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Author(s)	Zuhaib, Sheikh; Manton, Richard; Hajdukiewicz, Magdalena; Keane, Marcus M.; Goggins, Jamie
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Attitudes and approaches of Irish retrofit industry professionals towards achieving nearly zero-energy buildings

Sheikh Zuhaib^{1,2}, Richard Manton^{1,2}, Magdalena Hajdukiewicz^{1,2},
Marcus M. Keane^{1,2}, & Jamie Goggins^{1,2}

¹Informatics Research Unit for Sustainable Engineering (IRUSE), Civil Engineering, College of Engineering & Informatics, National University of Ireland, Galway, Ireland

² Centre for Marine and Renewable Energy (MaREI), Ryan Institute, National University of Ireland Galway, Ireland

Abstract

Purpose – There is profound demand for higher skills and expertise in retrofitting the existing building stock of Europe. The delivery of low- or nearly zero-energy retrofits is highly dependent on technical expertise, adoption of new materials, methods of construction and innovative technologies. Future Irish national building regulations will adopt the EPBD vision of retrofitting existing buildings to higher energy efficiency standards. The role of key stakeholders in the industry becomes highly responsible for achieving the energy performance targets. Specifically, the paper assesses the attitudes, approaches and experiences of Irish construction professionals regarding energy efficient buildings, particularly nZEBs.

Design/methodology/approach – Data were collected through a series of assessments under qualitative research including survey, workshop and detailed interviews with professionals in the retrofit industry. The structure of this approach was informed by preliminary data and information available on the Irish construction sector.

Findings – There is a substantial amount of ambiguity and reluctance among the professionals in reaching the Irish nearly zero-energy building (nZEB) targets. The growing retrofit industry demonstrates low-quality auditing and pre/post-retrofit analysis. Basic services and depth of retrofits are compromised by project budgets and marginal profits. Unaligned value supply chain, poor interaction among nZEB professionals and fragmented services are deterrents to industry standardisation.

Social implications – This study has implications for understanding the social barriers existing in retrofit projects. Support from clients/ owners has a diverse impact on energy performance and retrofit decisions. Community-based initiatives are key to unlock the promotion of nZEBs.

Practical implications – This study will enable construction industry stakeholders to make provisions for overcoming the barriers, gaps and challenges identified in the practices of the retrofit projects. It will also inform the formulation of policies that drive retrofit uptake.

Originality/value – This paper provides an overview of current activities of retrofit professionals and analyses the barriers, gaps and challenges in the industry.

Keywords Nearly zero-energy buildings, Energy efficiency, Retrofit industry, Construction professionals, Stakeholders

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1. Introduction

The focus of construction in Europe has shifted from new builds to refurbishment to achieve member states' energy efficiency targets. Indeed, the current rate of refurbishment in Europe is around 1% (BPIE, 2013). A major share of the building stock in Europe is older than 50 years and about 40% of the existing residential buildings were constructed before the 1960s when the building regulations for energy consumption of buildings were limited (BPIE, 2011). In Ireland, residential buildings cover 77.3% of the 234 million m² of total floor area (BPIE, 2015a) and comprise 27.1% of total energy consumption (Howley and Holland, 2014). During the *Celtic Tiger* construction boom (1990-2006), floor area increased in the average dwelling by 16.6%, indicating a rising energy demand (O'Leary et al., 2008). More recently, Irish government policies are targeting improvements in the energy efficiency of buildings, particularly in the residential sector. There are immense opportunities in this area for Ireland; for example, the potential primary energy savings of 13.5TWh in the residential sector would represent almost 30% of the total energy demand of 44TWh (Scheer, 2015). The delivery of nearly zero-energy buildings (nZEB) by upgrading existing buildings depends heavily on the policies, practices, and expertise of the construction industry.

UK has imposed a target of 80% reduction in carbon emissions by 2050 (HM Government, 2008). As a result, the sustainable retrofit market for social housing is being upscaled by the government through policy instruments, skill building and improvement of supply chains (Swan et al., 2013). A comparative study conducted on Sweden and Norway highlighted the lack of knowledge dissemination between stakeholders in nZEB renovations and how this impacts the decision-making process between the stakeholders (Lindkvist et al., 2014). Recent studies indicate that Germany has extensively promoted energy efficiency measures which have created huge benefits for owners, SME's, environment and economy (Achtnicht and Madlener, 2012; Kraft, 2015). This section of the paper outlines the Irish nZEB definition, the existing national framework and policies in place, involvement of the industry and development of the market, and the key role played by nZEB experts.

1.1 nZEB definition and Irish government policy

Article 9 of Energy Performance of Buildings Directive (EPBD) directs EU member states to develop nZEB definitions for existing buildings (EC, 2013). While 13 jurisdictions have so far identified criteria for existing buildings, only 8 countries (Austria, Cyprus, Czech Republic, Denmark, France, Latvia, Lithuania, and Brussels Capital Region) have established definitions. Ireland has followed these countries by setting up primary energy use requirements for existing buildings in the draft definition of the national nZEB plan (BPIE, 2015b). The nZEB definition of the Department of the Environment, Community and Local Government (DECLG) in Ireland demands an Energy Performance Coefficient of 0.302 and Carbon Performance Coefficient of 0.305 for a typical new-build dwelling with primary energy consumption of 45kWh/m²/yr. However, the target for existing dwellings that will receive significant renovation after 2020 is 75-150 kWh/m²/yr., including space and water heating, lighting and ventilation (DECLG, 2012). As of 2010, the average energy intensity per existing dwelling is equivalent to a D rating (225-300 kWh/m²/yr.) on a BER (Building Energy

Rating) scale (SEAI, 2010). For non-residential buildings, an improvement of 50-60% in the energy and carbon performance is proposed.

The Irish government first introduced building energy efficiency requirements in 1991 (ISB, 1991). Following this, the first performance-based code was introduced in 2002 with the implementation of the EPBD (EU, 2014). Current building regulations (Part-L) strengthen national policies with advanced aspects of building energy simulation, U-value requirements, air-tightness testing for all new dwellings, bioclimatic design, mandatory renewable energy requirements, and pre-occupancy commissioning with the aim of achieving nZEB by 2020 (DECLG, 2011). The recent release of the Irish government's third National Energy Efficiency Action Plan (NEEAP III) sets a national target of a 20% reduction in primary energy consumption by 2020, and a 33% reduction in the primary energy consumption of the public sector (DCENR, 2014a). A guide to energy efficient retrofits of dwellings (S.R.54:2014) has been developed by the DECLG, the Department of Communications, Energy and Natural Resources (DCENR), the Sustainable Energy Authority of Ireland (SEAI) and the National Standards Authority of Ireland (NSAI) in collaboration with the Building Research Establishment (BRE) (NSAI, 2014). It guides property managers, designers, specifiers and installers on building envelopes, application of retrofit packages, general building science, and management of retrofit projects. Ireland's energy policy priorities (DCENR, 2014b) include empowering energy citizens; markets, regulations, and prices; planning and implementing essential energy infrastructures; ensuring a balanced and secure energy mix; putting the energy system on a sustainable pathway; and driving economic opportunity. The efforts from the Irish government follow EU policy for medium and long-term energy-related improvements and they are expected to evolve into strict regulations in Ireland by 2020.

1.2 Retrofit industry and construction professionals

Building stock in Ireland was, until recently, amongst the least energy efficient in Northern Europe and new studies indicate a reduction of 4% in household energy consumption since 2008 (ODYSSEE-MURE, 2015a). This relates to the various energy efficiency measures for renovation and refurbishment taken by the government since the introduction of EPBD and the majority of schemes have been carried out in the residential sector in Ireland. The distribution of energy efficiency measures in the residential sector by the Irish government is based on financial, fiscal, legislative, normative, co-operative, information and education typologies. The residential energy efficiency measures pattern from early 2000 to 2014 suggests the majority of initiatives are legislative, financial and information/education based (ODYSSEE-MURE, 2015b). The Better Energy Homes scheme (residential retrofit), Low-Carbon Homes scheme and Building Regulations for Nearly Zero-Energy Homes are some of the schemes provided for the residential sector. Measures for the tertiary sector include the action plan for the public sector, the assessment of renewable energy alternatives at the design stage and tax relief for energy-saving equipment.

Market development, adaptability and filling the gaps in homeowner information are of vital importance and are governed by the growing construction industry. The provision of incentives

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supports the market penetration of nZEBs and a recent market report on Energy Service Companies (ESCOs) in Europe notes that the Irish retrofit industry is growing rapidly due to such incentives (Bertoldi et al., 2013). The retrofit industry is an important stakeholder for nZEB and key actors include professionals such as architects, engineers, small and medium businesses, contractors and other construction professionals. For example, Building Energy Rating (BER) assessors are trained professionals who carry out certified home energy audits (SEAI, 2014). Currently, there are 18 dwellings registered with a BER of A1 and 1,549 with a BER of A2 (SEAI, 2016). There have been a few vetted training and certification programmes initiated to produce qualified professionals at operative, craft and supervisory levels in the retrofit industry as shown in Table 1. Many initiatives are being taken by the stakeholders for nationally recognized industry credentials to train the skilled labour workforce. A large number of construction professionals still remain untrained in highly energy-efficient buildings and the rapid expansion of building standards in this area has created huge skill gap in the construction workforce.

