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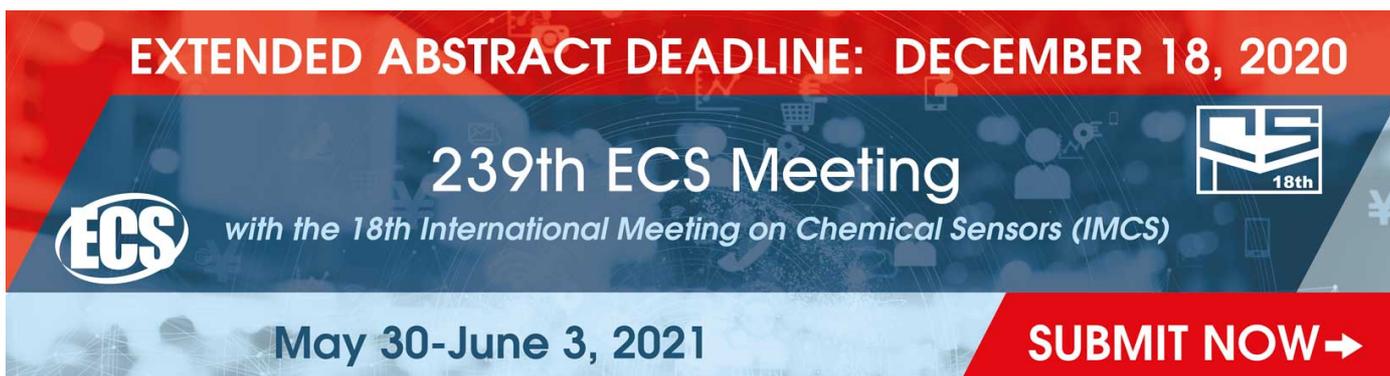
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Barriers and drivers to the uptake of innovative, affordable, and zero-energy dwellings in Belgium and Ireland

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Abstract. Despite efforts to promote and accelerate the adoption of innovative, affordable, and zero-energy dwelling solutions, the number of dwellings complying with standards such as the EPBD remains relatively low as we reach year 2020. Studies have already explored potential challenges and opportunities to the uptake of such designs. However, despite previous findings and recommendations, the market's response remains slow. Building on existing knowledge and as part of the Housing 4.0 Energy project, this study investigates current financial, cultural, legislative and technical barriers and drivers to the implementation and uptake of small, innovative, affordable, zero-energy dwellings in small towns in Belgium and Ireland. Focus groups gathering housing providers, decision makers, stakeholders, and contractors were conducted in Leuven and Kilkenny. Outcomes revealed that participants' general perceptions around barriers and drivers are similar between the two countries and are validated by previous research findings. However, a closer look at context specific barriers reveals considerable differences. The identification of these contextual differences enables a better apprehension of the current situation in every location leading to the formulation of context specific recommendations and a better allocation of precedence. Thus, this paper demonstrates the importance of context specific investigations not only in the identification of challenges to energy efficiency innovations but also in establishing more effective implementations.

1. Introduction

Over the past years, significant demographic, social and economic factors changed the nature of housing demand [1]. The increasing number of smaller households of one to two persons, the different household compositions, and the increasing affordability issues led the majority of EU households to need smaller, more affordable dwellings. The building sector's traditional housing designs no longer fulfil these significant changes in housing needs. This results in housing shortages and increasing dwelling prices both of which have a considerable impact on people's living conditions and economic growth. Simultaneously, the urgency of action regarding climate change calls for the building sector to abide by increasingly strict design, building and performance regulations for a healthier indoor and outdoor environment.

In 2010, the Energy Performance of Buildings Directive (EPBD) established a timeline that requires all new buildings to be nearly zero-energy by December 2020. Despite noticeable efforts made by EU countries, the 2016 EPBD's commission recommendations report stated that progress has been slow thus highlighting the need to increase and accelerate the building sector's efforts towards a nearly zero-energy built environment beyond 2020 [2].

Good health and well-being, economic growth, and healthy indoor and outdoor environments are all key components of what constitutes a sustainable city and community [3]. One way the building sector could contribute to the creation of sustainable cities and communities is through the provision of affordable, innovative (near) zero-energy housing and ensuring accessibility and safety to all. However, looking into the national European housing markets reveals insufficient investments directed towards energy-efficient dwellings which underlines a knowledge gap regarding the market potential of such innovative designs [4].



