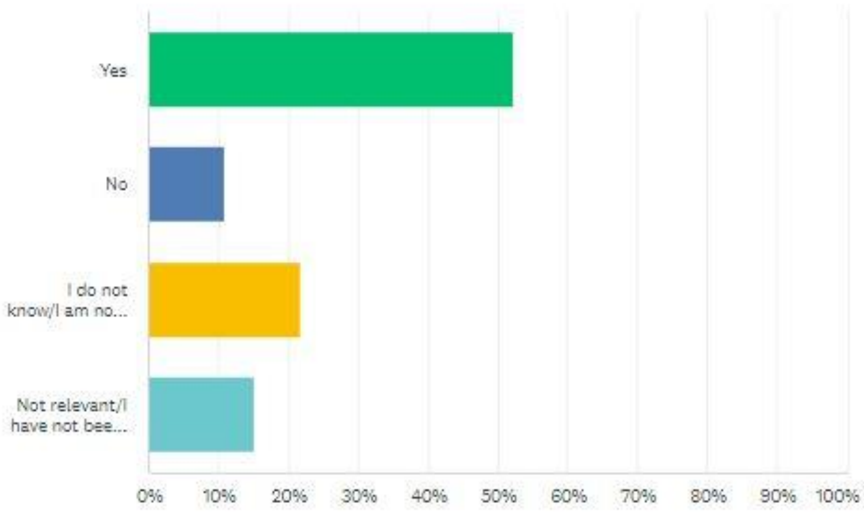
To (Q20), most replies were positive, and some clarifying answers were received in the comments:

1. "Research and innovation programmes"
2. "Build up skills"
3. "Keeping training about energy efficient construction at a construction company"
4. "Short CPDs on energy renovation, including renovation of traditionally built buildings"
5. "BUILD Up Skills Qualibuild, Train-to-Nzeb, VET4LEC, Construction Blueprint, BIMzeED, developing NZEB and BIM modules for VET and HEI"
6. "Developing courses"
7. "We were part of the projects Train-to-nZEB, BUILD UP Skills, BUILD UP Skills Enerpro. Currently part of the projects nZEB Roadshow and BUSLeague"
8."BuildUp skills"
9."12 years ago involved with championing energy efficiency in commercial buildings"
10. "Training of trainers, designers and construction managers"

Overall, the majority of respondents (61.90%) have been involved with knowledge and experience sharing in the construction sector, which shows a high level of knowledge amongthe respondents with regards to the subject of inquiry at hand.

11. "Through my study"
12. "Involved as a trainer"
13. "Passive house certification courses"

Answered: 46 Skipped: 6

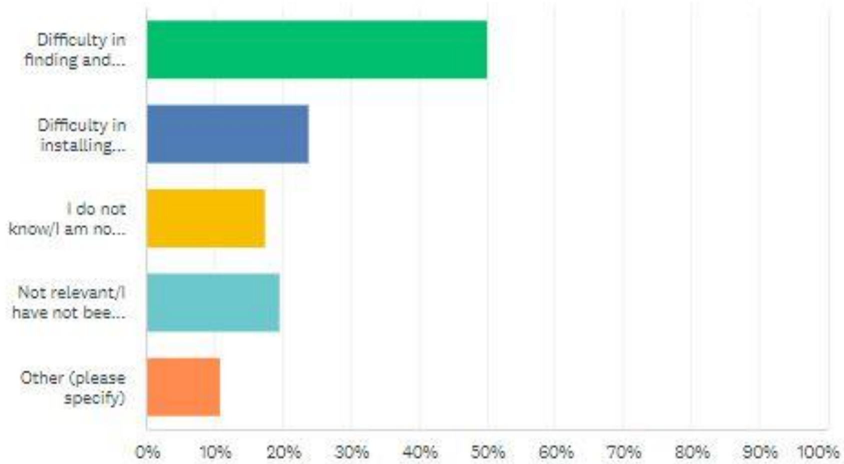


ANSWER CHOICES	RESPONSES	
Yes	52.17%	24
No	10.87%	5
I do not know/I am not sure	21.74%	10
Not relevant/I have not been involved with knowledge and experience sharing in the construction sector	15.22%	7
TOTAL		46

Figure 51. Responses received from survey Q21

(Q21) which refers to the previous question, shows an encouraging majority of (52.17%) stating that the training can be upscaled. This could mean that there are significant numbers of training programs at the moment, with this potential, which, of course, can be considered as positive in the context of the effort of further developing training for energy efficiency.

Answered: 46 Skipped: 6



ANSWER CHOICES		RESPONSES	
Difficulty in finding and training the required workforce		50.00%	23
Difficulty in installing technology		23.91%	11
I do not know/I am not sure		17.39%	8
Not relevant/I have not been involved with knowledge and experience sharing in the construction sector		19.57%	9
Other (please specify)	Responses	10.87%	5
Total Respondents: 46			

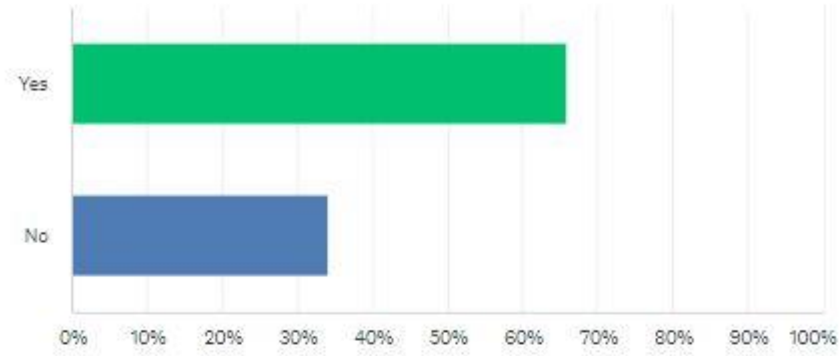
Figure 52. Responses received from survey Q22

Responses to (Q22) show that the most significant difficulty at the moment, concerning financial implications of training is the “Difficulty in finding and training the required workforce” (50.00%). Relevant comments, to the “Other options”, were:

1. “Difficulty allowing the workforce to use their working time for training”.
2. “Lack of governmental incentives”
3. “Financial obstacles”

Once again, as with previous questions, what emerges is how the workforce presents some of the most significant insights, with regards to issues around training and energy efficiency, in the construction sector.

Answered: 41 Skipped: 11



ANSWER CHOICES	RESPONSES	
Yes	65.85%	27
No	34.15%	14
TOTAL		41

Comments (13)

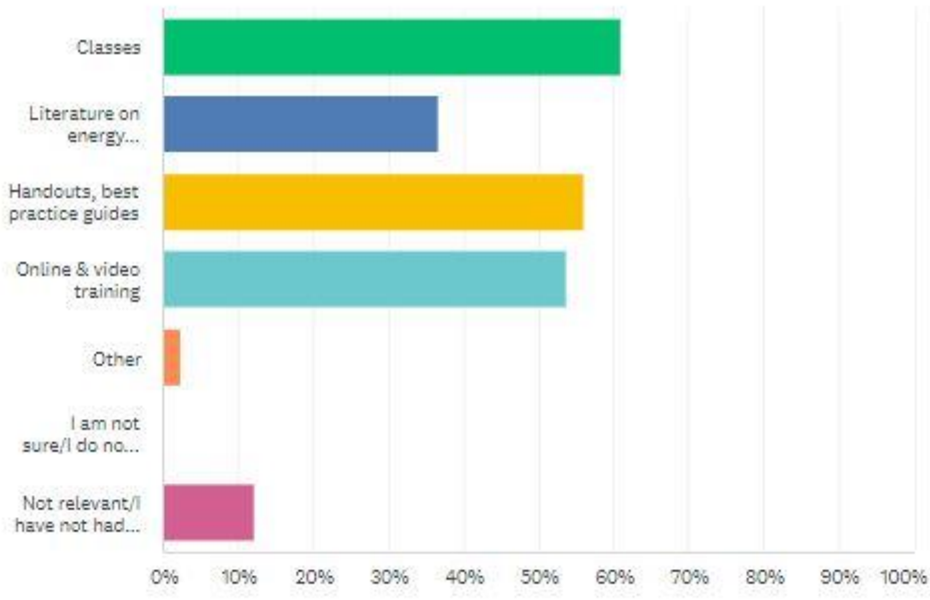
Figure 53. Responses received from survey Q23

Answers to (Q23) show a slightly larger sample of the responders having received training.Comments to this were added by some of the participants:

1. “EHPA (European Heat Pump Association) courses”
2. “ Energy renovation of traditionnaly built buildings”
3. “BIM and energy efficiency”
4. “MeNs program, developing NZEB Train the Trainer and developed WWETB NZEB programs”
5. “The Master Degree in a university”
6. “Train-to-nZEB for non-specialists”
7. “Have undertaken some government initiatives”
8. “Within a training of trainers programmes”
9. “EnEffect”
10. “University”
11. “During Master course”
12. “Passive house tradesperson course, General principles of nZEB by the Bulgarian Building Knowledge Hub”
13. “Training on energy efficiency of building, nZEBs”

Overall, the responses show a variety in the training programs undertaken by the respondents. However, the graph also shows a significant portion of the sample (34.15%) which lacks this type of training. This could be said to evidence how a lack of training is still significant, in the construction sector.

Answered: 41 Skipped: 11

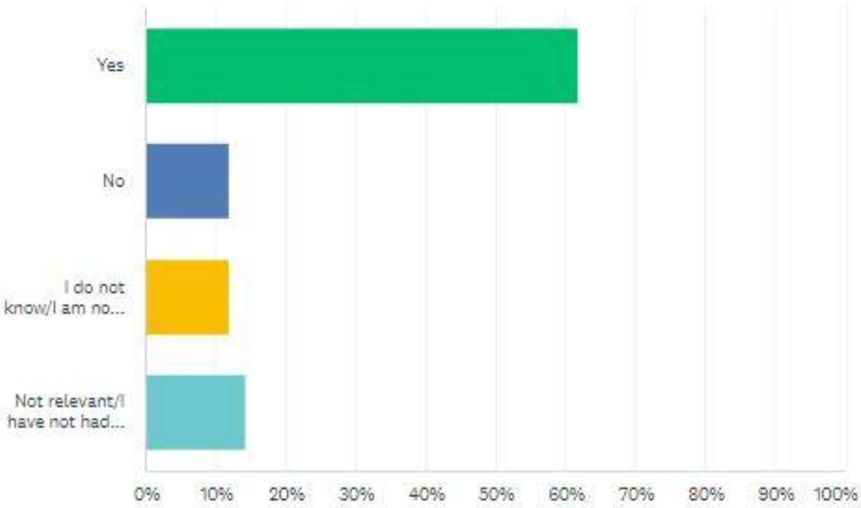


ANSWER CHOICES	RESPONSES	
Classes	60.98%	25
Literature on energy efficiency	36.59%	15
Handouts, best practice guides	56.10%	23
Online & video training	53.66%	22
Other	2.44%	1
I am not sure/I do not know	0.00%	0
Not relevant/I have not had experience with training	12.20%	5
Total Respondents: 41		

Figure 54. Responses received from survey Q24

(Q24) shows a tendency concerning the type of material used for these trainings, with most of them focusing mostly on “classes” (which presents the highest percentage 60.98%), handouts, best practice guides, and online & video training, and less on the literature on energy efficiency. Overall, it could be said that the training materials overall seems to offer flexibility, which is a good thing. As mentionedin previous questions, it is important that training offers a more appealing profile to professionals, anda space where training are tailored to their needs.

Answered: 42 Skipped: 10

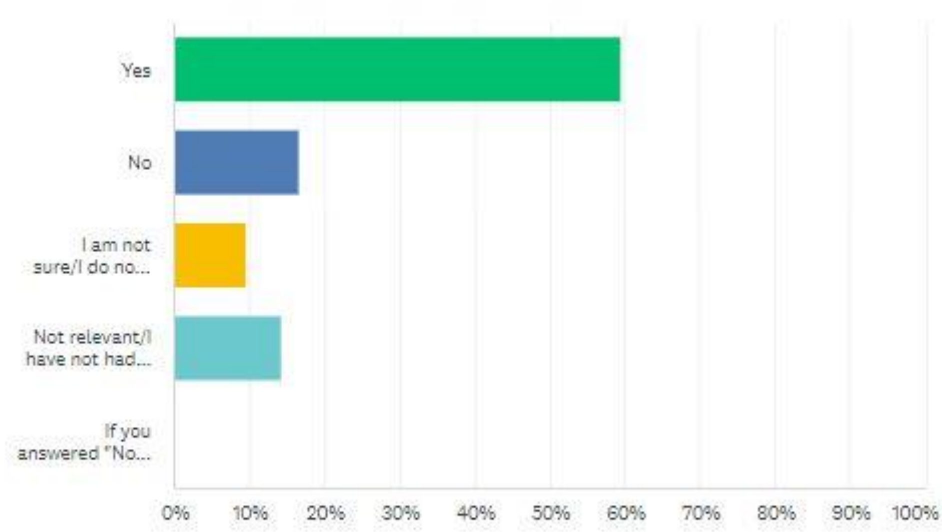


ANSWER CHOICES	RESPONSES	
Yes	61.90%	26
No	11.90%	5
I do not know/I am not sure	11.90%	5
Not relevant/I have not had experience with training	14.29%	6
Total Respondents: 42		

Figure 55. Responses received from survey Q25

From (Q25) emerges how the training of trainers in energy efficiency programs is perceived as sufficient, with a (11,90 %) arguing that the training of trainers is insufficient. This is a positive aspect, in terms of how the training is structured, and a rather significant, it could be argued.

Answered: 42 Skipped: 10

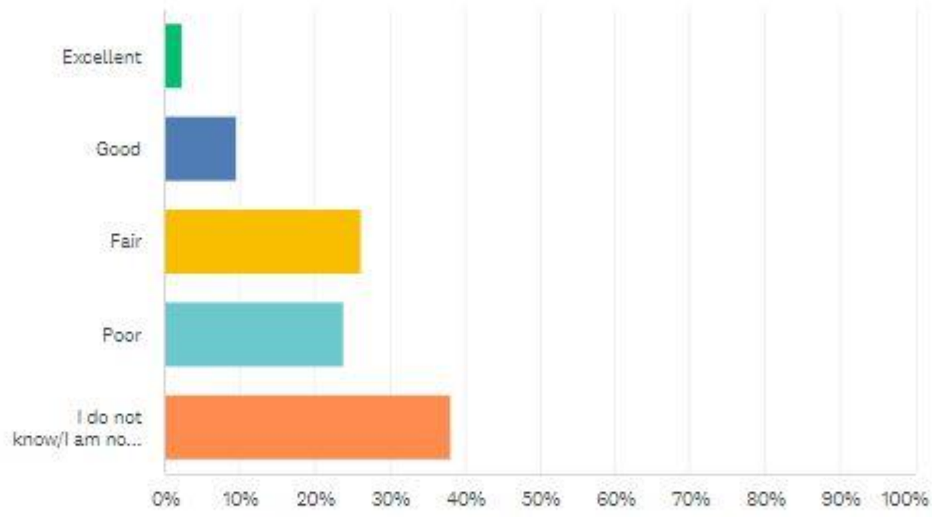


ANSWER CHOICES		RESPONSES	
Yes		59.52%	25
No		16.67%	7
I am not sure/I do not know		9.52%	4
Not relevant/I have not had experience with training		14.29%	6
If you answered "No", please briefly specify why	Responses	0.00%	0
Total Respondents: 42			

Figure 56. Responses received from survey Q26

Most participants answered to (Q26) with a positive response, which is also, as with the previous question, a positive aspect concerning the quality of training for energy efficiency, received in several programs, in the construction industry.