Table 1: Examples of retrofit up-skilling training programs and courses across Ireland

Provider	Type/Level	Title/Description
Engineers Ireland	Training	Retrofitting Buildings for Energy Efficiency
Homebond	Training	Building regulations training programme
Centre for Modern Environment	Course	Retrofitting Buildings for Energy Efficiency
Irish Green Building Council (IGBC)	Course	Foundation Energy Skills Course
Institute of Technology Blanchardstown	Course	Certificate in Energy Efficient Domestic Retrofit Technology
Saint-Gobain	Free training	Skills in areas such as internal insulation, air-tightness, moisture control and acoustics
Chevron training	Courses	Domestic & non-domestic BER assessor
Limerick Institute of Technology	Training	Retrofitting Multi-Storey Buildings
Dublin Institute of Technology	PG Certificate/MSc/Course	Digital Energy Analysis, Building Retrofit Retrofit Technology and MEnS training course
Waterford Institute of Technology	Part-time course	Retrofit Your Home
Galway-Mayo Institute of Technology	Course	Energy efficient retrofitting
German-Irish chamber of Industry and commerce	Training	Energy Efficient Retrofitting of buildings
Institute of Technology, Sligo	Bachelor	Advanced wood and sustainable building technology
SustainCo	Training	Achieving nZEB: Design Essentials

The level of training and scope of work requires a change in some of the traditional construction practices to achieve energy efficient buildings due to the complexity and demand of nZEB standards. The value supply chain of designers, developers, construction workers, clients and policy makers needs alignment to the current demand of quality and precision for highly efficient buildings. Traditional construction professions, such as carpenters, electricians and builders' merchants, come into direct contact with the owners and there is a need to identify the value supply chain in the Irish

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context similar to that presented by Haavik et. al (2006) in Figure 1. A key component of the Construction 2020 Strategy is the BuildUp Skills roadmap developed by a consortium of government departments, state agencies, training providers and construction workers for upskilling the professionals and tradesmen in retrofit businesses (RICS, 2014).

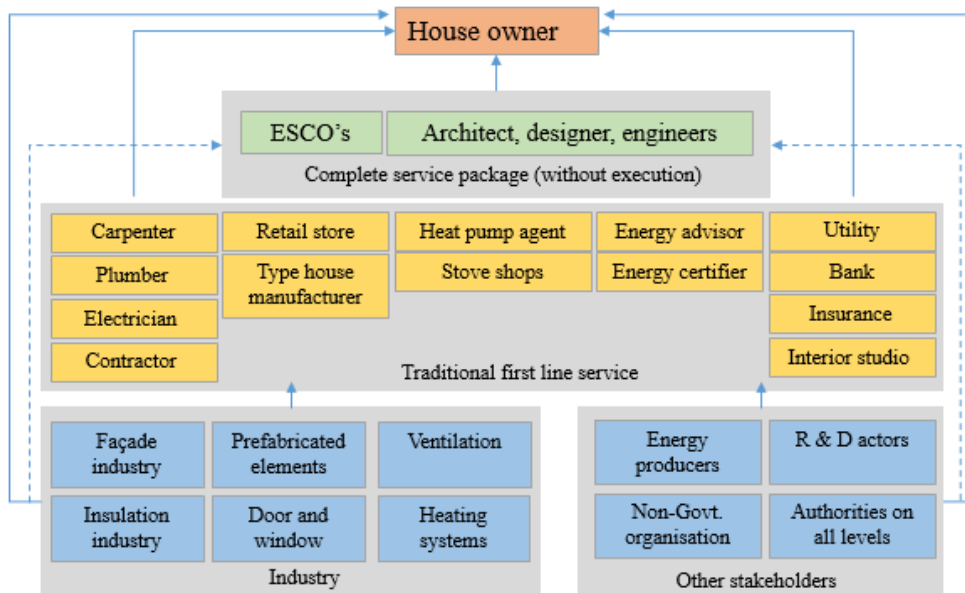


Figure 1: Value chain in renovation, (adapted from Haavik et al. 2006)

Retrofit businesses need consensus over processes, tools and best practices to overcome the existing technical, social, economic and environmental barriers as highlighted in this study. Cohesive interaction among industry stakeholders over project inception, development and delivery standards can raise the quality of retrofits required along with the tools and techniques to achieve them (Morrissey et al., 2014). Several studies have investigated the requirements of end users to assist in decision making in retrofits through the use of surveys (Ecodistr-ICT 2016; Vieider 2011; IEA 2010; Britnell & Dixon 2011). However, very few studies have evaluated the requirements of construction industry stakeholders in Europe in achieving low energy buildings (IEA 2013; BUSI 2013; VTT 2010). They indicated that most countries require information and training to push market development forward. They also stated that there is lack of trust and reliable information for growth of ESCOs in Europe. Existing skills in the construction sector are of high quality, yet they are not sufficiently aligned with the approach of low-energy building. The ZEBRA 2020 project is trying to develop frameworks for monitoring the market uptake of nZEBs across Europe and its recommendations are awaited (Schimschar et al., 2015); however, it does not include Ireland in its consortium.

Therefore, an extensive stakeholder consultation process was undertaken in this study to identify the barriers, gaps and challenges being faced by the retrofit industry in Ireland. This process, outlined in the following section of the paper, comprises a construction professional survey (Section 3.1), a

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workshop (Section 3.2) and in-depth interviews (Section 3.3). In the final section of the paper, the results of each element of the consultation process are synthesised and recommendations for the retrofit industry have been developed.

2. Methodology

The aim of this investigation is to understand the attitudes and approaches adopted by retrofit industry professionals in their practices or businesses towards delivering or achieving nearly zero-energy buildings. To this end, a three tier methodology was designed comprising of surveys (90 respondents), a workshop (85 participants) and a series of in-depth interviews (11 participants). The surveys, workshop and interviews were structured into themes to assemble details about the status of the industry and its stakeholders (Table 2). This methodology enabled the identification of major barriers, gaps and challenges existing in the retrofit industry in Ireland. A similar research technique was applied to evaluating the Irish industry scenario by a consortium of organisations in Ireland, although it was focussed on the upskilling of industry stakeholders through training (BUSI, 2013a). Davies and Osmani (2011) also adopted a triangulated approach to evaluating the low-carbon housing refurbishment challenges and incentives. Such use of different methods in data collection ensure consistency, reliability and validity of results (Gul and Menzies, 2012)

Table 2: Hierarchy of stakeholder engagement and outline of themes

No.	Investigations	Target Audience	Approach	Themes
1.	Industry Specific	nZEB experts and actors	Surveys (n = 90)	<ul style="list-style-type: none"> • Respondents and practice characteristics • Retrofitting methods • Technology and solutions in practice • Implementation and performance
2.	Policy and Regulations, Health and Comfort, State-of-the-art and Impact	All stakeholders	Workshop (n = 85)	<ul style="list-style-type: none"> • Governance, standardisation, and economics • Health, comfort, IAQ, and energy performance • Impact of technology and innovation • Showcasing best practice
3.	Envelope/ façade focused	Market players	Interviews (n = 11)	<ul style="list-style-type: none"> • Experience on envelope retrofits • Assessment of design, construction and delivery • Use of technology and systems • Issues and concerns

The Survey (first tier) was targeted towards main nZEB experts and actors of the supply chain who are directly involved in retrofit projects within the industry. A semi-structured online questionnaire was compiled in Google Forms and distributed through email between May and August 2015. The survey was composed of qualitative/ open-ended and quantitative questions based on multiple choice, rank order, Likert and rating scales designed to capture the characteristics of individual retrofit businesses. Of the 600 electronic invitations issued, 90 detailed responses were received, giving a response rate of 15%. A purposeful sampling technique was applied to select the respondents from

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within Ireland (Koerber and McMichael, 2008). The participants included professionals such as civil/structural engineers registered with Engineers Ireland, architects accredited with the Royal Institute of Architects in Ireland, construction managers, cost consultants, BER assessors (domestic and non-domestic) registered with SEAI, energy consultants, building services engineers and others.

The workshop (second tier) was organised to cross-evaluate the viewpoints, issues and efforts being fluxed in the industry by other stakeholders such as policy makers, planning authorities, NGO's, SME's, housing associations, financiers, clients and property owners. The workshop was organised through four themed plenary sessions, as shown in Table 2. Invitations were sent out using convenience sampling to other industry stakeholders including the survey respondents, and 85 people attended. The invited speakers outlined their experiences and perspectives on retrofitting in Ireland. Each session was followed by a brainstorming discussion which helped to determine the actions required to strengthen the propagation and effectiveness of energy efficient buildings. Workshops have proven to be a crucial instrument for the design and delivery of National Renovation Strategy for Ireland (v2.0) and an effective implementation plan (IGBC, 2016).

The first two tier of inquiries raised major concerns regarding building envelope/ façade performance. It forms a crucial component of deep retrofits and is critical in achieving nZEB performance targets (Martinez, 2013). Therefore, the theme of the in-depth open-ended interviews (third tier) was formulated based on envelope/ façade retrofits comprising descriptive and normative questions. A total of 11 experienced market players including architects, civil engineers, cost consultants, BER assessors, manufacturers and construction managers were interviewed with the aim of capturing detailed views of these professionals.

3. Results and discussion

3.1 Survey results: Assessing the retrofit practice

The survey was prepared in common for all nZEB experts and actors in consultation with retrofit professionals. The results are summarised and discussed in the following four categories:

- (1) Respondent and project characteristics
- (2) Retrofitting methods
- (3) Technology and solutions in practice
- (4) Implementation and performance

Respondent and project characteristics

Of the given categories, the majority of respondents represented architects (23), civil/structural engineers (20) and BER assessors / energy consultants (17). Table 3 indicates the number of respondents involved from each category of participating stakeholders.