2. Literature review

One way of evaluating market potential is to investigate existing or potential institutional, technical, financial, and social barriers and drivers challenging or inhibiting their successful uptake [5,6]. To that aim, several studies explored challenges from various perspectives covering the different sectors involved in the process of housing provision. Despite different research time, location, scope and methods, the studies reach similar outcomes [4–10]. For instance, in 2011, a study about low-carbon housing refurbishments from architects' point of view concluded that drivers promoting energy-efficient housing are insufficient [10]. The same conclusion was reached in 2012 through a study investigating energy-efficient housing from a policy perspective [9] and in 2015 through a study evaluating the construction industry's perspective regarding zero-carbon homes [4]. Moreover, throughout these studies, a recurrent distinction is made separating financial, cultural, legislative and technical barriers and drivers to the uptake innovative energy-efficient dwellings and designs. Accordingly, the following four sections summarize the common barriers and drivers found throughout the literature.

2.1. Financial barriers and drivers

Despite potentially lower operational and lifecycle costs, one of the most common perceived barriers to the application of innovative energy efficiency measures within the housing sector is higher initial costs [6,9–12]. Long payback periods [10] and continuously increasing real estate prices [6,7] also challenge the willingness to pay high initial costs although when it comes to property values, the literature reveals conflicting conclusions. Some deduce that having energy-efficient housing potentially increases the value of a property and leads to higher rents or sales prices [5,10]; however, others argue that this does not make up for the rapid and continuously increasing rate of real estate prices within the housing market [6,7]. Additionally, the literature highlights insufficient financial incentives within bank policies [4,5] and the need to increase financial schemes that provide people with additional funding, reduce their taxes, and other economic incentives promoting innovations [4,6,10]. However, it does underline that this is partly caused by the risks and uncertainties linked to innovative designs that are not compensated for [5,9]. The same applies to the insufficient industry investments in the field [6,7] that could be perceived as a prioritization of profitability [5,9].

2.2. Cultural barriers and drivers

A common perceived barrier is people's level of awareness when it comes to the need and the urgency of having an energy-neutral dwelling as well as their lack of knowledge of its various benefits [4,6,10]. This leads to a lack of engagement or sense of commitment from users vis-a-vis their dwellings [10]. People's habits also play an important role in challenging the adoption and successful use of new technologies. Combined with the absence of education and provision of information, all these factors contribute to limiting people's awareness levels [6,10]. Thus, it is crucial to raise public awareness [4,5,8] by providing adequate information and redirecting education first because it encourages sustainable behaviour; one of the common identified drivers [4–6,8]. Second, because some argue that policies and building regulations are effective only to a certain extent [10] and third because others argue it would positively impact market demand and increase it [4]. Finally, increasing end-users' involvement in the design and construction phases of dwellings is also another significant factor in raising awareness and especially in improving user behaviour [6,10].

2.3. Legislative barriers and drivers

The lack of a policy and regulatory framework supporting innovative zero-energy housing designs was revealed as one of the main legislative barriers to their successful uptake [4,6,7,10]. Literature also recognizes a lack of cooperation between the different policy departments covering energy efficiency and housing [7,9] and a lack of clarity specifically in building regulations related to energy efficiency innovations [4,10]. Thus, there is a need for proper coordination and collaboration of the different policy and regulation fields as well as clear guidelines and design standards whether they are

applicable to new build dwellings or housing refurbishments [4,10,11]. Moreover, the lack of severity of standards and regulations was perceived as another challenging characteristic and literature argues that their status should switch from prescriptive to mandatory since going beyond what is required is not common [6,10]. Mandatory building codes, energy performance standards, and certification specific to innovative energy-efficient dwellings and designs are recognized as part of the main drivers to an energy-efficient housing sector [5,6,9]. They are perceived as necessary and effective measures to the successful uptake of innovations like off-site or self-build constructions. Moreover, the periodical revision of such guidelines continuously aiming at higher standards and a better performance is also perceived as necessary. However, it can be argued that overregulation and the lack of flexibility can have a reverse effect and prohibit the uptake of innovative initiatives [9].

2.4. *Technical barriers and drivers*

General shortage of skills in both design and construction was revealed to be a significant common barrier. It was identified as a lack of knowledge and awareness during the design phase [5,9] and as a lack of skilled workers with sufficient technical experience to properly handle or install innovative technologies on site [6,10]. Contractors' acquired experience was identified as a main selection criterion in the process of adopting innovative housebuilding systems thus underlining the potential impact this barrier could have on future upscaling [12]. The gap was also found in the education and training of people towards innovative housing technologies such as prefabrication or net zero-energy performance [5,6]. Another common challenge is the lack of cooperation and proper coordination between housing professionals (designer-designer, contractor-contractor or designer-contractor). This could also be translated into insufficient communication between designers, manufacturers, contractors, and workers [6,9,11,12]. Technical drivers to the implementation of innovative dwellings are self-evident and include faster completion times, shorter project durations, shorter periods spent on site, a higher environmental performance, an improved energy efficiency, and a better indoor environmental quality [4,5].