Answered: 42 Skipped: 10

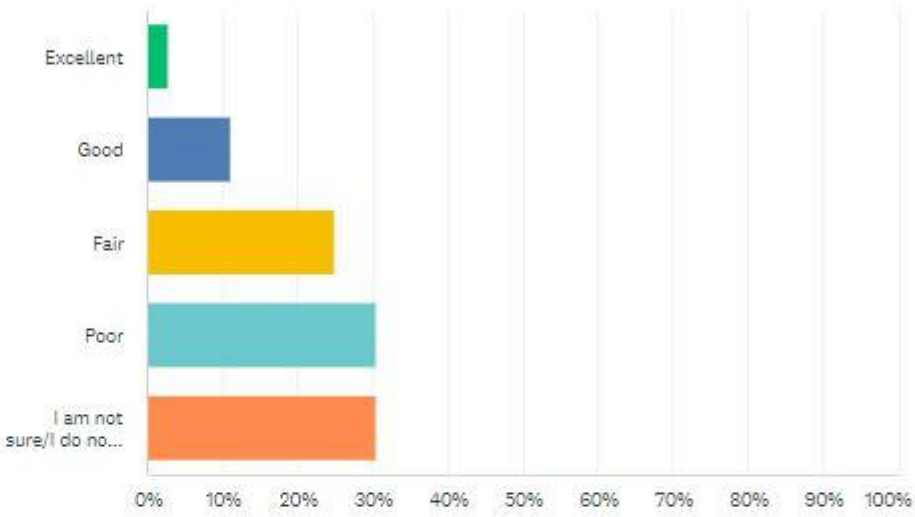


ANSWER CHOICES	RESPONSES	
Excellent	2.38%	1
Good	9.52%	4
Fair	26.19%	11
Poor	23.81%	10
I do not know/I am not sure	38.10%	16

Figure 57. Responses received from survey Q27

Almost half of the participants (38.10%) did not know how to respond to this (Q27), or were not sure. The other half of responses were divided between “good”, fair” and “poor”. None of them chose the option of “excellent”. This could potentially show that more attention should be paid to the issue. One participant argued: “Once more the refusal to change and adapt is a huge obstacle.”

Answered: 36 Skipped: 16

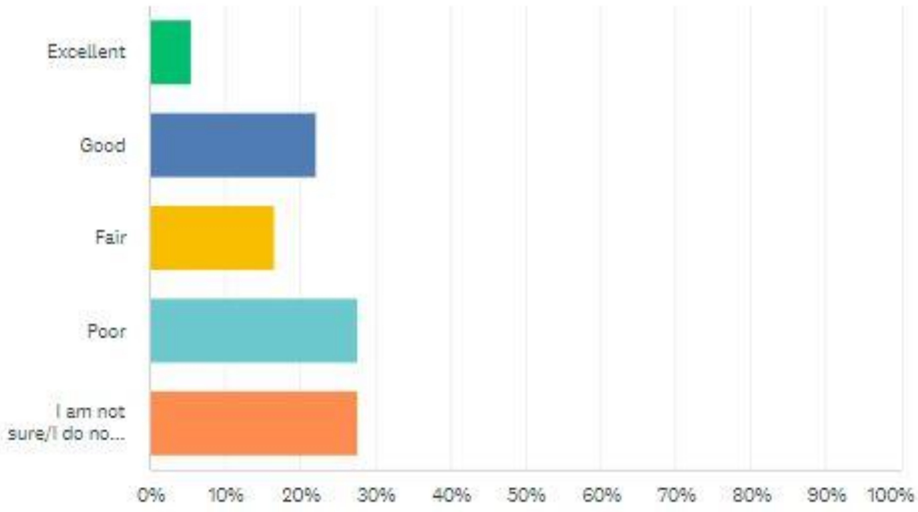


ANSWER CHOICES	RESPONSES	
Excellent	2.78%	1
Good	11.11%	4
Fair	25.00%	9
Poor	30.56%	11
I am not sure/I do not know	30.56%	11
Total Respondents: 36		

Figure 58. Responses received from survey Q28

To (Q28) participants, showed a similar tendency as with the previous question. Many of them responded they do not know how to answer this question, while none of them chose the "excellent" option, with most of them being divided between "poor" (30.56%) and "fair" (25.00%). Again, as with the previous question, it could be argued that more attention could be placed on this issue.

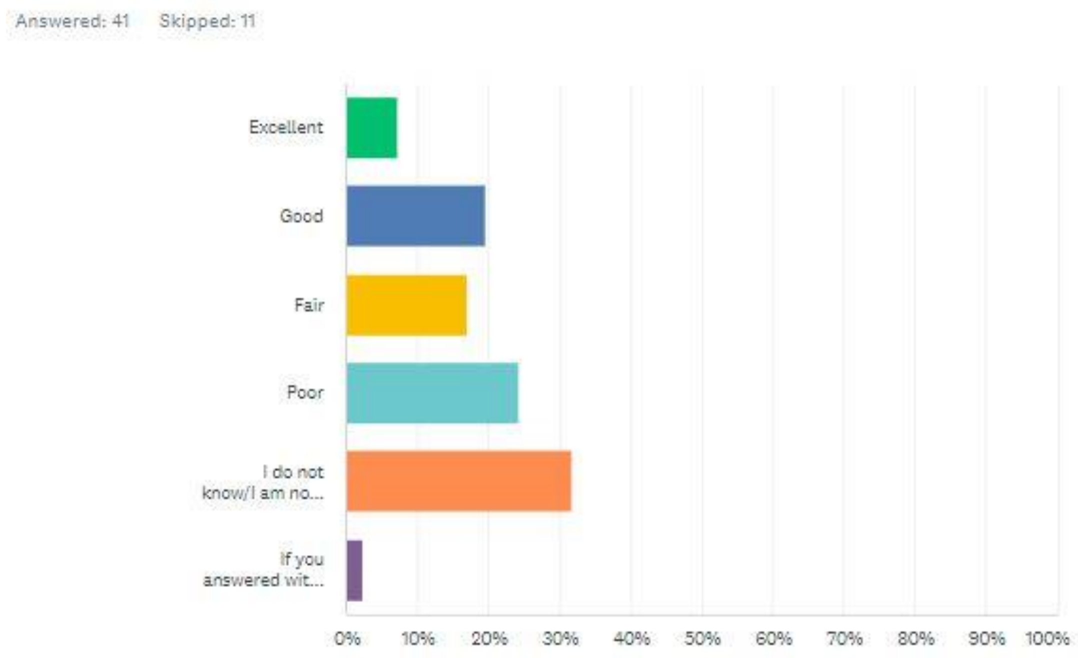
Answered: 36 Skipped: 16



ANSWER CHOICES	RESPONSES	
Excellent	5.56%	2
Good	22.22%	8
Fair	16.67%	6
Poor	27.78%	10
I am not sure/I do not know	27.78%	10
Total Respondents: 36		

Figure 59. Responses received from survey Q29

In (Q29) the majority of answers from respondents oscillated between “poor”(27.78%) and “good” (22.22%), with some of them arguing that the current state is “fair” and with even less choosing the “excellent” option. A number of participants did not know how to reply to the question. This is more optimistic, compared to the last previous two questions, but still shows a lot of room of improvementthat needs to take place in this regard.



ANSWER CHOICES		RESPONSES	
Excellent		7.32%	3
Good		19.51%	8
Fair		17.07%	7
Poor		24.39%	10
I do not know/I am not sure		31.71%	13
If you answered with "Good", "Fair", or "Poor", please briefly specify why	Responses	2.44%	1
Total Respondents: 41			

Figure 60. Responses received from survey Q30

In (Q30) the majority of answers from respondents chose the “I do not know/I am not sure” option (31.71%). Other than that responses were divided with most participants arguing that the integration is “good” (19.51%), poor (24.39%), and less argued about fair or (even less) excellent. Once again, as with (Q27), (Q28), (Q29) it could be argued that more attention could be placed to these issues, both in terms of providing solutions and training that responds to these matters adequately, as as well as in terms of awareness. Overall, the workforce seems to be an important player in the need of training for energy efficiency.

Q31 If you have any comments you would like to make, please write them below.

Answered: 5 Skipped: 47

#	RESPONSES	DATE
1	The training was focused on practices of energy efficiency not training strategies of workforce.	11/22/2020 3:01 AM
2	Important work, this must be continued.	10/29/2020 8:29 AM
3	Focus should really be on better better incentivising building professionals and construction workers to upskill in energy renovation. As it currently stands, they don't feel there is any reason to do it given they are competing (on price only) with many people who haven't upskilled in the area.	10/20/2020 2:29 PM
4	The training I mentioned was arranged by ourselves to emphasize on a broader sense the importance of Life cycle assessment and life cycle planning at the early stages of any construction project.	10/16/2020 8:22 AM
5	workers haven't enough training to globaly understand the keys aspects of EE.	10/6/2020 9:44 AM

Figure 61. Responses received from survey Q31

The last section of the questionnaire (Q31) gave the opportunity to participants to make last comments. From these three observations, it could be argued that focus is placed, on the workforce and professionals, and on how to improve their experience, understanding, and awareness in matters of energy efficiency.

10.4 Results - Interviews

This subchapter analyses the 28 interviews that were conducted, in the context of the INSTRUCT project. As mentioned in the methodology, NVIVO was used to analyse and group the data. From the themes emerging, diagrams were extracted, and qualitative observations were made. The chapter follows a detailed account of each question, followed by a relevant graph and a commentary for each result. The analysis follows an interpretive rationale of discussing the most highlighted tendencies and patterns, while linking them to the broader questions and aims of this study. For reasons of anonymity and privacy, interviewees are mentioned with the code "Interviewee" and the number next to it, e.g. "Interviewee 1", "Interviewee 2" etc. The actual questions to the interview begin from "Question no2", due to the fact that "Question no1" was a declaration of consent to the interview, to which all participants, replied positively. To avoid confusion, the numbers in the diagrams and chart show the replies received to each question. In some cases, respondents did not answer to a specific part of the question, and so their reply is not included in the numbers. In other cases, the respondent's answers belong in more than one category (e.g. type of barriers). Participants are referred to as either with "Interviewee X", or as "participant".

Demographics

Country:

Demographics Country	28
Italy	6
Bulgaria	6
Poland	5
UK	4
Finland	4
Slovenia	1
Romania	1
The Netherlands	1
France	1

Table 8. Countries of Interviewees

Q2. Could you please introduce yourself, and your professional role/position?

Type of position	28
Trainer, Research & Education	8
Architectural Engineering, Str	8
Project Management and Busi	5
Other	4
IT & Software related	2
Contractor or Subcontractor	1
Briefing	0
Electrical Engineering	0
Acoustics	0
Fire Engineering	0
Quantity Surveying	0
Facility Management	0

Table 9. Professional Position of Interviewees

One observation that needs to be stated, which is also a limitation of the data collected, is that the majority of participants were white-collar workers, with the exception of one participant.

Q3. How does training and skill development in the construction sector contribute to the increasing need for environmental awareness, in our societies?

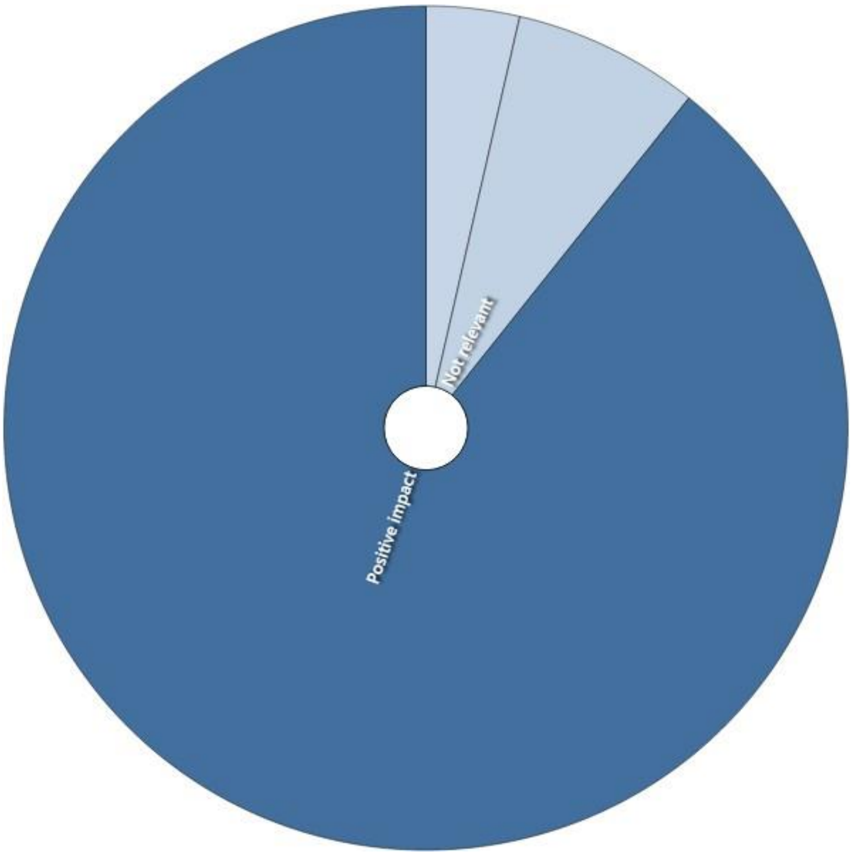


Figure 62. Question 3 as summarised in graph

Contribution to environmental awarene	28
Negative impact	1
Not relevant	2
Positive impact	25

Table 10. Detailed account of responses to question 3

Overall, to the response to this question, an overwhelmingly large number of respondents (except for one) could see a clear correlation between training for energy and an increasing need for environmental awareness. There were mentions of how this link should be further strengthened and observations of how even though it might currently not be contributing as much, this is surely the direction that we should be moving towards. In terms of how it contributes, as argued by Interviewee 14 "With practical examples that become more and more present". Further to that, Interviewee 16 argued: "There are at least two contributions: 1st – Improving knowledge of people in the construction sector gives them another tool to convince their clients, and there is a huge possibility to increase environmental awareness to the homeowners and investors. 2nd – Courses and training in energy efficiency area always increase the knowledge and awareness of the students in the area and increase the willingness to contribute to the fight against global warming". Also, the importance of keeping in mind long-terms results in this regard, was highlighted.Overall, in the context of the global warming emergency that we find ourselves into, sheds light on how training can significantly contribute not only to the needs and necessities of the construction industry, but also to larger societal and environmental needs, as well as needs for wellbeing. As observed by Interviewee 17: "The improved quality of the buildings, leading to lower energy bills and more comfortable indoor parameters is a clear demonstration for the society that energy efficiency isnot only political whim but have significant benefits for comfort and healthy environment".

Q4. What barriers can you identify in the field of training for energy efficiency, in the construction sector?