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Table 3: Categories of participating professionals

Professionals	Respondents (n=90)
Architect	23
Civil engineer/Structural engineer	20
BER Assessor/ Energy consultant	17
Construction manager	7
Building surveyor/ engineer	7
Quantity surveyor/ cost consultant	5
Contractor	3
Energy engineer/ manager	2
Researcher	2
Other	4

Respondents' retrofit experience was recorded in terms of range of frequencies as shown in Figure 2. These results indicate that semi-detached and detached buildings represent the most common types of building retrofits. Approximately 27% (n=17) and 22% (n=15) of professionals have worked on more than 16 projects involving semi-detached and detached dwellings, respectively. Comparatively, a trend was observed towards a low rate of retrofitting of non-domestic buildings in Ireland.

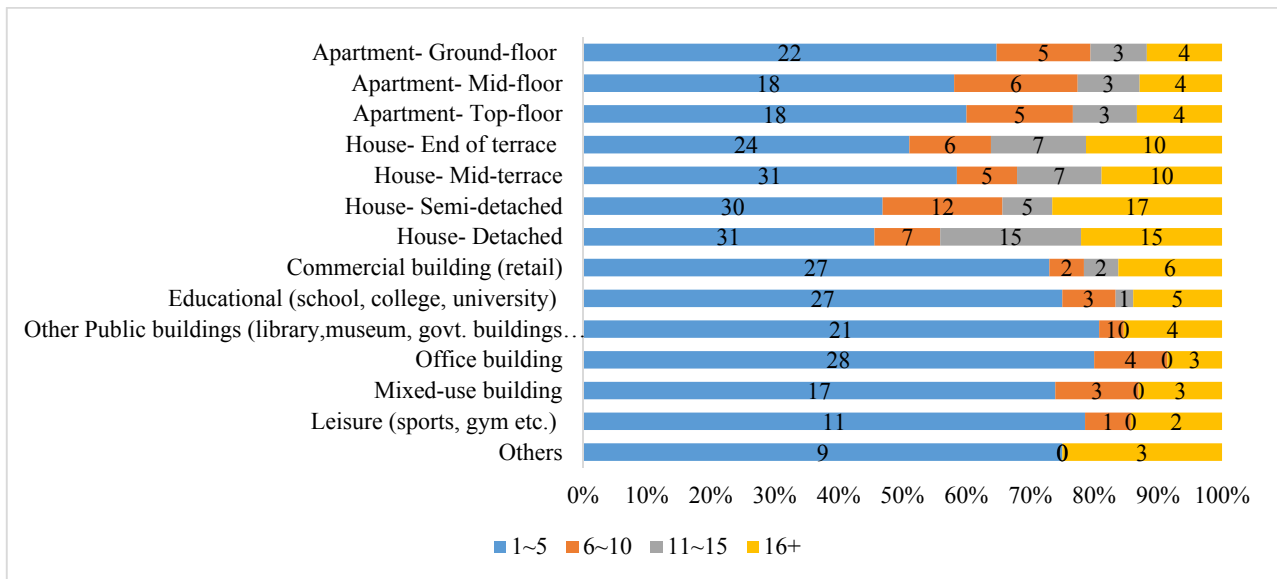


Figure 2: Types of retrofit projects

The purpose of building retrofits derives the performance requirements in a retrofit, approximately 82% of respondents highlighted energy and cost savings, whereas 69% identified renovation (Figure 3). This makes it clear that renovation and energy efficient refurbishment are carried out in parallel by most businesses, as illustrated in Figure 3. On the other hand, about 26% of respondents reported that the typical purpose was to improve indoor air quality and lighting. Also, only 29% of respondents noted 'code compliance' as a purpose of their retrofit in their projects.

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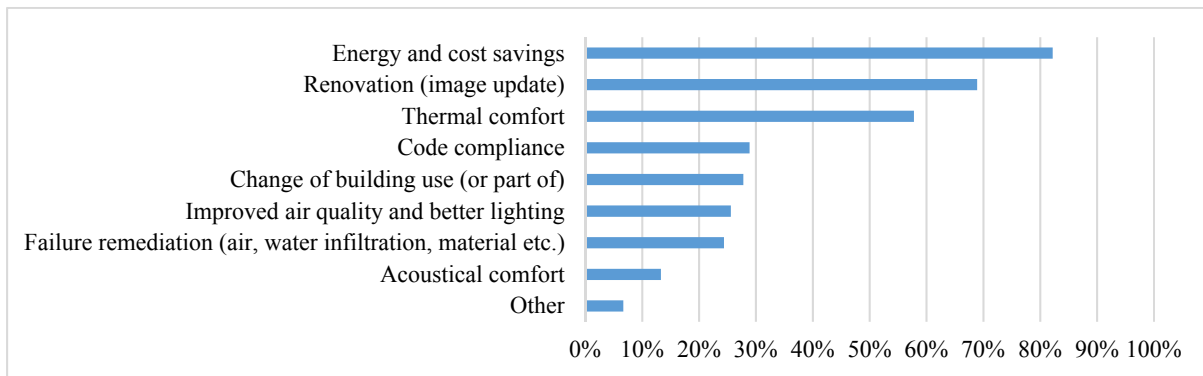


Figure 3: Typical purposes of retrofit projects

Retrofitting methods

To enable a successful retrofit upgrade project, integration of multiple actors is crucial (Gomez et al., 2012), encompassing the perspectives of the professionals involved and the careful choice of retrofit strategies, audit procedures, and regulations. Varied results were observed when appraising the factors governing the choice of retrofit strategies. For example, Figure 4 demonstrates that 51% of respondents considered ‘proven solutions and technologies’ as the major factor, as they aimed to minimise risks of new systems. Overall, 90% recorded that ‘cost involved’ is the driving factor for their choices in retrofit planning. This is supported by the fact that the market is currently in the process of developing cost-effective retrofit upgrade options and financing schemes for building owners. High upfront costs and homeowners’ reluctance for long-term cost savings over short-term expenditures are key barriers in Ireland (Curtin, 2009). Factors such as decision-making frequency, awareness and engagement, budget limits and willingness to pay affect the energy retrofit uptake.

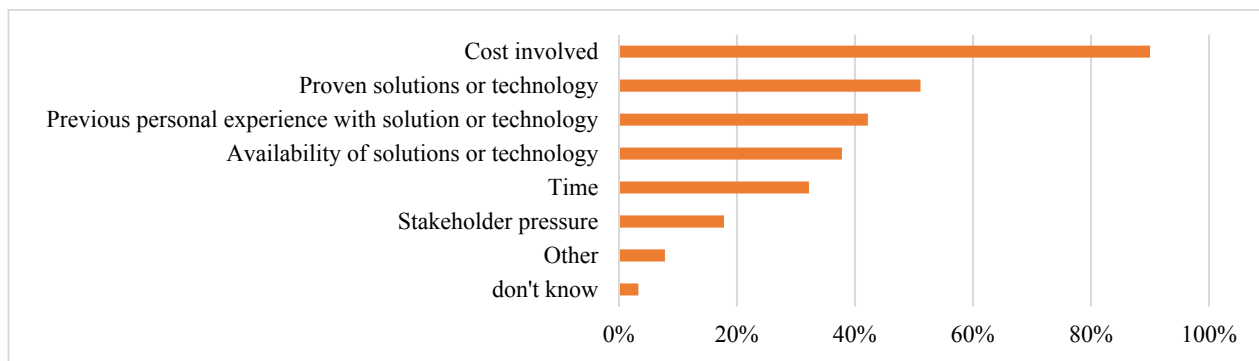


Figure 4: Factors governing choice of retrofit strategies

The survey also gauged some of the most frequently used audit practices before and after the building retrofits. Audit practices define state-of-art being used in practices. The responses, as shown in Figure 5, highlight that 80% of respondents recorded visual inspection as their standard practice. Yet this method is not effective in diagnosing all the problems in buildings to be retrofitted. On the other hand, only 30% of respondents selected on air-tightness test as an audit procedure. The air-tightness test generally involves a blower door test that determines the air-infiltration rate into the building and is a standard practice in Ireland (Sinnott and Dyer, 2011). This is also included as an option for

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calculating background air leakage in and out of a dwelling in the Dwelling Energy Assessment Procedure (DEAP) methodology required for the award of a BER. Infrared imaging is used to detect the thermal bridging, heat losses, and air-leakages. However, only 22% of construction professionals reported its use in their projects. This test is not commonly used as the equipment is costly compared to the air-tightness test.

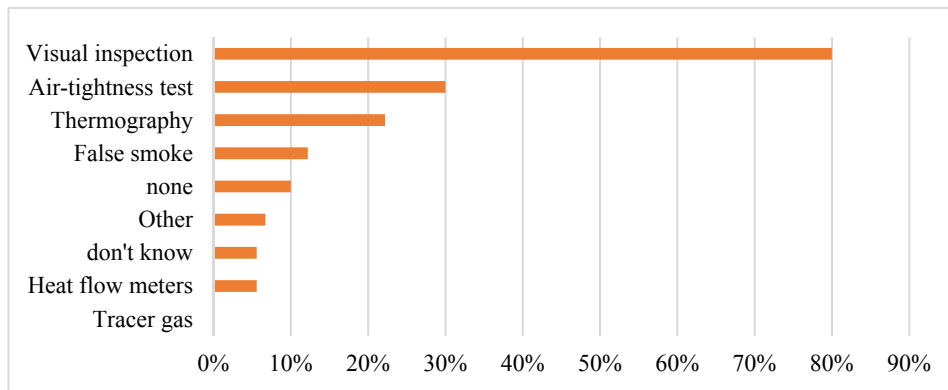


Figure 5: Audit methods used in practice

To understand the extent of their involvement, the level of engagement of stakeholders was assessed in domestic and non-domestic retrofit projects. Respondents selected the categories they had involved in their projects. Figure 6 demonstrates a lack of participation of financing agencies, housing associations, local authorities, NGOs and technology manufacturers. These stakeholders are important for overall market development and adoption of retrofits by owners (IEA, 2014a).