2.5. *Knowledge gap*

The literature reviewed in this study on challenges and opportunities reveals that there is a dominance of barriers over drivers. It also highlights that there is a considerable number of similar outcomes despite the different research scopes, perspectives, and methods. This indicates that the stated challenges are perceived by most professionals involved in the housing sector and that they apply to potentially all types of innovative energy efficiency measures whether it is low-carbon refurbishments, prefabrication or net zero-energy new build dwellings. More importantly, these outcomes also persisted through time. This can be interpreted as a validation of the established research conclusions, but it can also underline a certain limitation. A possible explanation to the persistence of similar results is the general level of analysis. While reaching generalizable outcomes and having a holistic view on challenges to the uptake of innovations is helpful, a more context specific level of analysis could help identify more context relevant challenges leading to more precise recommendations. Housing regulations, legislative structures, traditions and practices, and energy commitments vary from one country to another [7,9]. Context specific investigations are needed to take into account the importance of these individualities and contextual characteristics and their potentially significant impact on the formulation of effective recommendations. At present, there is a limited number of studies exploring in detail the challenges and opportunities to innovations and energy neutrality within the housing sector while taking into account local peculiarities. For this purpose, this research aims to contribute to this discussion and answer the following question: *What are the current and potential barriers and drivers to a successful implementation and uptake of innovative, affordable, small, and (near) zero-energy dwellings?* from the perspective of professionals involved in the commissioning, design, construction, and regulation of housing by conducting a context specific investigation in Belgium and Ireland.

3. Methodology

For a context specific elaboration on potential challenges and opportunities to the successful implementation and uptake of small, innovative, affordable, and (near) zero-energy housing, this study implemented a qualitative research method that consists of two focus groups; one in Leuven, Belgium and the other in Kilkenny, Ireland. These focus groups were conducted as part of an on-going project entitled Housing 4.0 Energy: Affordable and Sustainable Housing through Digitization (H4.0E) and funded by Interreg North-West Europe. Within the H4.0E project, the goal is to design 54 affordable (€65,000 to €138,000), small (46 to 92 m²), low carbon (timber frame) and (near) zero-energy dwellings for small households composed of one to two persons. These dwellings will be built and distributed between 4 northern European countries including Belgium and Ireland. The aim of the H4.0E project is not only to provide new and affordable housing solutions in Huldenberg, Kilkenny, Wexford, and Carlow but also to explore and facilitate the uptake of these dwellings within Flanders and Ireland [13].

Focus group participants were recruited by nomination [14] and consisted of housing designers, technical experts, housing providers, and local and regional authorities. Although this study focuses on housing professionals' perspectives, it emerges as the initial stage of a larger research within the H4.0E project that takes into account users' perspectives in its second phase through an evaluation of their housing preferences. Based on the literature review, the discussions start by a direct investigation of potential challenges and opportunities within each of the four categories previously identified: financial, cultural, legislative, and technical. The number of participants per focus group was 9 in Kilkenny and 12 in Leuven. With their consent, the focus group discussions were recorded then transcribed into detailed reports. The collected data was then analysed directly from these reports and coded into key discussion points and conclusions were drawn accordingly. Section 4 below provides and discusses the focus group outcomes.

4. Results

Housing professionals in both countries agreed on the apparent drivers to innovative and zero-energy dwelling designs. Mostly, they consist of better energy performance, lower lifecycle costs, shorter construction times and proper monitoring that would allow the provision of feedback to both occupants and manufacturers. All drivers are also recognized by previous literature [5,8,10]. However, similar to previous studies [4,9,10], the focus group data revealed that participants perceived more barriers than drivers to their successful implementation and uptake. While these barriers are interrelated, they are further discussed below within the same sub-sections adopted throughout the paper: financial, cultural, legislative and technical. Table 1 provides an overview of the outcomes.