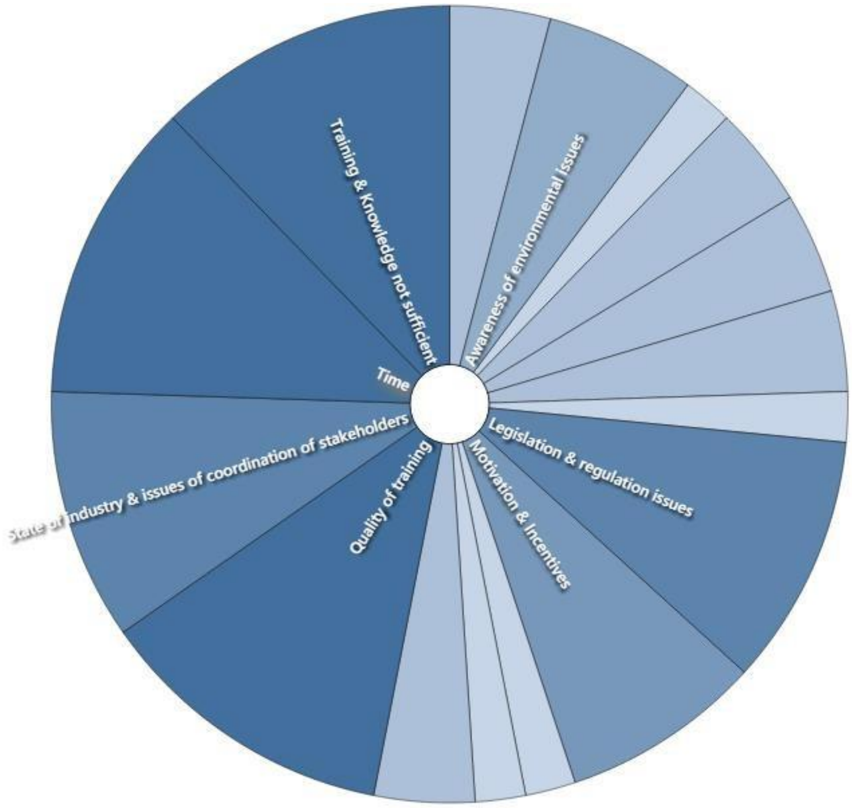


Figure 63. Distribution of barriers, question 4

With regards to barriers, and as seen by the diagram it could be argued that the data analysis points to training & education in itself as being at the top of concerns. The majority of interviewees argued on how training is not effective as it should, referring either to the material or the way it is conducted, or of more profound and structural issues of education, awareness of the value of energy efficiency, lack of skills in the field and education.

Barriers	28
Access to training	2
Awareness of environmental issue	3
Clients not paying for energy effic	1
Communication issues	2
Costs & Financial Issues	2
Lack of demand	2
Lack of interest	1
Legislation & regulation issues	5
Motivation & Incentives	4
No answer	1
No barriers	1
Perception of training for energy	2
Quality of training	6
State of industry & issues of coor	5
Time	6
Training & Knowledge not sufficie	6

Table 11. Detailed account of responses to question 4 and barriers

More specifically, as argued by Interviewee 25 "The trainings offered by training providers are focused on particular aspects of technology or materials they sell (because it is in their interest to make workers capable of installing their systems etc.), but there is a general lack of knowledge about energy efficiency, general design and implementation". Further to that, as argued by Interviewee 3: "Training and enhancing knowledge programmes are rare, limited and often their importance is underestimated. The basis of knowledge in the construction sector is strongly dynamic and regular enrichment is needed." Other barriers came up frequently as well, such as the fragmented state of the industry and issues of coordination between stakeholders, conservative nature of the industry, lack of time for training, legislation & regulation issues, as well as the lack of incentives and reasons to motivate and activate demand on behalf of both the clients, as well as the professionals to see training as a valuable resource.

Q5: What can be done, in your opinion, to increase demand for energy efficiency, in the constructionsector?

To this question, various suggestions emerged. Some of them point to the issues that emerged in the previous question, concerning barriers. Interviewee 4 observed: "Increasing the interest and demand for high energy efficiency in buildings requires: (a) raising the awareness of all participants in the investment process about the benefits of energy efficiency, based on appropriate communication, (b) availability of positive examples in recent practice and (c) availability of well-trained planners/designers and builders." The issue of awareness, training, and education was often mentioned in the replies of the respondents in one way or the other, as well as those regarding the importance of good examples/precedents. Interviewee 16 sustained: Huge campaign focused on the

problems listed above and proper implementation of legislation in the field, would have the best impact. A few changes in the legislation and EPC issue scheme could also help a lot in the campaign, such as improving the Building energy certificate, online register and improving the exciting software."
The quality, efficiency of training and methods used in trainings also were encountered in the responses as a method to modernise the field and increase demand, as well as the proper use of new technologies. Incentives, and the role of the client as well in the demand dynamics were also highlighted.
However, the answer that kept emerging repeatedly, is that concerning legislation & regulations. The majority of respondents in some way, elaborated on the matter. Suggestions varied, although they all pointed to the same direction and need. For example, Interviewee 18 argued: "In my opinion, to increase the demand for energy efficiency in the construction sector there should be new and adequate government legislation and incentives to aid construction companies and homeowners willing to implement energy-efficient methods for building." Further to that, the context seemed to emerge as an issue to keep in mind, for example with Interviewee 19 stating that "It is very difficult question also because different countries have different requirements. In Poland now we haveproblem with enough number of blue-collar workers that often go to other European countries to work. Good idea can be national and local initiatives raising the awareness and providing financial incentives for renovations done with a use of skilled workers. In construction still very important factorwhen choosing the contractor is the price. But the EC is doing the same." On the other hand, Interviewee 9 presented a slightly different perspective on the matter, where a two-way collaborationcould work best: "In terms of top-down approach, more regulation, legislation… getting the whip out,for example. But I think that when it is a top-down approach, it is usually not being done right. If peopleare doing it just because they have to, they will find a way to do it as a tickbox exercise rather than tryto do it in the best way possible. So, in my opinion it is more about educating professionals so that they push, they are middle agents to drive this. And also, incentivize clients to want that, to ask that, for the projects that they are commissioning. So that they ask for that when they are commissioning, so that they understand that there is added value for the buildings that they are building rather than spending money."
Therefore, from the above there seems to be (a) a correlation between the barriers that emerged in Q4, and (b) an understanding that the dynamics of demand are highly dependent on a plethora of equilibriums, in the construction sector, as well as dependent on the context. It could be suggested that the issue requires a closer look due to its complexity. What is being highlighted, however, is, once more, the importance of showing the value of awareness, proper education and clear communication of the value of energy efficiency to all actors in the field, which would give incentives to investments, positive changes, and organised efforts towards a common goal.

Q6. What is the current state of knowledge and experience sharing, with regards to energyefficiency, in your organisation, in your opinion? What can be done to improve it? Are thereany conflicting interests?

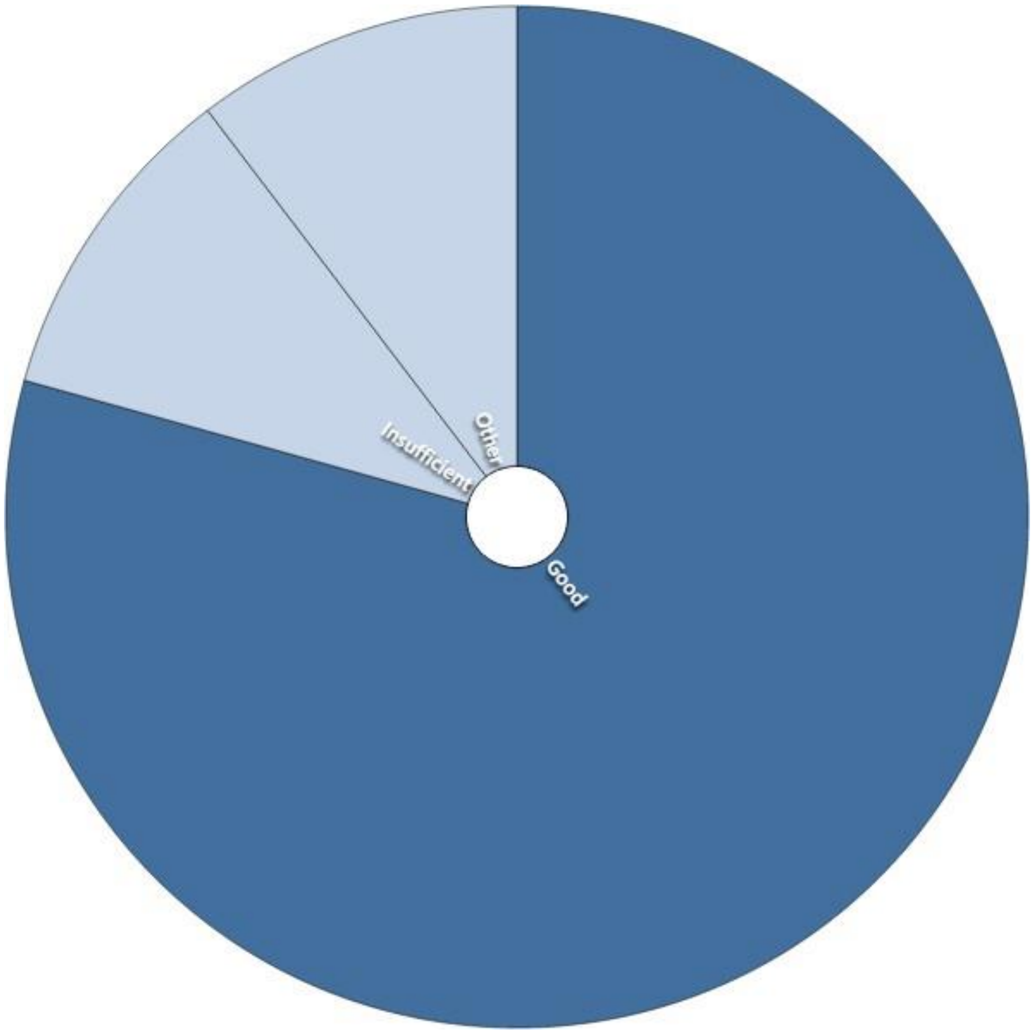


Figure 64. Distribution of responses to question 6

Organisation	28
Good	22
What can be done to improve it	14
Conflicting Interests	7
Insufficient	3
Other	3

Table 12. Detailed account of responses to question 6 and barriers

Overall, the majority of respondents replied to the question by presenting a positive perception of how their company works and how well it integrates knowledge and experience sharing, concerning energy efficiency. Only three respondents pointed to not a very positive experience within their organisation, which comes down to issues of how energy efficiency is not being taken into account. For example, Interviewee 8 argued: In my organization we are almost technical persons duly trained. Energy efficiency is a peculiar aspect of the construction sector and sometimes less considered, or at least finally considered. Most of the respondents stated that there are no conflicting interests, with some exceptions, such as Interviewee 4, who argued that: “Our organization's knowledge and experience of energy efficiency in buildings is good, but their level is maintained and constantly increasing. The main aim is to use appropriate means of communication to share and disseminate this knowledge and experience. Conflicts often arise between the high goals and requirements that we set in the training of specialists and the reconciliation with lower criteria in real practice”. Similarly, Interviewee 21 argued that: “So when we, as the directors, say, we need to cut our emissions to zero, the finance department says, yes, but it’s not gonna pay off. Minimizing CO_2 emissions and using renewable energy sources is expensive. That’s not gonna bring the revenue or we're gonna minimize the revenue. So, it’s money versus the environment. Secondly, internal education on energy efficiency and resources on an environmental impact takes time. People do not sell stuff. We are coming to the point that we need to improve our products to make them more sustainable, to make them more energy-efficient”. The conflicts seem to stem from a difference in priorities and perspectives, and a lack of a common language between stakeholders. In terms of ways to improve it, some significant suggestions were raised. For example, the intensification of sharing of information was one, while the improvement of physical and technical implementation of sharing was highlighted by another participant, as important. Investments in new technologies, better connections with the construction sector, training and education of all stakeholders, improvement of legislation and technologies, were also among the suggestions.

Q7. What is the current state of knowledge and experience sharing, with regards to energyefficiency, in the industry, in your opinion? What can be done to improve it? Are there any conflicting interests?

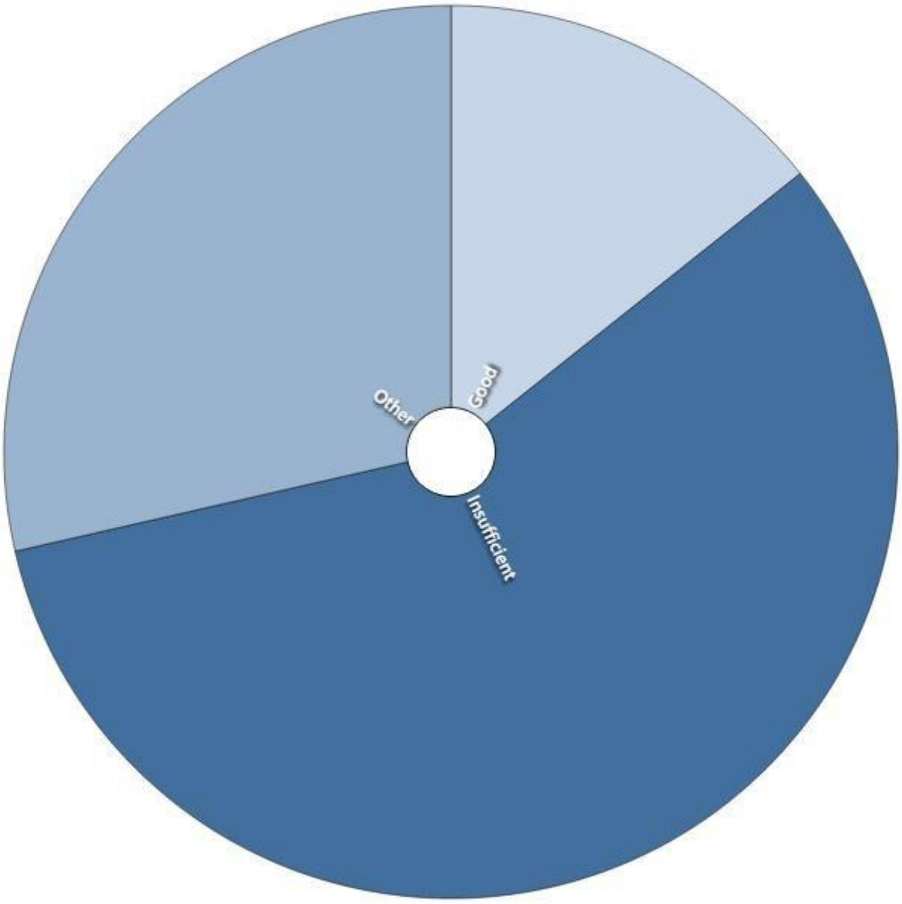


Figure 65. Distribution of responses to question 7

Industry	28
Insufficient	16
Other	8
Conflicting Interests	8
What can be done to improve it	8
Good	4

Table 13. Detailed account of responses to question 7

Moving on from Q6 to Q7, and even though the only variable changing in the question was the scale of the context (organisation versus industry), a significant shift in perception occurs. Here, the majority of participants argue that knowledge and experience sharing concerning energy efficiency do not present a positive landscape, but many more challenges. Some issues with regards to knowledge overall, and few companies focusing on energy efficiency were highlighted. What also emerged is the sometimes, theoretical rather than applied "success" of the construction industry, with regards to energy efficiency knowledge and experience sharing. Interviewee 18 argued, summarising a variety of issues: "At the moment the state of knowledge and experience sharing, with regards to energy efficiency, in the industry is very poor. Most companies lack trained manpower/staff, time, and money to provide adequate training to their workforce. I think that this can be improved by imposing new government legislation, providing adequate funding and incentives which will, in turn, create more demand for energy efficiency in the industry and will greatly increase the interest in the field". Interviewee 23 sustained: "It is rather trying to take advantage of the ignorance of the end-user and do so at its lowest cost. And this is a little bit of investors' fault because it is precisely in terms of costs that they are not, making strong pressure on the contractors and on all those involved in the construction process. That is to make it as cheap as possible. And these buildings are not cheap because we work with the right thicknesses of the individual partitions, with slightly different efficiencyof the equipment. In fact, if we build these two buildings, they will very often look physically the same". Regulation and legislation issues, issues of education, awareness & understanding, lack of how knowledge is disseminated, fragmented industry landscape, lack of post-occupancy evaluation and follow up to the results were also mentioned. Furthermore, a distinction was made with regards to the different size of enterprises. Interviewee 17 argued: "Depending on the size of the enterprises. In most cases, smaller enterprises with low share of energy expenses in the final product cost need knowledge and experience, while large companies are with better understanding on the topic. However, practical training is required in both cases". Also, competing interests and conflicts came up. For example, Interviewee 11 argued: "I think that that would be obviously something that they wouldn't do and they probably put first the interest in terms of like their interest as a company in terms of profit and future profits rather than actually the environmental perspective". Further to that, in some cases, a type of short-sighted approach was also highlighted. Interviewee 21 argued: "There is a conflict of the current business versus the interest of future generations. Today we are building buildings that emit a lot of CO_2. The developers and brick manufacturers earn money today, but then after 20, 40, 80 years, our kids will have a lot of CO_2 in the atmosphere. They will need to figure out how to remove the CO_2 out of the atmosphere. They're gonna pay for it, not today real estate developers". Also, Interviewee 26 pointed sustained that: "Conflict of interests are relevant in the tender process – it is difficult to include specific products in the tendering documentation". Further to that Interviewee 4 argued how: The main conflicts arise from the high needs for investment in energy efficiency and limited financial resources", shedding light on another issue, regarding the gap that sometimes exists, as highlighted in some other interviewee's comments, between ideal intentions and the reality of the market and the economy. Interviewee 9 argued: And clients are just mostly concentrated in the capital cost, rather than the overall cost of the building. Particularly if they are not the ones that they are going to occupy the building. There is a barrier between the interests of the client, with the interests of the eventual tenants.