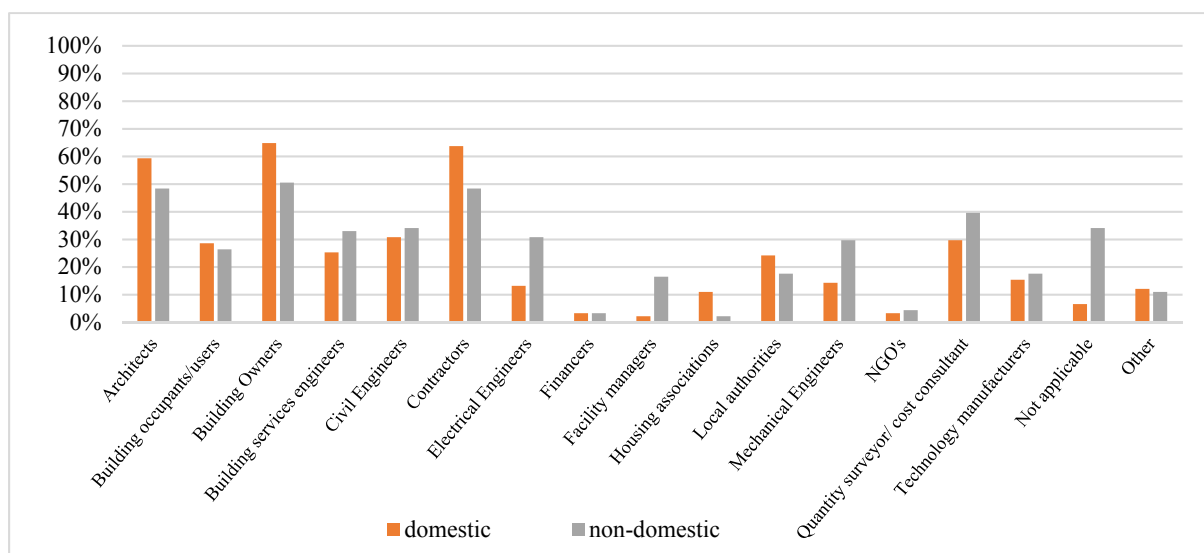


Figure 6: Stakeholders involved in domestic and non-domestic projects

Use of regulations and building standards drives effective implementation of maximum thermal conductivity (defined by U-values) for opaque and non-opaque elements, air-tightness levels, fire norms and other building parameters. The observed trends in standards and regulations compliance were surprising (see Figure 7). 20.9% of respondents do not follow any standards in non-domestic

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projects, whereas about 6.6% of respondents work without any standards in domestic retrofits. BER and general building regulations are common due to effective and mandatory policy enforcement by the Irish government.

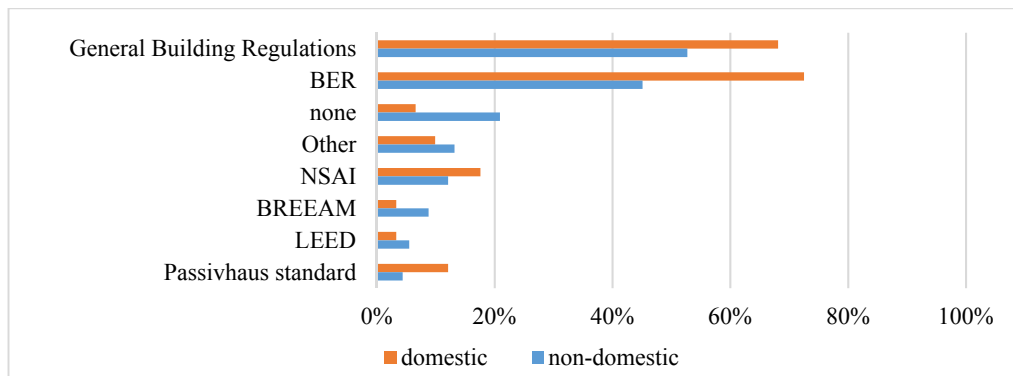


Figure 7: Building regulations followed in practice

Technology and solutions in practice

The availability of efficient construction methods, material, technologies and modelling tools and their use in retrofit industry in Ireland require greater acceptability to ensure the achievement of the nZEB goals. A section of the survey focussed on assessing the applicability of efficient methods and their implementation by retrofit industry actors.

Firstly, the construction professionals were asked to rate the requirement of retrofit analysis and modelling tools, across six categories, in order of their importance (Figure 8). A diverse response to these analysis methods indicates a low appetite and/or technical skill sets for computer modelling by construction professionals in the Irish retrofit industry. On the other hand, project planning tools were rated well above other tools. Different opinions were expected here as a broad range of construction professionals completed the survey and so their needs, experience and training vary significantly. However, there seems to be a requirement or an opportunity to inform construction professionals of the potential value of these tools at different stages of retrofit upgrade projects.

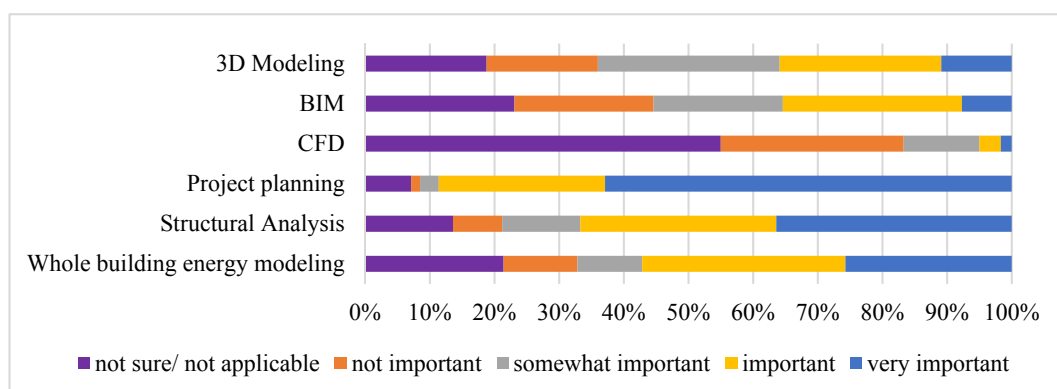


Figure 8: Analysis and modelling tools used

Furthermore, there has been a diverse trend observed in the type of facades retrofitted. 80% of respondents retrofitted façades with masonry cavity walls, approximately 66% selected single leaf masonry and 64% selected concrete block masonry. Highly glazed facades received the least attention (approximately 11%). Figure 9 indicates that a low percentage of the survey sample have experience with retrofitting of glazed facades.

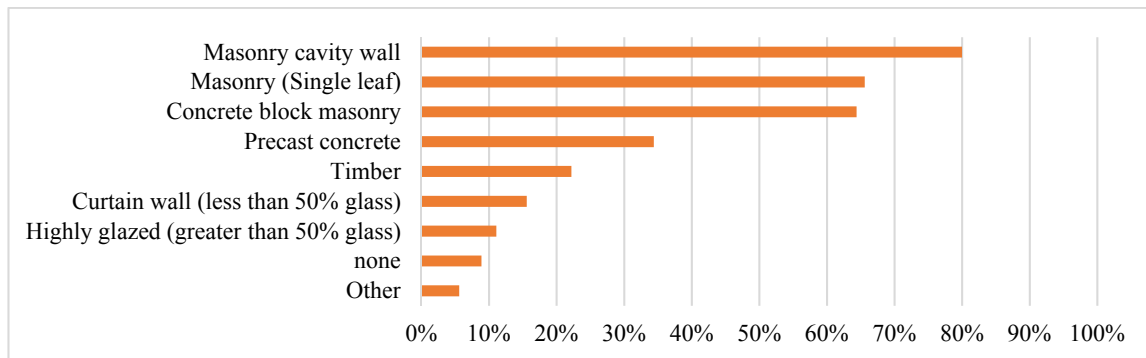


Figure 9: Retrofit experts with experience on various façade typologies

One of the aims of this survey was to ascertain the deficiency in the availability of appropriate solutions for retrofit upgrades to buildings. Figure 10 shows a total of 39% respondents expressing a lack of solutions to deal with cold bridging. Thermal breaks are very challenging when dealing with retrofits (Little and Arregi, 2011). Thermal insulation is the most widely available material, yet 23% of professionals reported a lack of availability and suitable insulation for their projects. This is potentially due to regional barriers in Ireland, such as transport, manufacturing, and imports. Acoustic insulation, building energy management systems and hot-water systems were among others that were of concern to 21% of respondents.

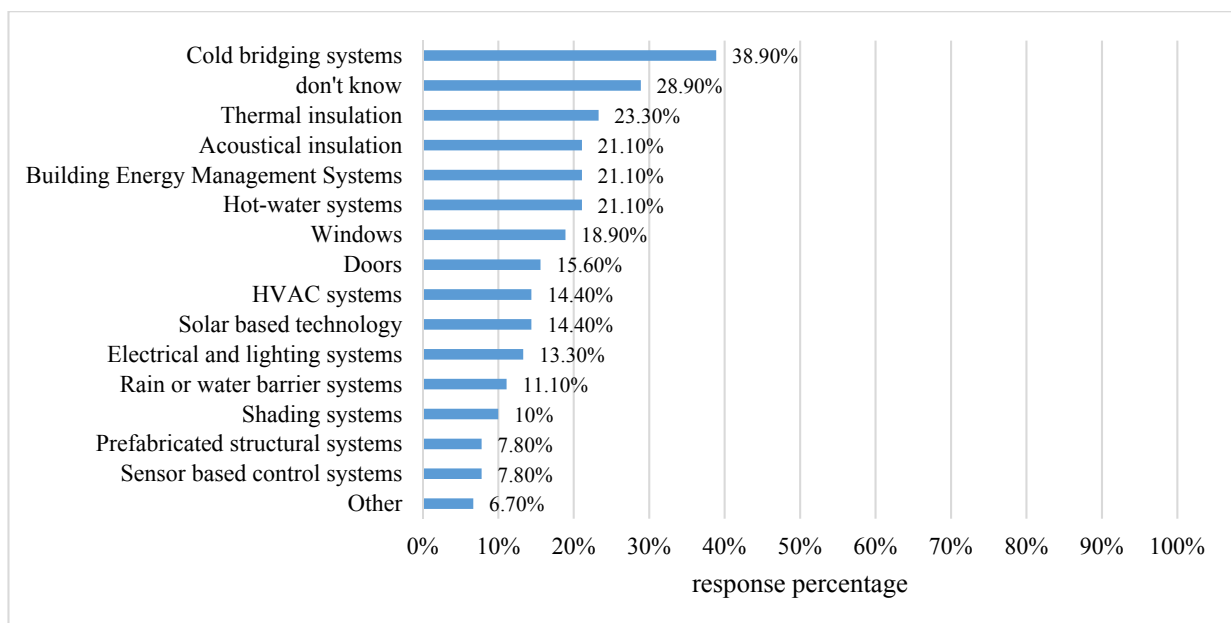


Figure 10: Retrofit technologies in the market

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In response to an open-ended question, the professionals shared their views on the cost-effectiveness of the retrofit technologies and systems.

- *'The product I felt was least effective was a geothermal heat pump, as the energy used to run the pump outweighed the benefit'*

- *'Solar hot water was cost-ineffective'*

Overall, they experienced that Mechanical Ventilation and Heat Recovery (MVHR) systems, heat pumps, geothermal heat pumps, solar PV and hot water systems may not generate enough payback through savings. Some studies show that few of these systems have higher investment cost, therefore, they are not cost optimal solutions for retrofits (Verbeeck & Hens 2005; Watson 2004). On the other hand cost analysis of a retrofitted house in Ireland by Mc Guinness (PHP, 2015) with MHVR, heat pump, solar PV, hot water panel was found to be cost optimal with the primary energy demand of 84 kWh/m²/yr (Coyle, 2015). Automated window opening systems and their high maintenance costs were also not cost-effective according to one respondent. Due to difficulty in scheduling works with residents, some respondents noted that cavity wall pumped insulation proved cost ineffective. Zone radiant heated slab tile flooring was among others that did not perform as expected after the retrofit.

Implementation and performance

The survey also assessed implementation and performance of projects, both pre- and post-retrofit, in terms of BER ratings. As shown in Figure 11, the majority of buildings had poor pre-retrofit primary energy performance and ranged from C3 (>200-225 kW/m²/yr) to G (>450 kW/m²/yr). The highest number of responses were recorded for detached, semi-detached, end-terrace and mid-terrace houses. Recording the post-retrofit performance, Figure 11 also demonstrates the BER that professionals were typically able to achieve in their projects. The largest response rates were recorded for the B1 (>75-100 kW/m²/yr) rating, followed by C1 (>150-175 kW/m²/yr) and B2. Current practices are facing multiple challenges in retrofitting existing dwellings to very high performance, i.e. the band of A1 (≤25-25 kW/m²/yr) to A3 (>50-75 kW/m²/yr) which applies to nZEB for new buildings.

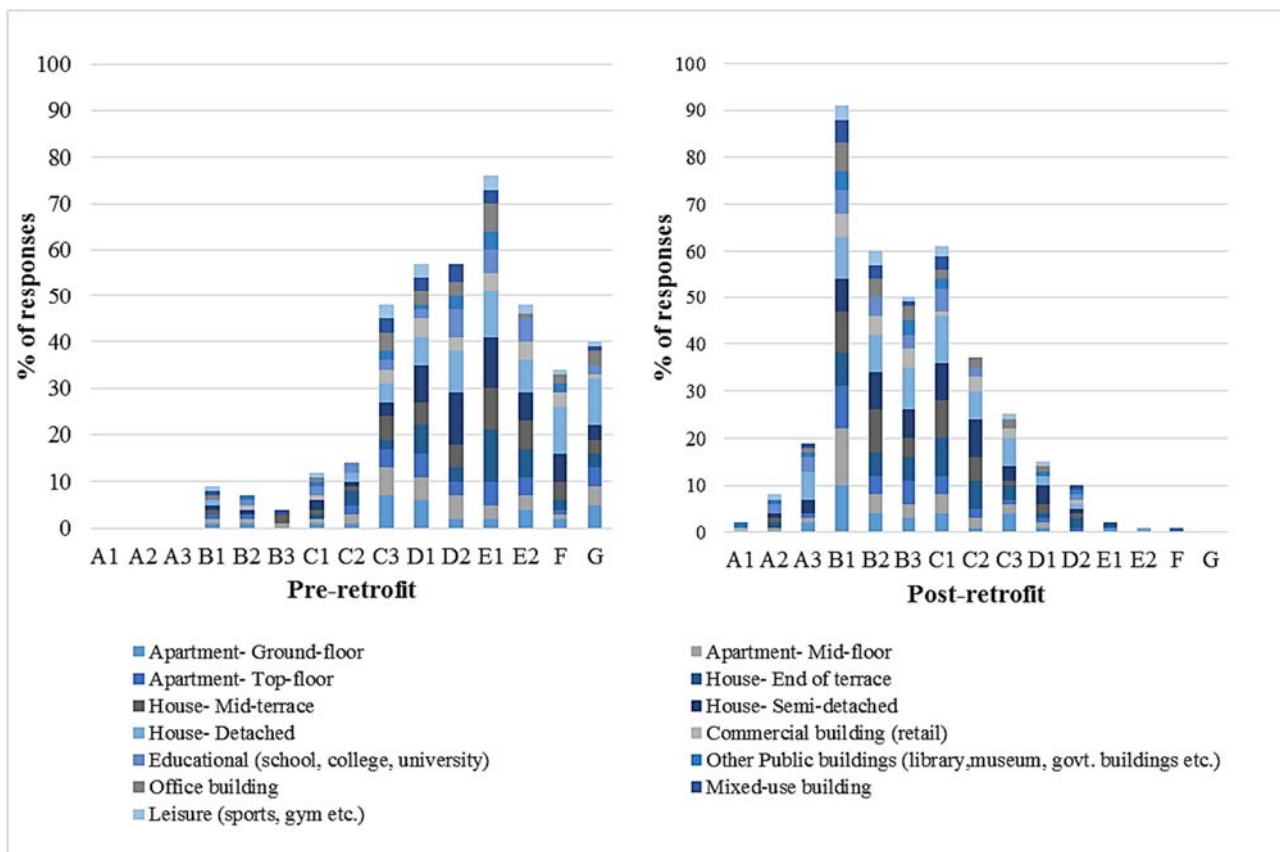


Figure 11: Pre- and post-retrofit performance BER

Informed decision-making and awareness among occupants, users and owners is essential to increase the knowledge level and propagate the benefits of retrofits (Swan and Brown, 2013). It also becomes imperative to give recommendations for maintenance and repairs. The professionals rated each level of consultation frequency - shown in Figure 12. 45% of respondents recorded that they generally consult the owners frequently for decision-making, while 48% reported that they sometimes consulted users. It is a concern that 13% and 12% of respondents never consulted with occupants and users, respectively, while only 9% and 2% always consulted occupants and users. This is an important finding as Moran et al. (2016) highlighted the importance of understanding occupant behaviour to determine appropriate solutions to reduce energy consumption and/or improve thermal comfort in buildings. Retrofits can motivate higher retrofit uptakes if owners, occupants and users are consulted regularly during the process (BEEM-UP, 2014).

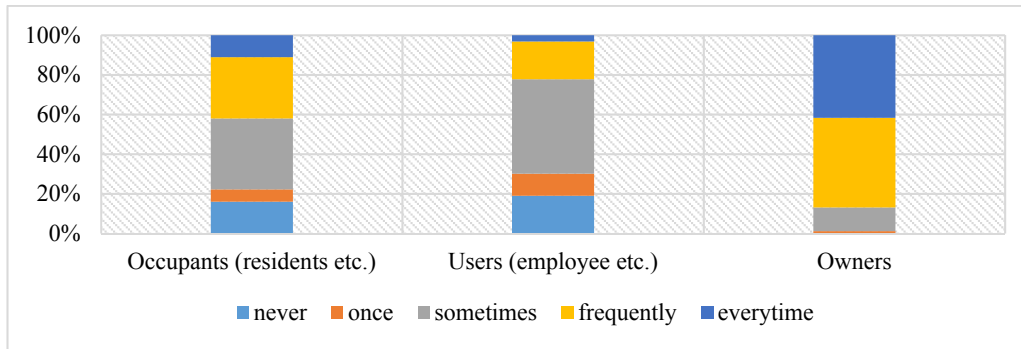


Figure 12: Frequency of consultation

The survey also highlighted issues and difficulty levels encountered during retrofits. From Figure 13, it is evident that the majority of the stakeholders expressed problems with the costs, skilled labour and quality, installation and performance level of components. However, most respondents stated these levels to be average for the adaptive technology, component size, aesthetics, flexibility in use, installation and operation and performance level.