With regards to things that can be improved, a variety of suggestions came up. Improvement of dissemination of the knowledge, collaborative spaces and shared drives, the importance of training, a more in-depth focus on how energy efficiency is integrated in education from an early-stage, improvement in legislations, continuous professional development, a more intense focus on tangible results rather than theoretical ones, energy efficiency technologies.

Q8. Could you please give your opinion on the level of demand for energy efficiency trainingand what you think will happen in the foreseeable future?

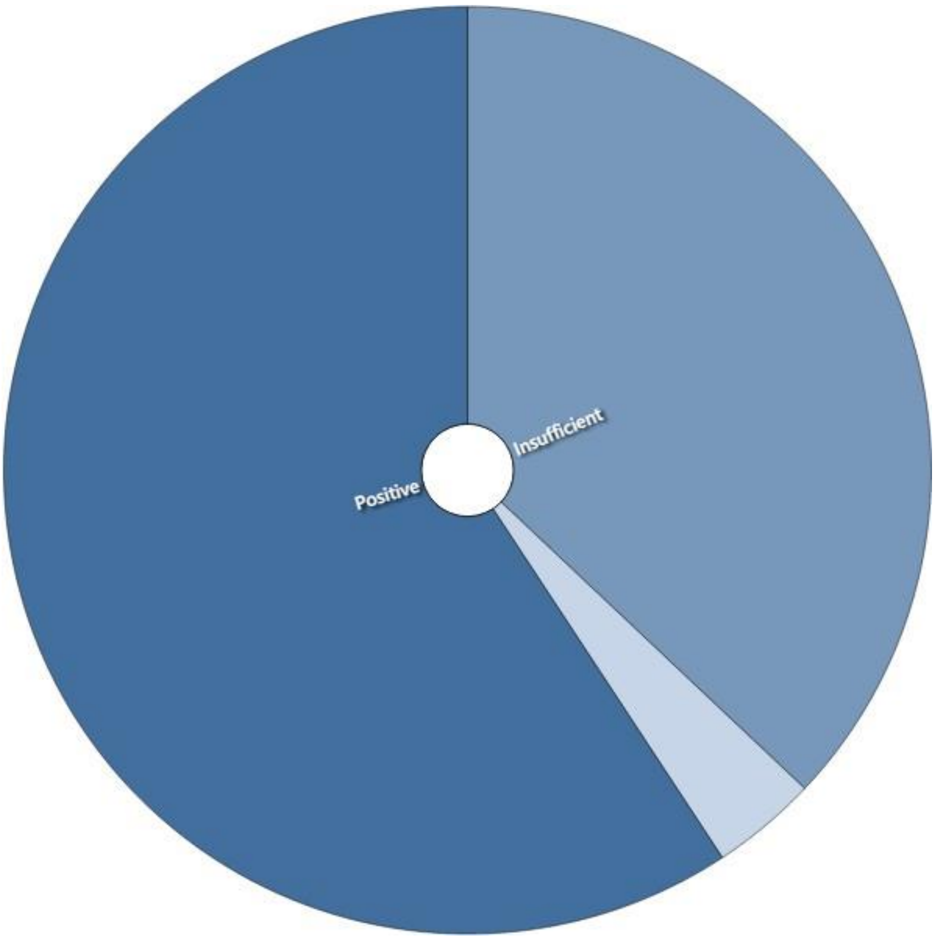


Figure 66. Distribution of responses to question 8

Demand	28
Future prediction	22
Insufficient	10
Neutral	1
Positive	16

Table 14. Detailed account of responses to question 8

The responses to this question showed in the majority a positive landscape as perceived by the interviewees, concerning the level of demand for energy efficiency training, and the majority of them also highlighted, the definite need to intensify the efforts and increase demand. Some clarifications were made, with regards to some prerequisites for this to happen. For example, Interviewee 1 argued "There is a reasonable level of demand, but only legislation will change the pace of uptake. The public sector is better than the private in this regard. On the other hand, Interviewee 19 argued: "If there will

be a demand for energy efficient construction, there will also be demand for the skilled workers". In the same spirit, Interviewee 26 argued: "The level of demand depends on various factors: (a) awareness of building owner/developer, (b) responsibility level/behaviour at decision-makers / regulating authority. It should increase rapidly with the enforcement of nZEB requirements for new buildings and deep renovation minimum energy performance requirements". The landscape of demand seems to be a complex one, however. Interviewee 4 sustained: Due to the lack of awareness of the benefits of energy efficiency, the objective need for training in this area is greater than the actual demand for these services. On the other hand, Interviewee 20 argued, concerning training programs: "The few in which I participated did not enjoy any great demand. Even if there were many people, this was due to the fact that there were many companies which had something to present".
In any case, however, and as overall observation, training seemed to emerge as a significant need, with the vast majority of participants arguing how even if the level is not good enough currently, there is a definite need to improve it.

Q9. In your opinion, is the importance for energy efficiency skills in the construction sectorbeing taken into consideration adequately, in your field?

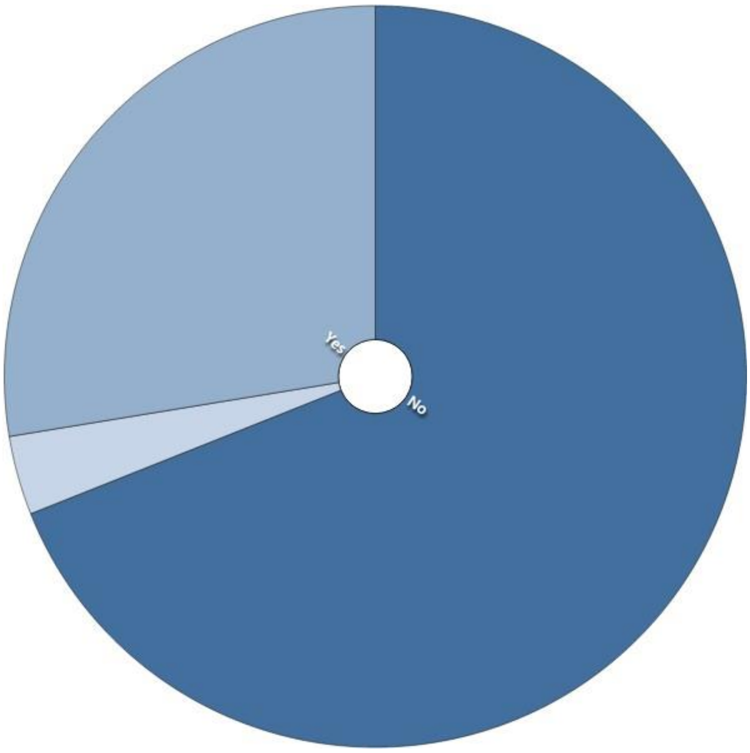


Figure 67. Distribution of responses to question 9

Importance for energy efficiency skills, t	28
No	20
No answer	1
Yes	8

Table 15. Detailed account of responses to question 9

To this question, responses were split in both a positive and a negative perception of whether the importance for energy efficiency skills in the construction sector is being taken into consideration adequately, leaning more towards a negative suggestion (more responses suggesting that). This data could be argued to indicate the imminent need for training and a more organised effort towards that goal needs to be placed in motion. These observations would tie in with responses to previous answers, regarding demand and training. Indicatively, some reservations shared from participants who argued the importance for energy efficiency skills is not taken into consideration as it should include the insufficient training, a lack of collaboration between professionals and companies on the matter, no demand, and in some cases, a sector which is rather conservative in its approaches. Also, it was argued that often it is only in theory and not in practice that they are taken into consideration efficiently. Some observations made by interviewees point to some parameters which affect energy efficiency skills being taken into consideration adequately in the construction field. Interviewee 2 argued: “When it comes to policymakers and advisers, yes. When it comes to companies themselves, many of the companies are holding off. When we look at training infrastructure, we are ready but when it comes to the rise in demand, the demand for training is not growing/developing as quickly as we think it should”. On the other hand, Interviewee 22 made a distinction on the type of buildings which are being addressed: Here, it would be necessary to distinguish between the new buildings and existing ones. Such requirements are defined by regulations. Maybe the difficulty lies in checking it out. Because the institutions that are supposed to check these documents do not know exactly if the building actually meets these requirements. However, when it comes to old construction and those subject to modernization, there is still quite a large area for improving the quality of training for people who carry out and people who prepare these investments. So here we come back to insulation designers and the auditors who perform these calculations, what is the area of intervention or thermal modernization investment”. On a similar note, Interviewee 7 argued: “If our company is responsible about maintenance, then we require EE skills from designers”.Further to this, issues about legislation and regulatory frameworks emerged, once more. Interviewee 26 stated: “Very high. But the process should be improved: quality compliance frameworks and awareness are crucial. Enforcement of performance requirements and sound communication for the impact of low- or no- skilled personnel (with bad examples) should be done. Interviewee 16 sustained:If there is a willingness in final customer to live in a good energy efficient house with health environment and perfect comfort, then yes. Otherwise even if it is forbidden to build different than NZEB building there will be ways to be issued a certificate for a poor designed and constructed building”.

From the above it could be argued that the importance for energy efficiency skills in the construction sector is taken into consideration but not always in a holistic manner, and this seem to affect the perception of how much these skills are needed.

Q10: Is the focus placed on training for energy efficiency sufficient? Please elaborate on your opinion.

The replies to this question seem to point to a clearer implication that the actual focus that is currently placed on training for energy efficiency is not sufficient. Aspects that have been raised include: Legislation, lack of proper skills, mostly architects & engineers need for information, more coordination among professional bodies, difference between workers from different professional backgrounds, with different perceptions in the field and set of skills, sometimes even a lack of ambition for the final result, lack of time for training. In one case, Interviewee 15 described a total lack of such schemes and training programs in their country: “Yes and no. […] Now there are no training courses in my region, but there are many courses online and with different approach at the energy efficiency solutions. For example, there are courses about a better insulation, or about a better heating systems.” Another issue that emerges from the training itself not being sufficiently accessible, which can create an obstacle even if there is a demand.

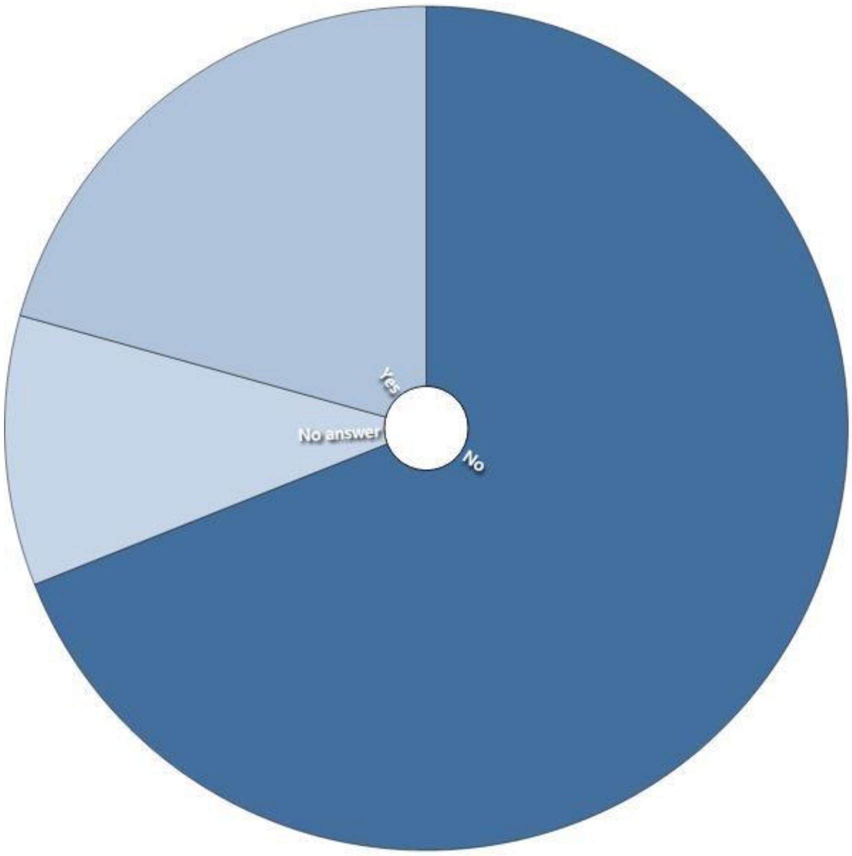


Figure 68. Distribution of responses to question 10

Focus on Training (Quality)	28
No	20
No answer	3
Yes	6

Table 16. Detailed account of responses to question 10

Interviewee 11 mentioned: “I don't think it is for reasons that yeah I said earlier I think that it should be made more accessible and be more accessible in terms of easy to find because it might seem silly sometimes trainings are very difficult to find, sometimes there are agreements that are made ahead that are done beforehand so which website can you access in which website you can't access your company so sometimes you don't have let's say a whole platform where you can find different topics so that you want to take a Python class it's not that easy because in the overall platform they might not have Python classes. And the providers that you are looking for they are not let's say in agreement with the company, so you need to find a reason for the company to pay for it so definitelyis not sufficient the stress”.

Q11: Could you give any examples of other training programs in the construction industry that youbelieve are contributing to energy efficiency, in the construction sector?

The answers to this question by gathering the accounts of the specific programs that the interviewees mentioned and the types of training they brought up. The suggestions are presented ina list below, verbatim:

2. “Courses about the environmental certifications (such as LEED, BREEAM, Well)”, as suggested by Interviewee 15
3. “Free training courses initiated by Bulgarian Sustainable Energy Development Agency, https://www.eetraining.eu/,” as suggested by Interviewee 17
4. “I would say the Academy of Healthy Building. This is a cool example of such training, which is, in principle, for everyone, for architects, is led by qualified trainers, architects, who show how to design, how to build buildings”, as Interviewee 20 argued
5. “There are some NGOs, like the Polish Passive House Association or the Green Building Council of Poland who are delivering training about the energy efficiency. There is the National KAPE and NAPE, which is the National Energy Efficiency Authority. They run some trainings for energy auditors, and they raise awareness, and they give overview knowledge on the issue. […] There are some nice courses for example the IZODOM company is running online courses for foreign house builders and designers”, as argued by Interviewee 21.
6. “The German Institute for Passive Construction, based on 30 years of experience, so they were not created yesterday, but were created on the basis of observation of these buildings for 30 years”, as suggested by Interviewee 23
7. “Train-to-nZEB – The Building Knowledge Hubs

   Fit-to-nZEB – training on deep energy renovation (towards nZEB).

   Also, new training programs are needed for new activities / requirements: calculation of thermal bridges, BIM, blower door testing, airtightness of building envelope etc”, as suggested by Interviewee 26
8. “NGOs, construction associations and some university faculties have their own programmes and

   thematic activities in the construction field which I believe contribute significantly”, as suggested by Interviewee 3.
9. “Universities, professional chambers of builders and architects, as well as various associations in the field of construction implement their own training initiatives in the field of energy efficiency. Curricula are also conducted on the basis of bilateral cooperation agreements between European countries. The Passive House Institute periodically conducts certification courses for designers and

builders", as argued by Interviewee 4

10. "There are several programs, e.g. in Kiinko, RIL, Metropolia etc. Also GBC (green building council) is giving some events", as presented by Interviewee 5

11. "I know that CIBSE has a lot of training available, RIBA (Royal Institute of British Architects) has training available, BRE has available training. That's for the workforce. Now in terms of other schools, Bath University has their Masters, UCL the Bartlett has. The Environmental Design Masters, at Cardiff University, at the WSA. CAT used to have the Centre for Alternative Technology in Machynlleth. So they had a very hands-on program, where students went and spent some time there, and they could see some of the technologies and how they worked-that was more for services. Or they had an earthwall in fact. So they had some of the examples, so students could see that live. So that was nice", as argued by Interviewee 9.

12. "We just started the 4th edition of a course, FACE. It is in the direction I mentioned before, the participants are already active in the market, all the training parts are quite proactive, so we push for having an active exchange amongst the participants, trainees and trainers. How to ensure effectiveness of training during the progression of a course taking into account aspects of project work, so how to put in practice what they are learning. We organise it in this way because we think it is an interesting and practical way to transfer knowledge. Local courses, such as at the energy agency, their courses are practical and more dedicated to designers. The courses show the basics related to building principles but also includes very practical parts. Their programmes and training agenda is quite interesting and very effective", as argued by Interviewee 27 suggested.

13. "Too many to list. Generally, the process starts with the very first concept designs where orientation, location of windows etc. can have a crucial impact. On the other end of the spectrum, training on cold-bridging details are hugely important too", as argued by Interviewee 1.

14. "A training program on smart buildings could be useful, since nowadays energy efficiency is in connection with the other parts of the building, by IoT technology" as argued by Interviewee 10.

15. "Sometimes secondments can be interesting so maybe within the same project it might be that you can get seconded to another company and possibly you can get exposure to different issues that you wouldn't have the chance to experience when you were in your first project […]. Any class that includes a little bit of computing is useful because of the want to perform an any type of optimization strategies or any type of optimization processes you need to know computing for anything that involves computing, I think is of fundamental importance." as Interviewee 11 suggested.

16. "I guess the obvious one for me would be accreditation schemes that are offered by energy modelling software companies" as Interviewee 12 suggested

17. "All construction skills programs, energy efficiency is part of a quality constructed building" as Interviewee 16 argued.

18. "Technical trainings for the blue-collar workers, trainings for the designers about energy efficient solutions" as suggested by Interviewee 19.

19. "There are many. We see several suppliers that have good training programmes. Wholesale companies are arranging training centres. Many schools are working together with the construction industry. When you look at those examples, many are doing too much themselves. One of my ambitions is to make them more cooperative with each other because then they can make much more impact with the same amount of money" as argued by Interviewee 2.

20. "If I should give a concrete example, I would say the Academy of Healthy Building. This is a cool

example of such training, which is, in principle, for everyone, for architects, is led by qualified trainers, architects, who show how to design, how to build buildings", as suggested by Interviewee 21. "We worked on two consecutive projects with Build Up Skills" as suggested by Interviewee 28 22. "In the construction industry, they offered me lectures on energy management in the building and energy auditing with a particular emphasis on energy efficiency at their annual meeting. […] Another such element is, of course, the entire school sector. […] Even a well-functioning university at the moment, I do not know its exact name, in Radom was based on our activities, on our training programs for auditors and building administrators" as suggested by Interviewee 22

Q12. Could you please describe the skills that are needed in the new energy efficiencytechnologies, in your field?

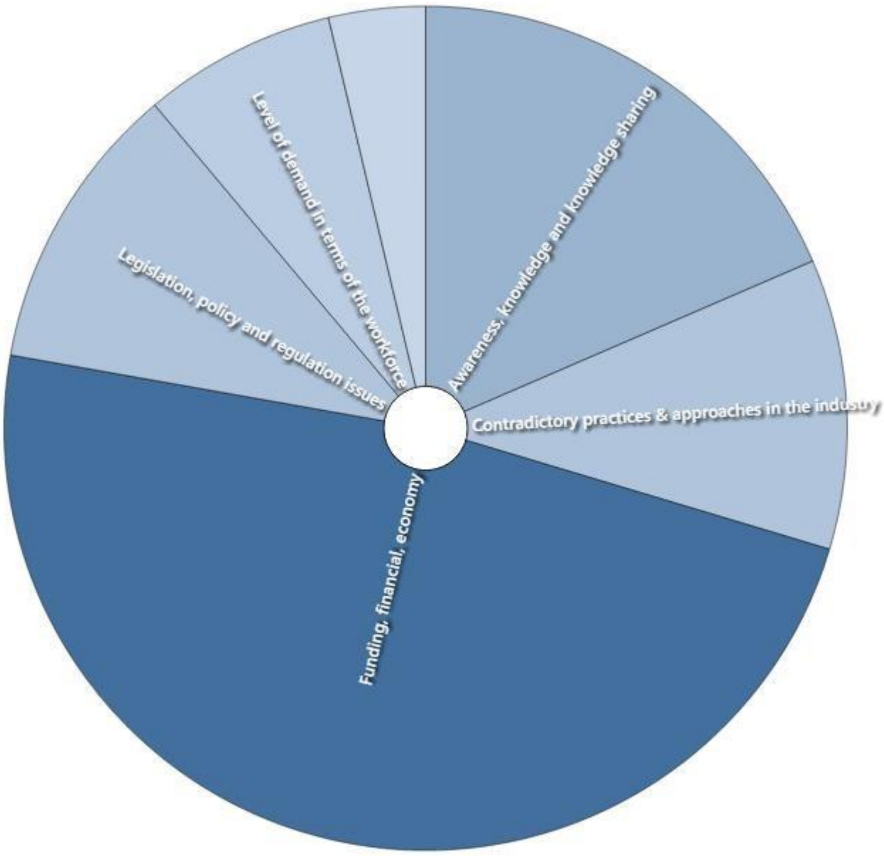


Figure 69. Distribution of responses to question 12

Type of market challenges	20
Funding, financial, economy	13
Awareness, knowledge and knowledge sharing	5
Contradictory practices & approaches in the industry	3
Legislation, policy and regulation issues	3
Level of demand in terms of the workforce	2
Time	1
Strategies	8
No answer, other	8

Table 17. Detailed account of responses to question 12

The answers for this question were grouped in terms of relevance. The vast majority of replies pointedtowards skills that have to do with awareness, conceptual knowledge and understanding skills, as beingthe most important. These observations are very significant in the context of this deliverable, as they highlight the importance of further intensifying efforts towards properly educating the workforce and the general audience, as well. Knowledge in this sense included a variety of fields, such as “knowledgeon the times of circular economy and resilience in the green economy”, as argued by Interviewee 14, technical skills, design skills, knowledge of materials, physics and technologies, Interviewee 1 argued: Good conceptual design skills and understanding of how layout, orientation etc.affects energy use; good IT skills underpinned by knowledge of energy efficient design and how to achieve this. There are several complex software programmes to assist us as designers, but these canbe time consuming to learn”.

Q13. Does energy efficiency in the construction sector contribute to a vision of long-term employment?

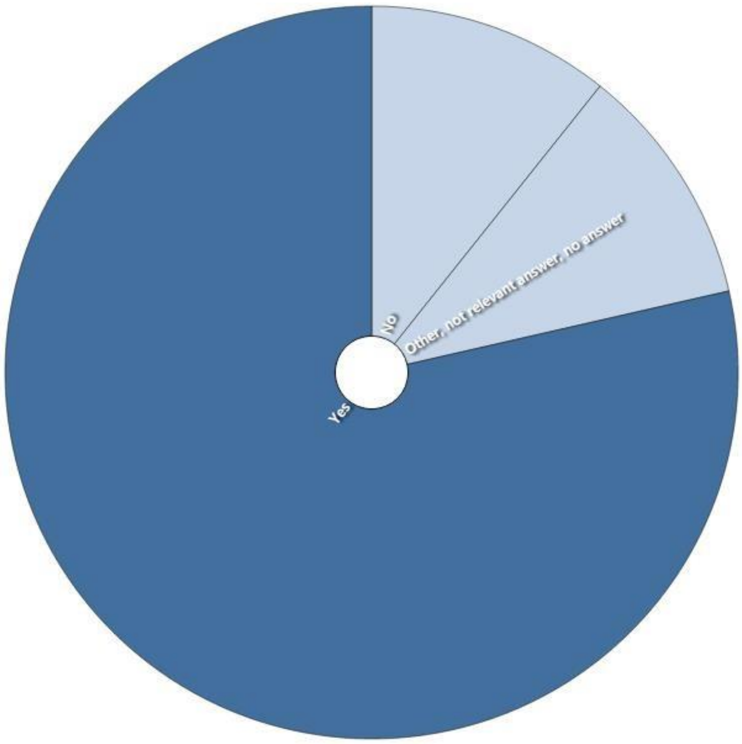


Figure 70. Distribution of responses to question 13

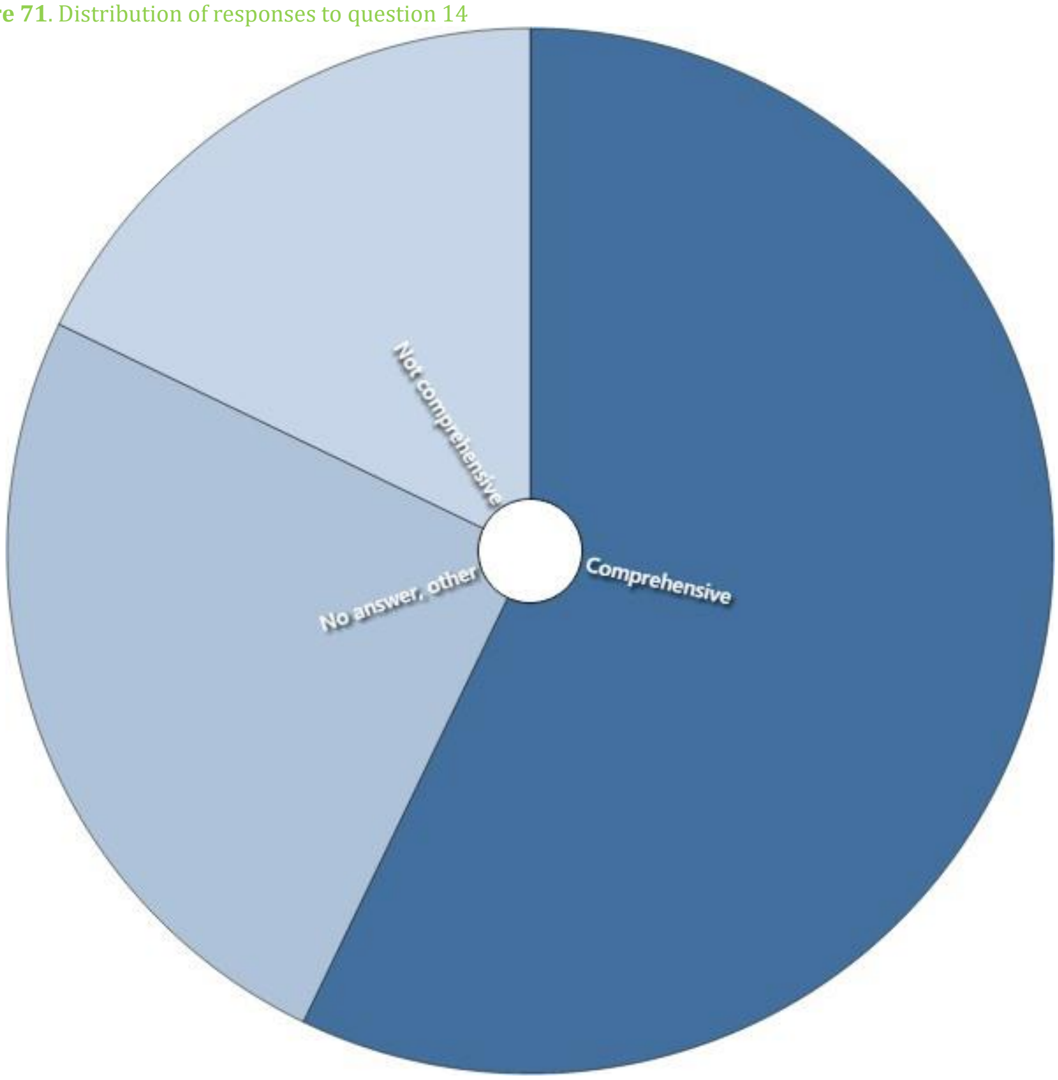
Contribution to vision of long term employment	28
Yes	22
No	3
Other, not relevant answer, no answer	3

Table 18. Detailed account of responses to question 13

To this question, an overwhelming number of Interviewees replied with “yes” pointing to a clear link between energy efficiency and long-term employment. Interviewee 25 answered: “I think it does, particularly for young people entering higher education/ university. They will be part of the new employment. There are new roles to be defined within the sector, and so new types of skills will be combined to make new jobs that are not necessarily prevalent right now in the sector. It will be easier for young people to go for these new roles”. Interviewee 17 argued: “Yes, as more qualified and better-paid experts will be required to fulfil the nZEB definition”. On the other hand, Interviewee 16 suggested that: “Could be, especially if there is regulation for construction companies to have this kind of specialists”. From those who expressed reservations and did not necessarily agree to such a long-term vision, Interviewee 2 argued: “That depends. The construction sector is highly influenced by policy making. If the government is making the wrong decisions, then the employment vision is not sustainable. Ideally want we want in the is a gradual growth in the market until the peak is reached then a gradual decline in the market”. Overall, it seems that according to the participants, if the market moves to the direction is moving today, and the efforts towards better energy efficiency policies improve, the field could be a space where long-term employment becomes a reality.

Q14. How comprehensive is the training material for energy efficiency in the construction sector that you are familiar/involved with (and if you can elaborate on what that training is)? How can it be improved?