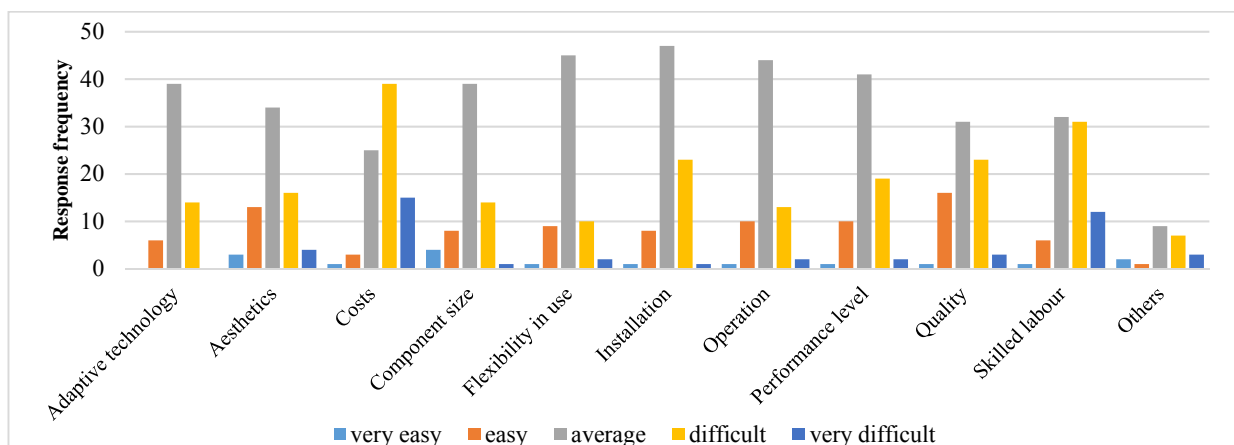


Figure 13: Issues in retrofitting of buildings

General findings

The nZEB benchmark requires deep intervention into current industry practices and scoping out of regular problems, such as lack of information about ways to improve energy efficiency, evaluation of energy performance post-retrofits and continuous end-user feedback. The attitudes of industry stakeholders are key in shaping retrofits over the coming decades. The retrofit upgrade market of buildings in Ireland has too many conflicting opinions for achieving the nZEB goals as understood from these results. Value and effectiveness of retrofits is generally not documented sufficiently frequently and, therefore, it becomes very difficult to access such information. A thematic analysis was conducted on the survey results as it offers deep descriptions on the data and generate unexpected insights (Clarke and Braun, 2006). Since there were four pre-determined themes, it provided a framework to analyse the data and extract the findings in three major categories (market trends, advanced measures, government and public measures).

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Market trends

The results of the survey indicate that residential retrofits are favoured by the market in terms of schemes, technology and products available. The market has yet to make many strides in retrofitting non-domestic buildings, which face bigger challenges and offer larger energy saving opportunities. Results suggest a lack of information on energy-saving technologies and the lack of availability of many retrofit technologies. For example, approximately 20% of respondents reported that basic components like windows and hot-water systems are difficult to source. It was further concluded that there is major dissatisfaction among professionals towards the supply of specific products. Generally, professionals have built up trust with existing suppliers and may avoid experimenting with new manufacturers and their products. This could explain the challenges in achieving low-energy targets as seen in BER results. About 90% of the professionals highlighted cost as the major barrier in decision-making and product selection. Grant support is currently limited and requires a new or reformed model to accelerate retrofit uptake by owners. The hesitation to overspend on retrofitting costs and unreliable paybacks is also a barrier. Lack of skilled workers is a major concern, as raised by 40% of the respondents. Up-skilling programs by the government have yet to be fully unveiled, but are gradually being introduced over the coming years. For example, the BUILD UP Skills training programme for craftsmen and on-site workers was concluded in 2013 (BUSI, 2013b). As a follow-up, QualiBuild project based on the BUSI recommendations was introduced for training of construction workers and is set for national roll out in 2016 (IEA, 2016).

Using advanced measures

The results also suggest a deficiency in the use of new analysis and modelling tools within the retrofit industry. Many professionals have not embraced new measurement and verification methods, and there was a deficiency of some audit practices. This may expose issues within the industry, such as inexperienced auditing. Improper implementation of audit practices can lead to the lowering of opportunities for improving the energy efficiency of buildings. The recommendations required for building envelope, attic insulation, air-tightness, thermal breaks and condensation are often difficult for owners to understand. Therefore, professionals must follow systematic procedures for auditing.

Government and public measures

Many professionals cited the role of government as a major factor affecting their practices. They pointed towards loopholes in policies, funding support and the approach to retrofitting. Also, there is a dearth of data available for the evaluation of the impact of retrofit upgrades, which could inform policies and funding mechanisms. One potential solution identified in the survey results is for greater post-retrofit consultation with owners and occupiers, including the collection of data on energy performance. In general, the survey results highlighted a number of areas concerning legislation and policy and a workshop was organised to confirm the validity of survey results and to unpack the attitudes and approaches of retrofit industry stakeholders in greater depth.

3.2 Workshop results: Engaging retrofit stakeholders

A detailed all stakeholder engagement activity were organised in the form of an nZEB-retrofit workshop in August 2015, following the surveys which were only for nZEB experts and actors. This attracted 85 participants from across Ireland. The objective of the workshop was to bring together a wide range of stakeholders to share expert opinions on meeting clients’ needs for building retrofits, as well as the nearly zero-energy targets set by the European Union. They comprised architects, academics, planning authorities, community partners, contractors, construction and facility managers, engineers, financiers, manufacturers, consultants, BER assessors, housing associations, general clients, property owners and researchers, among others.

While the survey results indicated industry specific concerns and current issues, the workshop focussed on discussing various other elements of the growing retrofit market by assessing policy and regulation level, comfort, state-of-art and their impact. Hence, the workshop was organised into four plenary sessions with stakeholders from several organisations presenting their work under the following themes:

1. Governance, standardisation, and economics
2. Health, comfort, indoor air quality, and energy performance
3. Impact through technology, innovation, and implementation
4. Showcasing energy efficient retrofits

Each of the plenary sessions was initiated by contextual presentations followed by moderated discussions which helped to gain insight into the different perspectives of the stakeholders and to identify points requiring further attention. The speakers presented their work and informed the stakeholders about cause and effect relationships between the problems and solutions that would allow effective retrofitting of the building stock in Ireland. One of the major objectives was to identify the role of government in the retrofit processes and their level of ambition, policies, finance, energy efficiency obligation schemes and skill gaps. Opportunities to address health and human comfort, the status of the innovation scenario in the market and best practices were also discussed. A summary of the key discussions is presented in Table 4 leading to an assessment of the stakeholder requirements, perspectives on policies, market conditions and expectations of the Irish market.

Table 4: Summary of workshop discussions

Categories	Key issues and initiatives discussed
Building envelopes/ façades	Retaining character requires attention in regulations Envelopes must be designed with consideration given to the vicinity Form of the building is not usually taken into consideration in retrofits Roof height clearance is required from authorities during retrofits
Community initiatives	Community wind farms have been proposed Web and television programmes should reach out to the community about retrofits
Cost optimality	Retrofits must be carried out with renovation to save up to 50-60% cost Holistic approaches that consider Life Cycle Cost (LCC) are required Larger problems and failures are encountered in most cases of cost-optimal retrofits Economic value of house is related to BER, it should be based on LCC
Financial structure	Financing institutions must support retrofits (e.g. banks, insurers etc.)

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	Specific financing schemes are required to increase the uptake of retrofits Bigger incentives are required for achieving higher BER
Government initiatives	Government should introduce plans to help pay for micro-generation On-site energy storage initiatives should be undertaken SEAI should document EPDs, embodied energy and embodied carbon for products in Ireland Funding systems require better structure for effective distribution Tax rebates should be given to professionals for effective services
Industry initiatives	A Home Quality Rating project should address embodied energy One-stop shops are required to defragment the industry
Information gap	Public is not informed about heat energy savings Users should be informed about the availability of credible retrofitters in the vicinity Technical information is required for public to understand the needs of professionals Technology suppliers have limited information about products There are under-qualified professionals in the industry
Manufacturers and suppliers	Difficult to get unbiased test information about the product No comparative product information is available in the market
nZEB performance target	Impracticality in payback of renewables by 2020 Lack of certainty on requirements and how to achieve targets
Performance monitoring	Calibration of temperature sensors requires huge effort Energy consumption data in kWh/m ² does not reflect the size of the household Lack of protocols for data collection and verification Big gap in performance and predicted/ design performance
Professionals	People are not ready to pay high fees for professional services Professionals are ill-equipped with latest advances in retrofitting and support tools
Radon concentration	Ventilation and passive sump are promising measures Positive pressurisation of dwelling is effective to prevent radon concentration Few people are aware of radon concentration and its health effects
Regulation and standards	Flaw in DEAP regarding glazing calculations SR-54 for retrofits has very basic view for professionals and the public General guidelines for nZEB are required
Retrofits	Opportunity to improve built environment Operational energy requires integration in retrofit planning Embodied energy needs elaboration in regulations and industry End user requirement needs more detail
Supply and demand	Problems convincing people of connection between supply and efficiency Customer wants cheapest solutions

During the workshop, varying agreement levels were observed in the discussions of the topics listed in Table 5. There was consensus reached on several items agreed to be of immediate concern whereas there was no consensus on topics such as Life cycle costing, embodied energy and risk assessments among others. However, there were mixed responses to issues such as holistic retrofits and recycling or reuse. The study measured the depth of barriers and challenges towards retrofitting that exist among the industry stakeholders', users, clients and authorities and these are discussed in Section 4. Common concerns highlighted issues such as the level of clarity in standards, which are required to be more specific and focused. Interest was also expressed in the initiation of awareness programmes.