Figure 71. Distribution of responses to question 14



Training Material-How comprehensive	28
Comprehensive	16
How it can be improved	15
No answer, other	7
Not comprehensive	5

Table 19. Detailed account of responses to question 14

To this question, the majority of participants replied with an optimistic perspective, by suggesting that the training material is quite comprehensive. However, most of them identified limitations, and some suggestions were made of ways to improve it. Several participants suggested that they are comprehensive in a specific field, rather than having a more holistic approach. Interviewee 12 argued: "So the training material that I've come across is comprehensive however perhaps it is comprehensive on a particular product or a particular specification at any given time so it's more of an advert for that product or for that specification standard or accreditation. Perhaps the training material could especially in terms of private companies they could be they could come from within and could be focused on an energy efficiency outlook rather than the energy efficiency around this certain product or standard". Regulations and laws are also mentioned in terms of missing elements of the material, while the need for the material to be constantly updated also emerged, as well as the need to make sure that how training is connected to achieving greater energy efficiency is also being communicated. Further to that, the importance of presenting the practical impact for the investors was also raised. Other interviewees raised other issues. For example, Interviewee 17 suggested: "There are training materials with the needed quality, but not enough qualified trainers and no desire for trainings from the construction companies". On a similar note, Interviewee 2 argued: "It's quite comprehensive. Many of the trainings are developed by white collar workers and are quite theoretical. The knowledgeis available, but to train the large workforce it needs to be much more practical. One the job training is also required. It can be improved by micro learnings, e learnings, together with wholesale companies (many workers visit their stores regularly) so training workshops at the stores would be convenient". Language also emerged as a parameter potentially hindering the effectiveness of the learning material. On the other hand, aims for improvements for the future were shared, showing a promising development of the field of training for energy efficiency. For example, Interviewee 9 argued: "We are looking at updating our curriculum. Training at environmental design has mostly looked at the building and kind of first do no harm approach and we want to raise the bar, because we've been a program for 20 years now and raise the bar to do rather than not to harm, so how do buildings in a good way in a city that they are in, how can they attract species, and how can they incorporate nature in them. So rather than not just release carbon, how do we make them good for the city, how do we give back to the city. So, this is the improvement that we are looking at". Other significant observations were also raised: "We are constantly improving this, basically every time a person who conducts this type of training takes part in the processes and is professionally active, because I think that this is the main problem of the university, that there are mostly people there who are fantastic teachers, but who are theoreticians, not practitioners", as argued by Interviewee 23. Furthermore, in terms of the focus of the material, there was an observation by Interviewee 28 who argued that the focus of the training needs to be also placed on other aspects of building: "It has been identified that there is still a need for more training and materials on custom renovation construction, as it is very different from new construction, it needs more skills and materials and is a different process from new construction". On the other hand, significant limitations were raised by those who thought the material was not comprehensive. Interviewee 21 highlighted: It's not comprehensive. If I go on the market in Poland and I say, I want to become a passive house specialist or I wanna be a deep retrofit specialist, so thereare two or three places I can go and attend a passive house designer or passive house tradesperson course. Actually, there are two in Poland. On a similar note, Interviewee 25 suggested: "One way this can be achieved is by building centres across Europe to provide consistent trainings to people in the construction industry".To summarise, it seems like the training material is in general comprehensive, yet with a lot of roomto improve, on many fronts.

Q15. How much of previous knowledge is considered in training programs for energy efficiency inthe construction sector? Is informal learning & training being properly integrated?

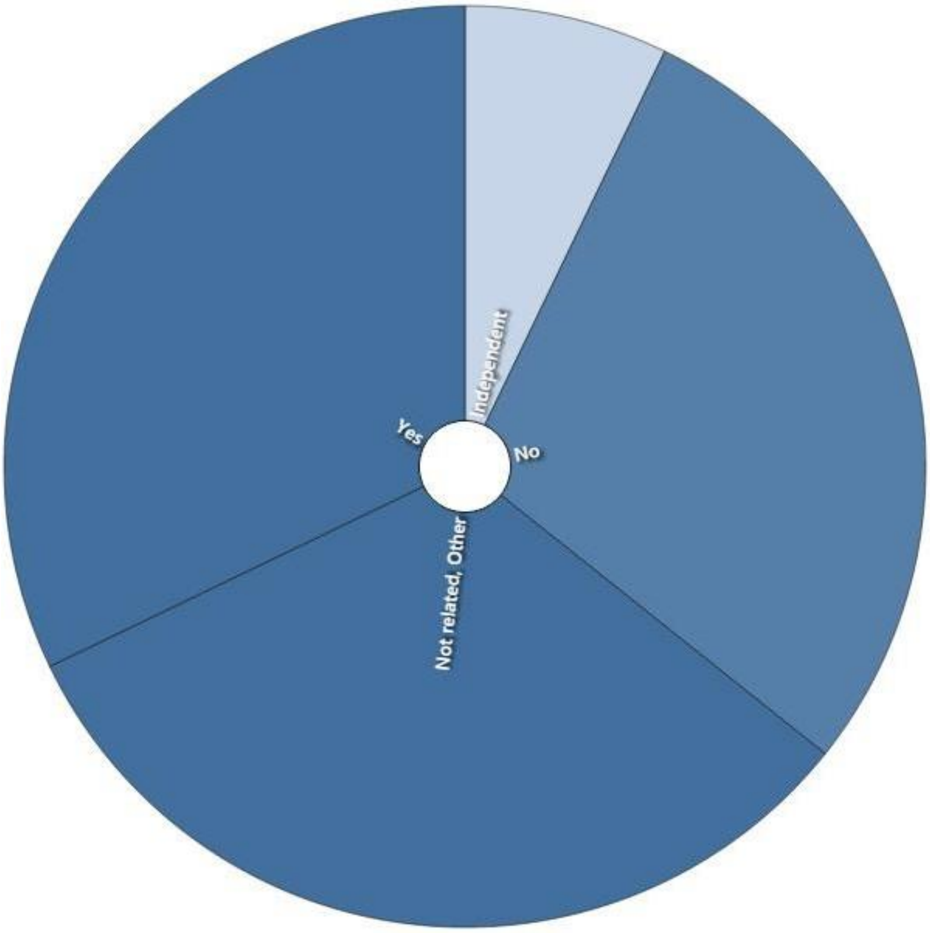


Figure 72. Distribution of responses to question 15

Previous Knowledge, informal learning & training being integrated	28
Independent	2
No	8
Not related, Other	9
Yes	9

Table 20. Detailed account of responses to question 15

Most participants answered positively to this question by suggesting that such opportunities can actually be present in training, and that the training takes into consideration a wide range of skills and different backgrounds and/or modes of knowledge. For example, Interviewee 9 argued “So, we very much tell our new students you bring with you some experiences, you bring with you your previous education, and because sometimes we have different professions, we have some architects, some mechanical engineers, some civil engineers, so we say that, informally you can learn from one another”. Interviewee 23 argued: “Yes. So, this is always the basis. In fact, we cannot draw logical conclusions in order to make these buildings even better, even cheaper and even more effective without looking back, which has resulted in the functioning of those buildings which have already been completed. So this is extremely important, and that is why, as I said, these training materials are valuable precisely because they have all this, this margin and this whole history, that they have been monitored and checked, that solutions have been verified, and we know that some of them do not work so well, and others are fantastic and work very well, and others will work only in an office building and not necessarily in a multi-family building. And so on and so forth. So that is the knowledge which is very much needed based on experience”. On the other hand, those who had a different opinion presented a different view on the matter. Interviewee 2 argued “Most of the programmes start from zero and do not require previous knowledge. Informal learning and training are not properly integrated and is also not properly rewarded by companies”. Some suggestions were also made, such as Interviewee 25 suggested: “There are many challenges, particularly on how to include the informal trainings, such as by webinars, and apply it to the sector. Best practices from other countries can probably be implemented in order to make changes in this regard.

Q16. Does completing training result in any formal (e.g. accredited) qualification? Do thesequalifications increase employability?

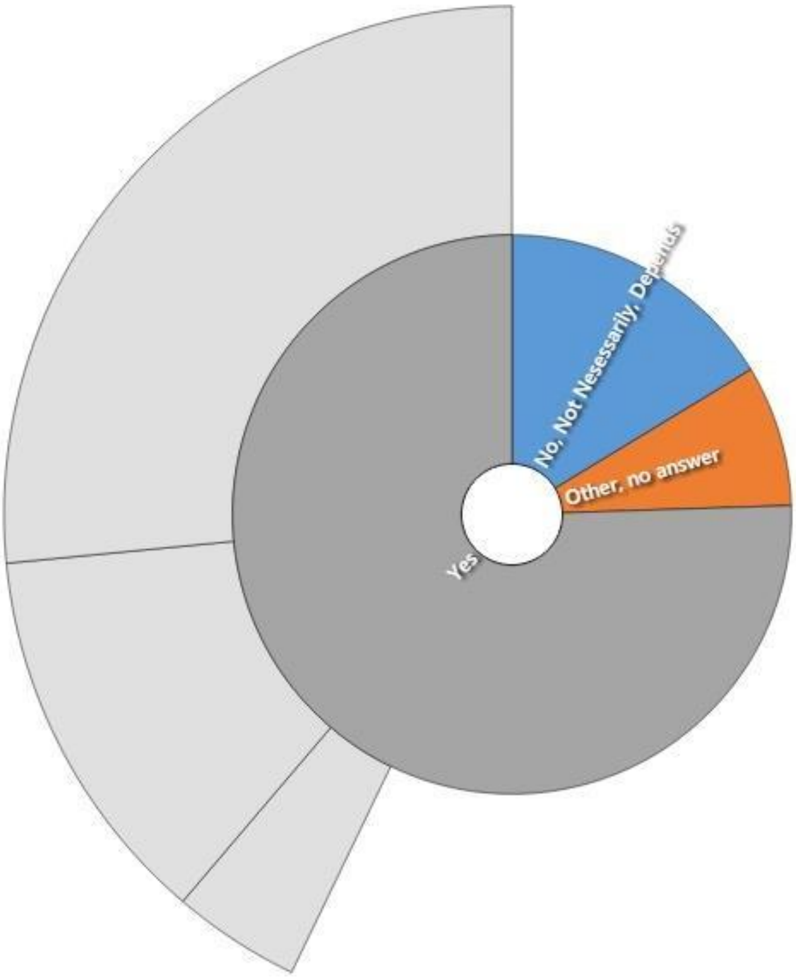


Figure 73.Distribution of responses to question 16

Qualification	28
No, Not Nesessarily, Depends	8
Other, no answer	4
Yes	16
Other	2
This qualification does not increase employability	6
This qualification increases employability	13

Table 21.. Detailed account of responses to question 16

The responses to this question, were in their vast majority positive, suggesting that training result in accreditation. Others expressed a different perspective, sharing reservations and observing how this

is dependent of the type of training. For example, Interviewee 25 argued: “That is the challenge in the system, there is no official accreditation when you take part in informal trainings. More trainings are going online, so people can attend any time, however this raises questions such as how do we measure and evaluate their participation/ competences? This is something that requires work. Preferred accreditations vary from employer to employer and so to have a universal accreditation for energy efficiency in the construction industry would be sure to increase a person's employability, if they achieved that accreditation."

From those who suggested that these qualifications exist, a large number suggested that these qualifications do increase employability. Interviewee 1 argued: "Certainly yes. Accreditation is sought after and can be crucial to certain roles in the industry".

Others, however, were not so sure, suggesting that this is highly dependent on the type of training. For example, Interviewee 5 argued: "Yes they do. But in energy efficiency the qualification does not have that high importance compared to e.g structural engineering" while Interviewee 4 stated:

"If it is done to improve the technical side of improving energy efficiency skills, yes. However, if the focus is on sensibilisation and awareness it has indirect impacts but not heavily influencing the employability like the first one".

To summarise, it could be argued that qualifications and employability can be connected, however, this depends on the training offers, and, as a broader discussion, it could be argued that it is dependent on whether energy efficiency is perceived as something of great importance in the industry, and to what degree.

Q17. With regards to policies & legislation, how effectively do you believe they integrate training? (e.g the European Green Deal, which focuses on making EU's economy sustainable and EU climate neutral by 2050)

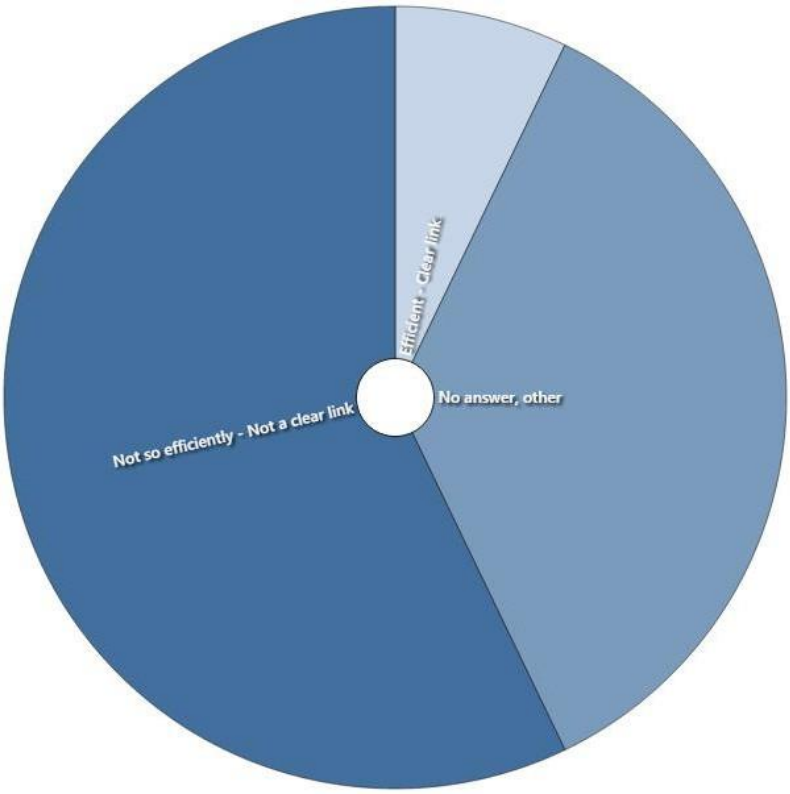


Figure 74. Distribution of responses to question 17

Integration of training in legislations and policies	28
Efficient - Clear link	2
No answer, other	10
Not so efficiently - Not a clear link	16

Table 22. Detailed account of responses to question 17

The replies to this question indicate a general consensus that the link is not clear. Very few responses suggested there is a clear link. For example, Interviewee 20 argued: “There are EU programmes, like Horizon 2020, which simply include this. Do these policies affect? They do, because someone is conducting such training with EU money.” On a similar note, Interviewee 17 asserted: “At this stage enough resources for training are provided.” Other responses had many reservations and suggested the link is not clear, due to several reasons, such as lack of coordination between policy makers and the industry, and a gap between theory and practice.

Interviewee 2 suggested: “Europe gives a lot of room for the member states to do whatever they want, so we see a lot of implementation on paper but not in practice. We hear a lot of green talk from member states because they want to be recognised and rewarded. What is highly needed is proper training of people in policy making. We see many people working and local, regional and national governments that are not skilled enough to make proper decisions about the energy transition and sustaining the built environment. If you are making decisions with the wrong skill set, you are ‘incompetent’, and I think most of the governments are incompetent regarding this topic. There is a huge latent need of upskilling there.” In the same spirit Interviewee 3 argued: “National legislation (which includes European legislation) has a poor practical reflection in relation to the trainings in the construction sector. In accordance with upcoming changes related to the European Green Deal, energy efficiency should be more integrated and focused on significant practice implementations.” Lastly, Interviewee 9 suggested: “I think training is suggested everywhere but there is no clear guideline, no clear push as to “you need to do that”. So, I don’t think that we’ve had. We know that there is a push for incorporating it in the curriculum for example, but there is no actual test. I don’t think the EU or the UK, look we’ll check your curriculum and if you’re not training architects to design in an environmental friendly way, we’re not giving you the right to be a school of architecture”. I don’t think this is done, and I think it should be done. I think that the policies have it as important, but in a theoretical way.” Overall, there seems to still be a lot of room for improvement and more efficient coordination and integration of training in policies.

Q18. How much do training programs develop synergies between academic and vocational training?What could be done to further strengthen this link?

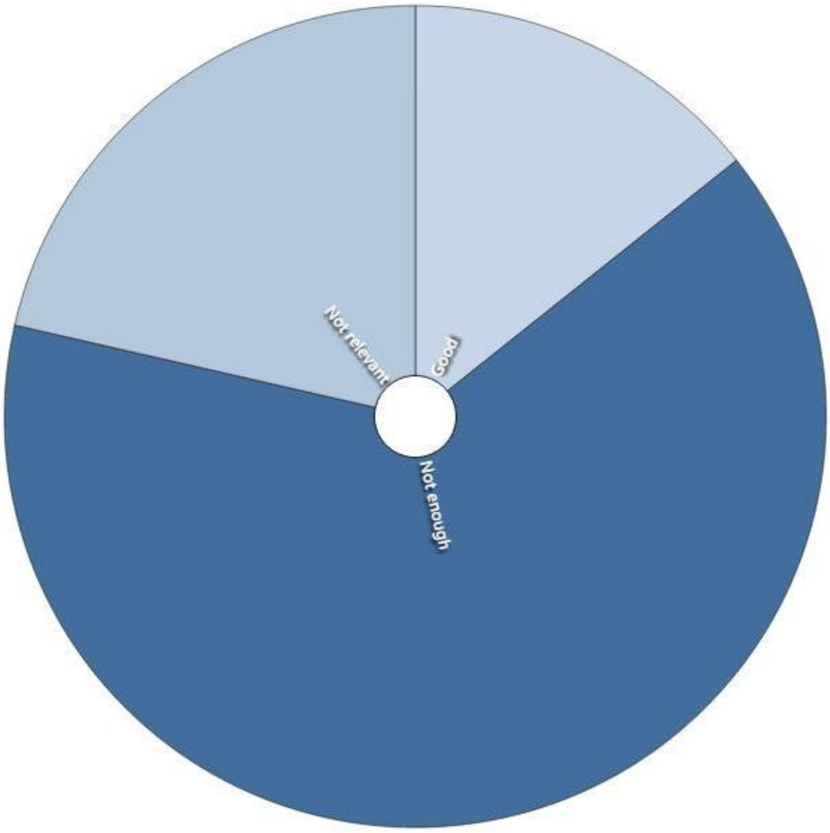


Figure 75. Distribution of responses to question 18

Link Between Academic & Vocational Training	28
Good	4
Not enough	18
Not relevant	6
What can be done to further strengthen the link	15

Table 23. Detailed account of responses to question 18

The replies to this question show that the link is not strong enough, as the graph shows. Some participants argued that this is not the case, however, stating the link is established, even if improvements need to be made. For example, Interviewee 16 suggested: "The connection is quite good, but the training could be more connected to the practical implementation". On the other hand, sceptics suggest there is a significant gap. Interviewee 12 argued: "I don't think training programme are particularly good at synergising academic and vocational training. I think there is very much a separation of the two, especially in industry. From my experience being in industry and research I think the two are very much separated. I think some companies are heading in this direction, I think there's quite a lot of interest amongst the construction sector at the minute in branching out, especially by the big companies, of branching out into research area. Perhaps linked to the current pandemic situation and perhaps they are looking for a way where other branches to go down. So perhaps there,

there is something to develop and build upon". In the same spirit Interviewee 17 suggested: "We see that most of the training programmes are separate. The academic world is self-servicing themselves as they are highly skilled and developed professionals. When it comes to vocational training, we see alack of internal capacity to deliver the right educational quality and so many persons active invocational training are not skilled enough themselves in order to deliver the right quality of trainings. In the Netherlands when we develop new trainings we invite people from the whole value chain to work together and develop the trainings together. For example, for heat pumps, a group of people willwork on developing heat pumps training, the group will consist of practical people, moderately skilledpeople, and academically skilled people. Together they deliver a chain of training elements for the several functions that are based around heat pumps. One of the means that are used and is very valuable are integral task-based qualifications. By making and using these integral qualifications you can train the full value chain, including on key parts where different occupations have to work togetherin order to perform". Further to this point, matters of communication arise, as argued by Interviewee21: "There is no synergy. The relation is reverse. The technical universities, the issue of energy efficiency is present. It's just 1 out of 10 or 20 topics. It's not really important, but it is. Technical universities are teaching architects, designers and site managers. When the engineer goes out on a construction site and talks to the workers, they speak 2 different languages, because workers have no idea what energy efficiency is. So, there is no synergy".

In some contexts, however, this collaboration appeared to be strong. As mentioned by Interviewee 28: "In Finland, the universities of applied science already integrate academic and vocational training. Many vocation trainings work together with technical universities. Our material from BUILD UP Skills is usable for blue collar workers and the construction trainers, many of which have an academic background". This indicates that there is the potential for the right collaborations to emerge, under theright context, and is a positive sign.

As for suggestions that were made, participants presented a variety of ideas. Legislation & quality frameworks playing a more crucial role, networking activities, awareness raising and improving education, motivation and encouragement of better communication between the academic and vocational training so as for them to work together, exchange of experience, make sure more real-world experiences and knowledge are integrated into education.

Overall, it could be argued that the replies, as vocational training often differs from country to country and is very context related. In any case, however, there seems to be a common agreement from most participants that such a collaboration would be ideal for the industry in terms of training for energy efficiency.

Q19. What market challenges can you identify, concerning demand & economic changes? Are thereany strategies that have been identified as successful in dealing with these challenges?

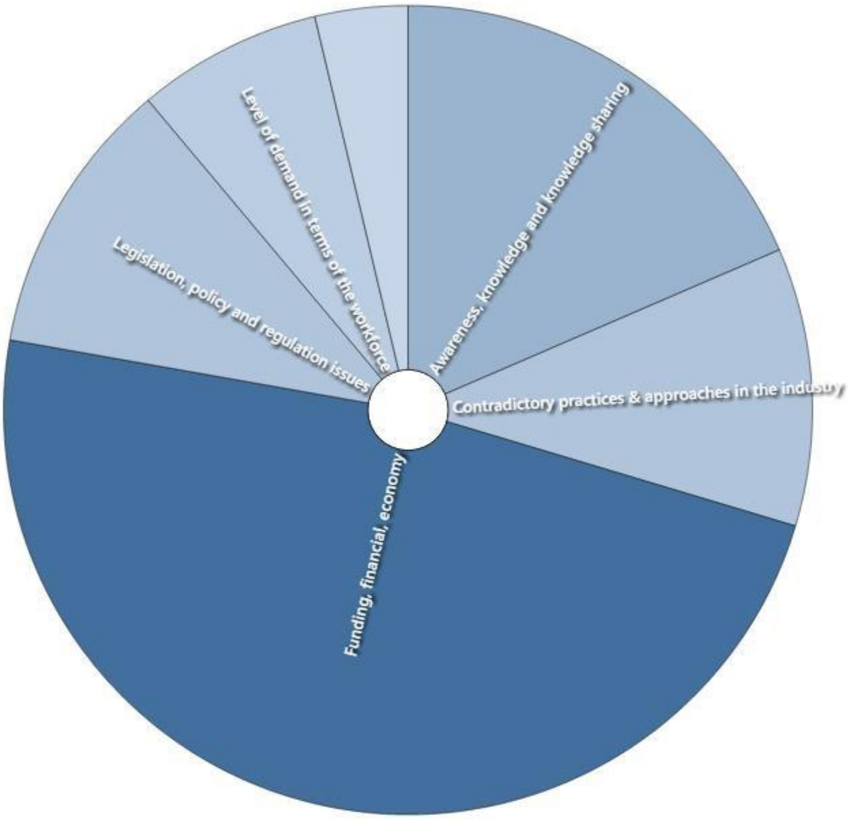


Figure 76. Distribution of responses to question 19

Type of market challenges	20
Funding, financial, economy	13
Awareness, knowledge and knowledge sharing	5
Contradictory practices & approaches in the industry	3
Legislation, policy and regulation issues	3
Level of demand in terms of the workforce	2
Time	1
Strategies	8
No answer, other	8

Table 24. Detailed account of responses to question 19

As it can be observed from the graph, many market challenges came up. However, the most frequently encountered in the interviews was the one regarding funding, finance issues and the general trajectory of the economies. Interviewee 1 argued: "In our field of work, housing, there is a perception that increased energy efficiency equals greater capital cost, cost which cannot be reclaimed against the sale value of dwellings. Generally, it is only local authorities and HA which push for greater efficiencies. This rarely comes from private developers." Further to that, Interviewee 18 stated: "The main market challenge that I see is the volatile demand for energy efficient materials and buildings as well as all the unknowns surrounding the current global economic situation. In my opinion, as long as there are suitable and reliable legislations, regulations and incentives the market demand will be stable". With regards to strategies that could potentially deal with market challenges a number of ideas were brought forth. Legislation & regulations, improved awareness on the topic/campaigns, more attention to material and new technologies, modernisation of methods, good examples of practice as precedents, as well as methods to tackle with lack of workforce. As argued by Interviewee 2: "The biggest challenge is making sure that people working in the sector stay in the sector and attracting more people to work in the sector. We already have a shortage when it comes to the regular work so sustaining is additional work and there is a shortage. On the other hand, in the economic tide we are expecting a downturn due to COVID, on the one hand we need a lot of workers and on the other hand we are making plans to lay off a group of workers because we can no longer pay them. Ideally if a worker is laid off there should be an employment pool where they can be upskilled and hired by another company that still has enough work". Some were most pessimistic about the state of the market. Interviewee 16 stated: "There are no strategies helping the market to be prepared. The challenges remain unanswered."

Overall, the market presents several challenges, and its state is highly dependent on much broader issues and dynamics on a global level. However, it could be argued that being aware of the issues, and take into account some of the potential strategies that could work, is a good first step.

Q20. Have any aspects/insights of the training that you have been involved with been included intonational strategies?

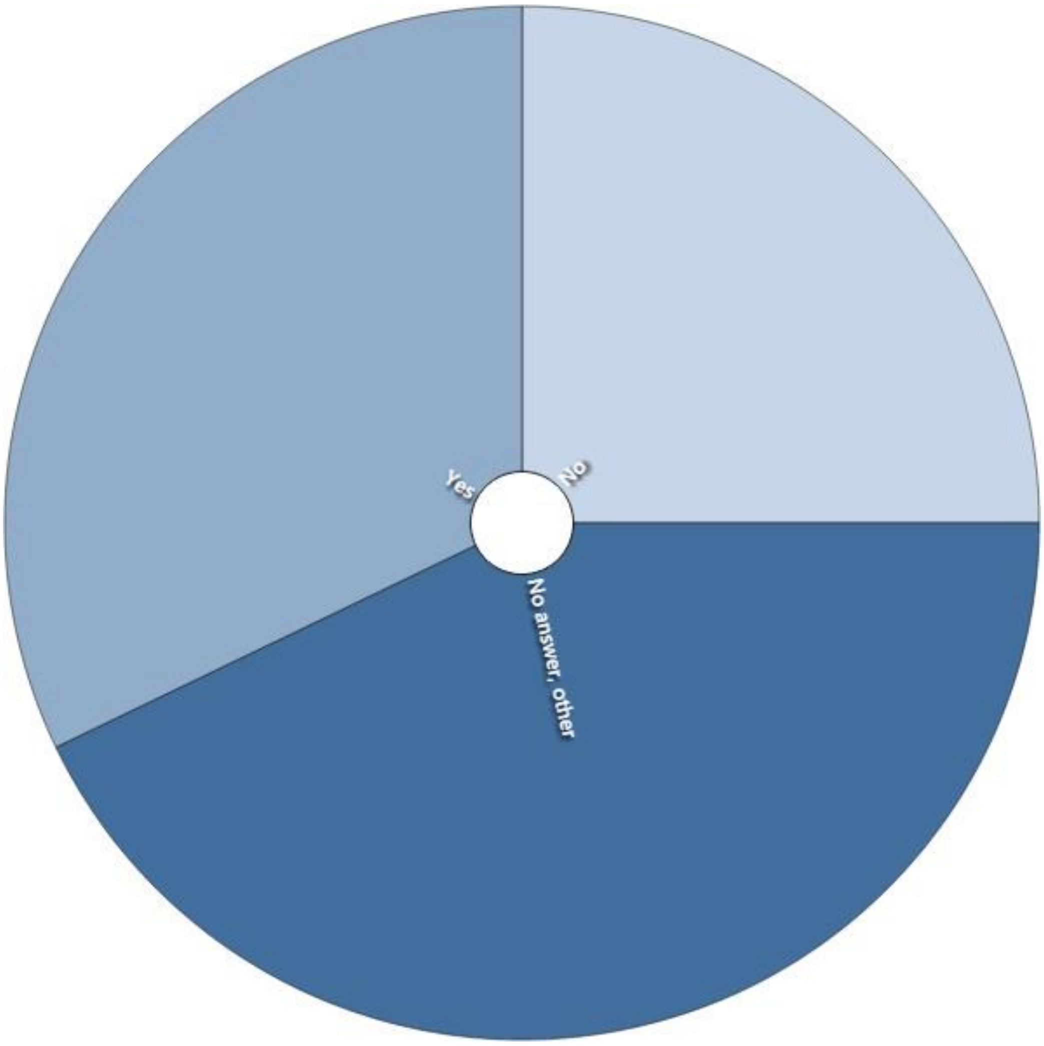


Figure 77. Distribution of responses to question 20

Integration of training in national strategies	28
No answer, other	12
Yes	9
No	7

Table 25. Detailed account of responses to question 20

This question received few relevant replies, but out of them, there were more examples of training being integrated in national strategies, in one way or the other, than not.

For example, Interviewee 23 argued: “Locally, rather than globally. I think that we are still the day before this to happen. So that is all that is going on there with regards 2021, that is just a phase. But I am counting on those people who have been and have had the opportunity to be trained, that this was also in order to somehow introduce further regulations or further improvements to these. And these improvements were introduced on the basis of, for example, tools for verifying certain solutions.”

Further to that, Interviewee 26 stated: "Yes, but only partially. The minimum requirements and detailed definition of nZEB have been improved in the revised regulation (under approval).

There is a need for new training courses in order to certify the specialists who will implement the new requirements (thermal bridges calculation, airtightness testing, mechanical ventilation with heat recovery, energy auditors)". Also, Interviewee 9 highlighted: "In terms of the previous project that I mentioned, the WEFO that one it was a Welsh, it was part of the national strategy to upskill the workforce. I know that was a national strategy of the Welsh government in collaboration with European funding […]. It was particularly aimed to upskill the convergent areas of Wales, the convergent areas of Wales, is not so developed as the rest of it, so it was trying to upskill the workforce of construction by equipping them with knowledge and skills of research, so that they are more advanced".

This data could suggest that perhaps this is an area of development, and that legislation could further integrate insights from the industry with regards to training and energy efficiency.