Table 5: Summary of topics discussed and their consensus levels

Consensus	No consensus	Neutral
<ul style="list-style-type: none"> • Energy monitoring methods • Effective supply and demand • Public awareness and engagement • Stimulation of financiers • Educating craftsmen • Data from public • Market transformation • Cost optimisation • Building character • Technical, economic and behavioral data 	<ul style="list-style-type: none"> • Life cycle costing • Embodied energy • Risk assessments • Environmental factors • nZEB targets • Comparative information on products • Tax rebates to professionals • Deep-retrofits 	<ul style="list-style-type: none"> • Ambition setting process • Measurement systems and methods • Improved built environment • Holistic retrofits • Courses and training • Recycling and reuse • District water heating • Non-domestic buildings (commercial etc.)

The workshop helped in understanding diverse opinions within the retrofit industry, bridging the gap between stated-preference survey results and the motivations of industry professionals. One of the main findings was that the introduction of new regulations and their acceptance is not mutually understood among professionals due to an information gap. People trust established technologies, as newer technologies often do not declare accurate performance information. The value supply chain is weakened by skill gaps and the lack of one-stop-shops affects the uptake of available solutions by owners. Building envelope/façade retrofitting was identified as one of the key issues throughout the survey and workshop and, therefore, in-depth interviews were planned to elaborate on their role and importance in retrofits. Since there is a multitude of issues available for in-depth interviews but one was prioritised over others.

3.3 Interview results: investigating envelope/façade retrofits

In-depth interviews were conducted as the final component of this study on retrofit practices. The interviews were semi-structured of 60 minutes' duration which gave the interviewees the freedom to share their thoughts, ideas and experiences. Interview questions focussed on the professionals' most interesting and useful experiences and solutions in the area of building envelope retrofits that have maximum impact on building energy (IEA, 2014b). The results of the interviews are based on responses to open-ended questions which reflected the independent perspective of the interviewees. A thematic analysis was conducted to analyse the results. A total of 11 interviews were conducted and participants were selected from different backgrounds and practices in renovation and refurbishment activities in domestic and non-domestic buildings following purposeful sampling technique. The aim of this phase of the study was to interview the process actors as widely as possible. The interviews were divided into pre-determined four main themes of descriptive and normative questions: (1) Experience of envelope retrofits, (2) Assessment of design, construction and delivery, (3) Technology and systems, and (4) Issues and concerns over envelope retrofits. Further, the findings were collated in each theme to present the overall picture. Quotations have been used to improve the interpretation of the findings.

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Experience of envelope/façade retrofits

There appears to be a lack of motivation for the deep retrofit of building envelopes, mainly due to cost-driven factors. Generally, residual building life is shorter to complete longer paybacks for envelope retrofits with larger upfront investment (PHI, 2013). Better ventilation concepts are required for dwellings, together with maximising the use of solar gain and natural light. There should be minimum environmental impact of the envelope retrofit during its life cycle.

It is a cost dependent component and has a lot to do with affordability...I think Passive House Standard is going to be the norm...people are buying the level of comfort

60% of participants considered envelope retrofits to be a fundamental problem.

There is extreme ignorance in Ireland towards envelopes...preservation of original architecture is important...

Contractual documents are generally poor and there is lack of integrated design practice and consensus over standardised detailing. There are challenges with the inclusion of services, their connections in the envelope, workmanship, moisture penetration, noise from mechanical ventilation system, and operational energy costs.

I had contractual issues in the projects and there is no integration of work in the projects...

General methods of diagnosis involved in projects are visual inspection, BER assessments, occupant feedback and sequential evaluation, air-tightness and hygrothermal analyses. Preference is given to the over-riding issues which are budget dependent and driven by client requirements. Interviewees expressed that there are considerable risks in eliminating thermal bridges and this requires additional work. External insulation, tapes and membranes are being used as mitigating measures in retrofit projects, as well as thermal imaging and careful design of projected features.

It is difficult to get rid of them all...issues with semi-detached owners...occupancy of the building is a serious problem while retrofitting...

Assessment of design, construction and delivery

5 out of 11 interviewees outlined that clients are typically more concerned with image update than energy in retrofits.

It matters a lot to the clients...clients are ready to pay for the aesthetics in the projects...

Types of construction materials, preservation, insulation condition, the status of the building, budget and client needs are some of the main factors to be considered in envelope/façade retrofits. 30% of interviewees recorded that no assessments are carried out post-retrofits. Half of the interviewees use BER, meters/sensors with data logging, feedback from occupants and calculations as measures to record post-retrofit performance.

They are satisfied generally and have a comfort takeback...sometimes get feedback from the residents...

They described that current regulations do not allow significant changes in geometry of the existing building envelope when considered together with cost and space considerations. The addition of windows, glass replacement, re-roofing applications and south-side extensions were the most common envelope improvement in their projects. A few professionals indicated that there is large and sensible growth in the market. Residential solutions are easily available compared to non-residential. Furthermore, suppliers do not focus on specifications during retrofits.

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I found residential solutions good and well performing...specification understanding is not good...

The general expertise of the interviewees was in traditional masonry, timber frame, stone cladding, concrete block masonry, mass concrete and curtain walling. Professionals have uncertainty over performance and affordability of advanced materials and there is little motivation for experimentation in their projects. 50% of the interviewees consider embodied energy to be important, but found embodied energy considerations unfeasible for small-scale retrofits with low-budgets.

Yes, it is important but generally in practice it is not taken into account...it is important information if provided correctly by manufacturer...

They also do not find Part-L of the building regulations (DECLG, 2011) sufficiently detailed and comprehensive for practice. To adhere to regulations, interviewees generally follow Passive House Standard, EnerPHit, NSAI, LEED and BREEAM. As a measure for passive design, they have used eco-cements, GGBS, wood based insulation, extensions to south faces, double walls, passive slabs and roof transformation.

Technology and systems

Among the expectations for new technologies were ventilation systems integrated with façades, breathable insulation for timber facades as well as thermodynamic insulations, waste heat recovery solutions, effective CHP technology and smaller heat pumps. The anticipated risks in envelope retrofits were internal humidity levels, interstitial condensation and moisture accumulation, the life of the insulation and overheating. 80% of the interviewees were conscious of reducing energy consumption of the buildings in their retrofit projects and achieving minimum standards is the general target.

It is absolutely essential to have this approach in the current scenario... We place effort to achieve good performance...

Regarding the preference between cost and energy performance, longer paybacks of new efficient systems deter their adoption and achieving a balance between the two is the target, although clients play a decisive role. The tools used for design and analyses included software such as WUFI, SCI-Therm, Sketchup, Builddesk, DEAP and PHPP, as well as the use of rules-of-thumb and calculations in MS Excel.

Issues and concerns over envelope retrofits

Among other concerns, off-site training for envelope retrofits was highlighted by 3 interviewees and they regarded licensing of practitioners in retrofits as important. There should be insurance schemes to pay for the damage caused during deep retrofitting of building envelopes. Norms and construction details in retrofits should be established to enable the industry to become aware of its importance such as newly introduced SR 54:2014 (NSAI, 2014).

SR 54 which was recently finally released this month is a very limited piece of work (some of its guidance is high risk) but no doubt... any messages that conflict with it will be regarded as retrograde or non-compliant...

Clear guidance on the suitability of materials over their life cycle should be provided in the regulations. Improved methods and guidance on ventilation control are also required for better retrofits.

These interview results suggest that the construction sector is fragmented and that there lacks coherent strategies surrounding retrofit processes. The interviews provided a detailed representation of the individuals' activities where the barriers are generally financial, technical, governmental, social and organisational. The practicing professionals have varying opinions over the acceptable quality levels of nZEB practices and, therefore, limited efforts to achieve nZEB levels were seen. The lack of skilled workers, contractual issues, product quality, ready available appropriate technology, lack of knowledge and motivation can be observed in the current practice of professionals. There are challenges to the envelope retrofits for maintaining cultural and historic values. There are high performance ambitions from the existing buildings, but existing solutions do not support the efforts. The key to the organisation of retrofit efforts requires commitment, cooperation and collaboration by the nZEB actors.

4. Summary and Conclusions

The three-tier study outlined the spectrum of attitudes and approaches in the retrofit industry, highlighting multiple barriers, gaps, and challenges in Ireland. The results from section 3.1, 3.2 and 3.3 are summarised in Table 6 below under two broad headings: (a) *Practice and Industry* (Technical, Environmental, and Industrial), and (b) *Enforcement and Governance* (Legislative, Social, and Economic); and followed by comprehensive briefings on these categories.

Table 6: Barriers, gaps and challenges in the retrofit industry in Ireland

Practice and Industry	Enforcement and Governance
<p><i>Technical</i></p> <ul style="list-style-type: none"> • Low quality auditing • Lack of openness to new solutions • Absence of coherent technologies • Lack of standards and details • Low cost development of technologies • High reliability of proven solutions • Variation in measured and actual performance <p><i>Environmental</i></p> <ul style="list-style-type: none"> • Low preference for IAQ and acoustics • Neglecting air-quality testing post retrofits and radon concentration • Limited availability of recyclable products • Little emphasis on LCA and its impact • Few studies on health impact of retrofits • Passive design methods rare in practice • Environmental approach less feasible in small scale retrofits <p><i>Industrial</i></p> <ul style="list-style-type: none"> • Less involvement of experts • Unskilled operators in market 	<p><i>Legislative</i></p> <ul style="list-style-type: none"> • Lack of incentives • Poor ventilation standards • No documentation on embodied energy for retrofits • Inflexibility in building regulations w.r.t. retrofits • Less focus on operational energy in standards • Lack of general reference manuals, and comprehensive nZEB regulations • DEAP does not address all issues <p><i>Social</i></p> <ul style="list-style-type: none"> • Lack of awareness of long-term retrofit benefits • Lack of involvement of owners/occupiers • Missing communication to owners • Insensitive towards architectural and cultural aspects • Insufficient infrastructure for growing population • Community-based energy production methods not adopted • No desire or support from client to record data and monitor <p><i>Economic</i></p> <ul style="list-style-type: none"> • High upfront costs for owners • Tax-free opportunities should be explored

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- | | |
|---|---|
| <ul style="list-style-type: none"> • Lack of availability of one-stop solutions • Low collaborative approach in projects • Conflicting opinions among stakeholders • Requirement of assessment of chain effects in retrofits • Lack of comparative product information | <ul style="list-style-type: none"> • Measure for non-domestic buildings required • Envelopes considered as cost-driven components • Imbalance between typology of building retrofit vs split incentives between owner and industry • Lack of retrofit services in rural areas with focus only on urban areas with high economic gains |
|---|---|

Practice and Industry

One of the key technical barriers observed in practice are low quality auditing and low versatility for intervention in existing buildings. Professionals lack expertise on non-domestic retrofits, on the other hand there is a general trend of reliance on existing solutions and a lack of adoption of new solutions for domestic retrofits. In general, suppliers have inadequate technical information with a prevalent absence of coherent technologies that can work with existing systems. Very few retrofit concepts are available in practice to deal with solar gain, natural light issues and hygrothermal evaluation. An uneven mix of retrofit experts exists in the industry and retrofit businesses lack technical standards for nZEB. This suggests a greater need for identification of dedicated technical roles and responsibilities and standardised detailing for retrofits within the practices. There are many technical challenges, such as the upgrading of protocols for retrofitting, low-cost development of retrofit technologies, and a lack of proven solutions and expertise. Correct information on products and monitoring actual energy performance in retrofits are seen as important factors to overcome.

It is also worthwhile to note that a much lower preference was observed for environmental concerns than for technical challenges in retrofit practices. Barriers such as improvement in IAQ and acoustics are generally left unaddressed in projects with the emphasis lying only on energy savings. Professionals often don't conduct radon concentration or air-quality testing inside the building post-retrofits. With a lack of focus on environmental retrofit approaches in small-scale retrofits and limited availability of recyclable and re-usable products in the market, there is insufficient emphasis on Life Cycle Assessments (LCA). Furthermore, few studies exist which quantify the health issues of pre/post retrofits in Ireland. These challenges require fast retrofitting solutions and the exploration of local materials for manufacturing environmentally-friendly building products. Also, many more studies are required to examine the environmental impact of building envelopes. Retrofit practices must overcome the challenges encountered in previous retrofits such as noise pollution, health effects on workers and recoding of radon concentration. This can be achieved by integrating these challenges within policy frameworks and national implementation strategies for environmental improvement.

To improve retrofitting in Ireland, industry is a crucial sector in dealing with technical, environmental and other barriers. There is a low level of involvement by experts in domestic retrofits, while contractors are carrying out retrofits at very low rates. On the other hand, unskilled operators are selling products with little understanding of specifications. The lack of sharing of information and knowledge among stakeholders gives rise to conflicting opinions among the stakeholders. There is a huge gap between the development of models for contractual arrangement in retrofits and the parallel assessment of the chain effects in buildings being retrofitted. A government guide to contractual

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structures for retrofit businesses can be very useful to address this issue. Holistic retrofit methods and greater collaborations are required in the industry and among different actors for the improvement of future retrofits.

Enforcement and Governance

An absence of government incentives for achieving higher energy efficiency goals was described in this study. Lack of flexibility in building regulations for retrofits (e.g. extensions, change in geometry etc.) and traditional measures for improvement of existing facades were some of the major barriers observed. There is an absence of comprehensive documentation and databases to address environmental impacts of products in Ireland. Furthermore, greater control of low-quality retrofits taking place across the country and compilation of explanatory nZEB regulations based on consensus are key challenges to be pursued through legislation and policy interventions

There are many social barriers in retrofit projects arising mostly from the client side. Generally, there is less desire and support from the client/owner to record and monitor data on energy performance and retrofit decisions are made by the client/owner with little or no experience. Professional advice is not sought in the majority of retrofit projects and several architectural and cultural issues limit the possibility of retrofits. Community-based initiatives are missing in practice and information on credible retrofitting professionals and contractors in the regions are not available. A lack of infrastructure and insensitivity towards harmonising existing building with surroundings are questions of deep concern. The opportunities to explore local energy producing methods, and technologies and concepts to improve the quality of built environment are also important gaps to be addressed. However, it may also be noted that achieving higher energy performance with historical buildings or protected structure is comparatively difficult. Another of the major challenges is the communication of benefits about the monitoring of data to the residents and the role of professionals in retrofits. Increasing the retrofitting rate to match the demand and availability of unbiased information from the manufacturers are some of the other challenges to be met.

Society is closely affected by the economic barriers in retrofitting whereas greater inclination is found towards residential sector retrofits due to reliable sources of income. Higher density of retrofit businesses exist in urban areas with higher economic gains. As can be noted above through the practice and industry trends, client orientation is generally towards buying cheaper solutions with lower budgets - high upfront costs make them reluctant to uptake retrofits. One of the important barriers affecting their motivation for retrofits is short-term ownerships affecting long-term paybacks and initial investment into a property, and the Governments' lack of funding for ancillary works with null tax rebates for professionals providing retrofit services. A rising trend in Ireland suggests that property values are affected by BER, but not by life cycle potential which presents a major social barrier. These economic gaps demand motivational measures for retrofitting non-residential buildings as they consume a significant amount of energy. Solutions for retrofitting while maintaining occupancy and exploring tax-free opportunities for building retrofit products can bring massive changes in the industry. Deep retrofit benefits must be elaborated for tapping into the existing

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opportunities in the Irish context through building regulations and policies. Significant challenges involve balancing the typologies for building retrofit and split incentives for uptake of such projects among the owners and industry. The spread of retrofit services across suburban and rural regions can make a huge impact in saving energy. This also includes calculating the economics of the retrofit for the owners without public funds, provision of incentives for achieving higher energy efficiency goals, and control on the escalation of the property values. Low-cost development of envelope retrofit components and lack of general agreement on retrofit strategies are other important concerns for retrofits.

Concluding Remarks

Individual stakeholders hold specific requirements which represent the industry as a whole. Many barriers can be overcome within the industry and its stakeholders, for successful growth of nearly zero-energy buildings (nZEB's). The gaps that exist present an opportunity for adopting appropriate solutions for effective retrofitting. Technical lag among expert actors poses serious impacts on quality and performance of retrofits in Ireland and innovative measures for incentives. Tax benefits are required to further support the growth of retrofits. Environmental barriers are an integrated part of the industry and can be controlled through legislation. The legislative perspective has a deep influence over the motivation and approach of the professionals to follow nZEB targets. Also, social barriers can be eliminated by involving the occupants and owners and filling the necessary information gap along with ways to economise retrofitting. Several findings from this research can inform formulation of policy and practice standards that fall within the scope of environmental, economic and social regulations. The recognised gaps can be addressed by research and industry innovation through collaborative approaches and the support of the public. The overall collective picture represents the attitudes and approaches of the industry stakeholders that define the shape and growth of the industry for future nZEBs.

Limitations of the study

This study represents a first step in understanding the major barriers in industry practices in Ireland. During this research there were several limitations and which may have influenced the results and findings.

1. It is a convenience sample rather than a random sample and therefore this may affect the generalisability of the findings. This sampling technique may also include selection bias.
2. The study focused on the construction industry Ireland, which experienced an unprecedented construction boom and collapse in the past 20 years. The Irish housing, construction, and retrofitting markets also include some significant differences from the remainder of Europe, e.g. high proportion of owner-occupiers and single-family dwellings.
3. The study only considered construction professionals and did not include the perspectives of site workers and end users, this may have affected the scope of the findings.
4. The survey questions were limited and generalised for a number of professionals, which restricted their flexibility to answer.

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However, it is envisaged that the comprehensive three-tier methodology and varied sample enabled the capturing of a wide range of perspectives which we analysed in depth. It was clear that a number of key issues were raised at each stage by several participants. Therefore, further research is required to overcome these key issues in form of in-depth interviews for each category of stakeholders that could guide in developing successful retrofit initiatives for Ireland.

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