Q21. In your opinion, have initiatives such as the BUILD UP Skills been successful and in what manner?

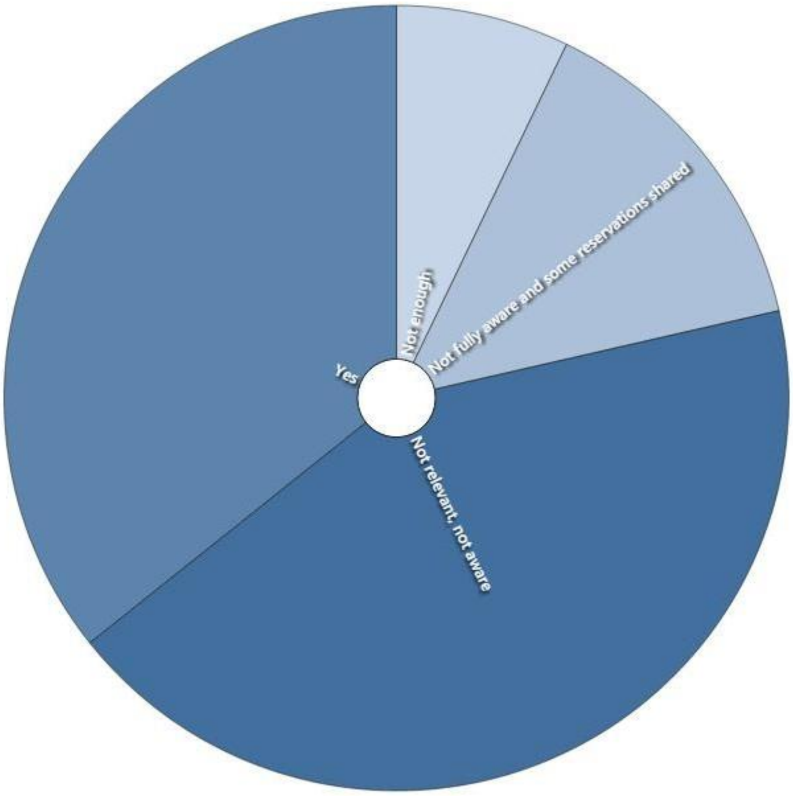


Figure 78. Distribution of responses to question 21

BUILD UP Skills & Relevant Programs	28
No	0
Not enough	2
Not fully aware and some reserva	4
Not relevant, not aware	12
Yes	10

Table 26. Detailed account of responses to question 21

Responses to this question were split between a large number of people who were not aware of the program, or were not fully aware of it, and almost half of the sample of participants stating they were aware of the program and that it was successful in its goals. This split shows that there is still some way to go, with regards to making sure that such opportunities, at least on a European level, are being integrated more and more into the education of professionals, so that they are aware of what is available and the current state of developments in their field. Several observations as to how it was successful were made. For example, Interviewee 17 stated: "Yes, through supporting elaboration of up-to-date training materials, establishment of training centres and the organized trainings", while Interviewee 19 stated: "Yes, these initiatives have been successful. They raise the peoples' awareness and show the best practices in the field". Important benefits were highlighted by Interviewee 2 who argued that: "Yes. They have been successful in creating an independent group of people working on the same topic and they are not doing it for their own government or for their national finances but for the European Union. And that means if I am doing an EU project then the doors of all sectors are opening because others want to be involved into the broader perspective. BUILD UP has also allowed countries to benchmark. All over Europe we work with the same challenges and so you can benchmark your own country with the other countries you are working with. It is good to find out where we are in terms of performance, the next steps and to cooperate with other EU countries on how to achieve the next step more quickly". Further to that, Interviewee 4 suggested: "The BUILD UP Skills initiative was useful for Bulgarian practice mainly as a tool for directing attention and efforts in the field of education and training in energy efficiency in buildings. At the same time, it is a valuable source of useful information". However, participants also highlighted how there can be a gap, without proper legislation or coordinated actions. For example, Interviewee 26 argued: "Analyses, strategies and roadmaps are still resting on various shelfs and need to be included in the updated policies and regulatory system". Others such as Interviewee 21 presented a set of difficulties: "It caught my interests, but I tried to talk to the industrial organization I'm involved in […] but no one paid no attention and actually I speak of last three, four weeks. I'm just learning why. Because they don't care. It's not their problem. Their problem is to keep the status quo, keep on manufacturing what they do with the contractors and clients they have. The contractors and the clients who have those skills for the old technologies. So, there was no interest and no understanding for the need of the change and, as a consequence, there was no one willing to have a look together with me on the BUILD UP Skills program. There is no pull at least from the polish industry for the program. But I believe it can be interesting to use".

Overall, the positives highlighted by the participants allude to the fact that BUILD UP Skills provided a very effective structure of dissemination of information, as well as to the fact such initiatives such definitely be more encouraged in the future.

10.5 Workshop Insights

INSTRUCT project partners were asked to invite experts to participate in the workshop. This allowed for a mix of participants from different countries and professional backgrounds. In this case, experts were defined as an individual with experience and knowledge of the construction sector with an interest/ knowledge on education, energy performance and quality in the sector.

The workshop was attended by 15 participants from eight countries across Europe. The graph below presents the participants by country.

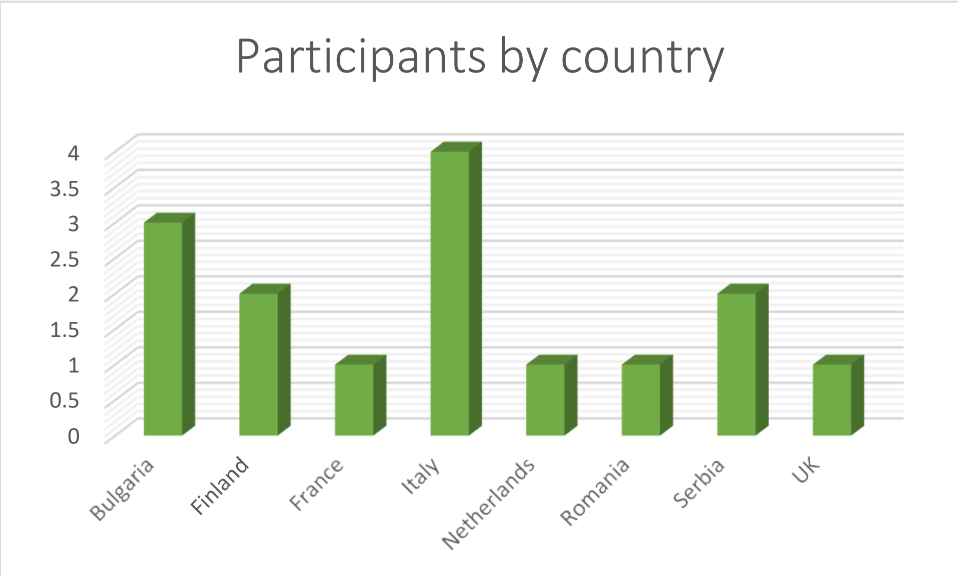


Figure 79. Represents the number of workshop participants and their country

Of those that participated in the workshop, many held different job roles. This contributed to a wider view of the sector. It is important to acknowledge that there were no representatives of blue collar workers at the workshop, however, some of the workshop participants have experience of working and managing blue collar workers, and may contribute to a more rounded view of the sector. This barrier is discussed in more detail in section 5 of the report.

The chart below (Figure 29), shows that the role of project manager was the most prominent job profile for the workshop participants. Civil engineers, senior researcher and cluster/knowledge hub coordinator were the second most prominent roles, with 13%.

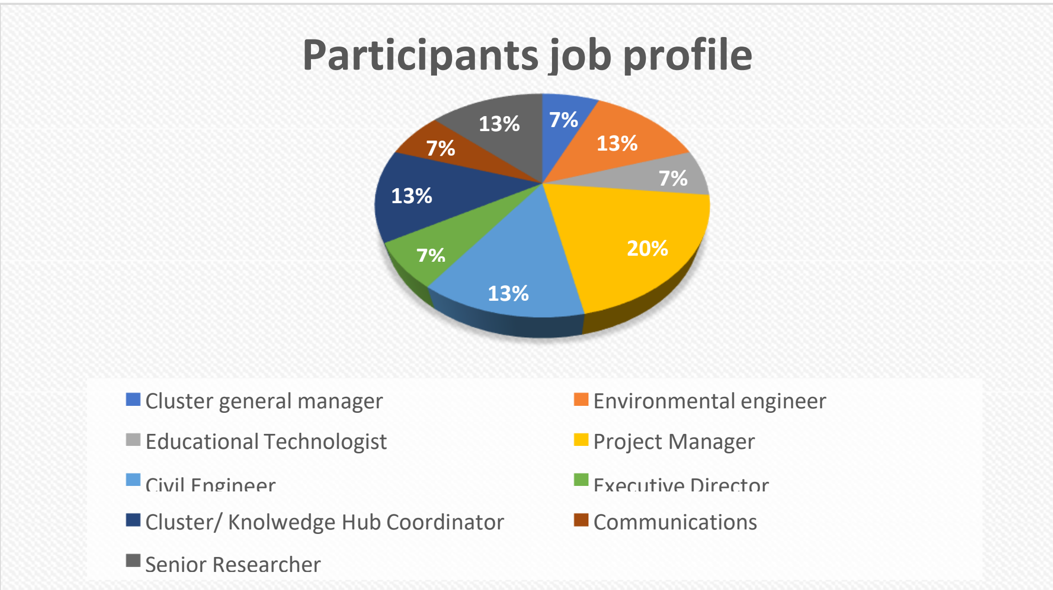


Figure 80. Presents the workshop participants job profile

Figure 80 and 81 present the workshop participants shared areas of expertise and the knowledge/ experience from which they were able to contribute to the workshop discussions. Energy efficiency was the most shared area of expertise, with 7 of the participants.

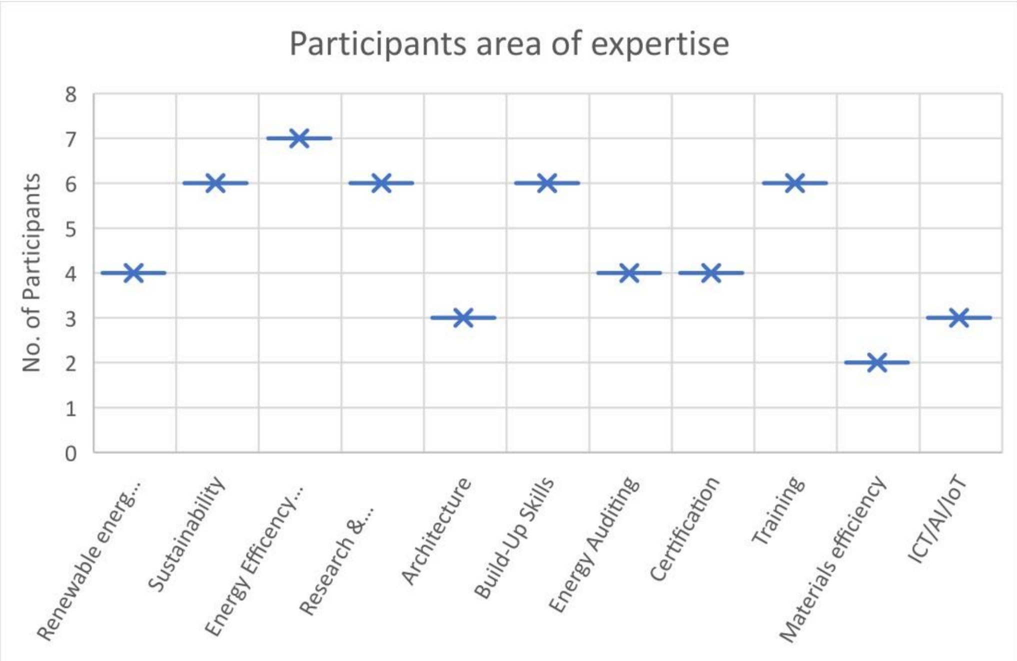


Figure 81. Area of expertise

The following section summarises the key insights derived from the workshop discussions.

Theme	Key insights
Lack of access to useful information, knowledge, and best practice guides for energy efficient interventions.	▪ Demand and access go hand in hand. Without demand, there will inevitably be a lack of access, therefore the priority should be on building demand. ▪ Clients are more inclined to ask for the energy efficient solutions, however delivering energy efficient buildings is not a priority for construction workers. ▪ The people that should be pushing for energy efficient solutions are not pressing hard enough for it, however it is thought this could change once policy landscape also changes. ▪ Whilst the building sector is making strides towards energy efficiency, other areas of infrastructure are behind in this regard. i.e. transportation infrastructure. ▪ There is an abundance of information, knowledge and guides available, however the challenge is sourcing targeted training that relates to specific roles. ▪ Workers should be guided to appropriate training that relates only to their role. This targeted training is more likely to be absorbed by the worker and used in practice. ▪ There are challenges in stimulating demand for training programmes. ▪ There is a need to develop awareness of the various end user groups.
Lack of demand for skilled workforce in energy efficiency	▪ Construction workers are in high demand and is leading to the employment of lower skilled workers. ▪ European countries are setting stringent carbon neutral targets; however, there are not enough skilled workers to produce energy efficient buildings.

	▪ Companies should be shown the correlation between a skilled workforce and quality of a building to highlight the importance of skilled workers. ▪ Companies need to value the importance of upskilling workers, and to not see it as a drain on time/finances. ▪ Companies are more inclined to use the same processes instead of innovating and adapting to tackle new markets. ▪ Companies will not upskill their workers until clients demand change. ▪ A skilled workforce is desirable but difficult to access. ▪ Demand for a skilled workforce and legislation are interlinked. Financial/tax incentives appear to be successful motivators for increasing the demand for energy efficiency in the construction sector. ▪ The adoption of Artificial Intelligence, ICT tools etc. can be used as a contributor/instrument to deliver a skilled workforce.
Lack of availability, or inadequate, training programs (in terms of scope, quality, content, cost, etc.).	▪ There are lots of training programs available, however they are similar in content, quality, and theory. They do not meet the needs of the workforce. ▪ Training for blue collar workers should be less theory based and more practical. ▪ 'On the job' training would be more suitable for blue collar workers. ▪ Whilst the participants agreed that 'on the job' training was the best approach. It was also highlighted that there would be challenges in providing such training on site. ▪ Lack of time is preventing workers from accessing training. ▪ Prioritising training would require a top-down approach. ▪ It is important to integrate qualifications into on-site training.
Lack of shared vision and values for energy efficiency across the supply chain.	▪ Finland has formulated carbon neutral road maps for 2030-2050 (for all industries). It will be interesting to see if they have considered energy efficiency at a workforce level, to ensure carbon neutrality throughout the whole value chain. ▪ Raising awareness should be priority. The more demand industries see for energy efficiency, the more likely it is to be adopted. ▪ It was suggested that to become truly energy efficient all the sectors involved must behave in the same way and share the same vision for energy efficiency. This, however, is not currently the case. ▪ Low carbon targets are useless unless there are defined mechanisms/ responsible parties to put it into practice.

	▪ Companies will transition to energy efficiency when legislation

	pressurises them to do so.
Inadequate policy landscape, including lack of government incentives	▪ Government support is essential for any real changes in energy efficiency to occur. ▪ Policy landscape varies depending on the countries priorities. ▪ It was argued that pressure from industry can influence policy. There should be scope in the policy landscape that would allow for construction experts to mandate such policies. ▪ Better communication is required amongst countries to share energy efficiency instruments, best practice guides etc. and to improve policy landscape.

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