4.1. Financial barriers

The focus group outcomes revealed that the perception of higher initial costs is a generalizable barrier that applies to both contexts. This underlines the established assumption that innovative and zero-energy dwellings are more costly. This also echoes previous research findings that link the focus on higher initial costs rather than potential lifecycle savings to the uncertainty and risk associated with innovation [5,9,12]. Looking into context specific barriers, participants in Leuven were mostly concerned about inaccessible land prices. Within the social housing context, participants also underlined the 'split incentive' between providers and tenants as a potential barrier. The general perception is that while social housing organizations make the investments for the implementation of energy efficiency measures, tenants benefit more through lower energy costs. In Kilkenny, participants expressed the difficulty of individuals in the private sector to obtain a mortgage for innovative designs and construction methods. To release funds, their process requires most of the construction works to be completed and approved by architects and engineers. Moreover, participants highlighted the potential impact of the established loan to security scheme on the willingness of financial institutions to lend. Under the assumption that these innovative dwellings are less durable and not as robust as traditionally built dwellings, their value would depreciate faster. Another contextual barrier relevant to

the Irish context and related to financial institutions is the discrepancies and the lack of consistency in benchmarks for green financing from one institution to the other.

4.2. Cultural barriers

Participants from both focus groups agreed on the low level of public awareness when it comes to the urgent need and benefits of having an energy neutral built environment which affects the market demand and market potential of these dwellings; another outcome repeatedly highlighted by previous studies [4,6,10]. Additionally, they highlighted general established perceptions and habits not only challenging their uptake but also resulting in the misuse and ineffectiveness of the new technologies. A closer look into each context reveals differences within these perceptions and habits. For instance, in the Flemish context, participants' concern was linked to people's perceptions of small housing. There is a negative connotation linked to a small dwelling size as they are associated with "container homes" or tiny houses. Whereas in the Irish context, the concern was about the robustness of different building materials. People perceive timber frame and/or off-site constructions as lower quality and less durable than traditional brick or concrete structures. When it comes to habits and building services, in the Flemish context, despite the lower costs of new technologies such as underfloor heating, people still prefer to have traditional heating systems like radiators. In the Irish context, despite the considerably high costs of traditional fuel types such as coal, people do not perceive it as an expenditure burden because they are accustomed to it. This forms a potential challenge since it creates reluctance to changing energy sources. Moreover, when it comes to the uptake of these new dwellings, participants in Leuven highlighted people's reluctance to move out of their homes until they absolutely have to. Whereas in Kilkenny, third party objections coming from local citizens based on a "not in my backyard" mindset towards innovative designs were perceived as potentially obstructive.

4.3. Legislative barriers

The focus groups outcomes echo previous research findings when it comes to the absence of a general policy framework [4,6,7,10], the absence of mandatory standards for innovative construction methods, materials and design [6,10] or the "business-as-usual" mindset amongst housing providers. Participants perceived that the current priority of housing policy leans towards providing more traditional new build dwellings at potentially the same cost especially since a zero-energy performance is not mandatory. Moreover, focusing on the context highlighted differences within planning and land use policies. In Leuven, the main concern was land use regulations regarding the allowable number of dwellings to be built on a plot. Often it is limited to one house per a relatively large plot which was perceived to discourage the uptake of smaller dwellings. In Kilkenny, the concern was planning policies regarding the individual scheme certification system. Each required certification needed an individual application and pre-certification is not possible even if dwelling designs are being replicated. Thus, the length and cost of the process stay the same. Moreover, participants particularly highlighted the Disability Access Certificate and the Fire Certificate as potentially challenging to the implementation of small, innovative and zero-energy dwelling designs.

4.4. Technical barriers

On a general level of analysis, participants echoed the lack of experience and knowledge amongst developers, contractors and builders when it comes to innovative zero-energy dwellings, technologies and systems [5,6,9,10,12]. They also highlighted the potential impact this has on commissioning, installation, testing, certification, management, and maintenance leading to another barrier which is higher maintenance costs. This was revealed to be particularly important in the social housing sector where social landlords need to maintain the dwellings' performance over longer periods of time. Hence more frequent maintenance and renovations are needed compared to the private housing sector. On a context specific level of analysis, participants in Leuven perceived current building and planning regulations as restrictive to small-scale living. Specifically, imposed minimum living area requirements make it difficult to obtain building permits for small zero-energy dwellings. This concern

is also manifested within the social housing sector where current design standards and requirements are perceived as outdated and too prescriptive with the aim to be universal and cover all household types. In Kilkenny, accessibility and fire requirements were perceived as a potential barrier since participants highlighted a lack of information and experience of professionals when it comes to compliance of these innovative designs. Within the social housing sector, the limited level of involvement of housing providers in the designs was highlighted as challenging. It is common for Approved Housing Bodies to adopt turnkey projects from private developers.

Table 1. Context specific implementation barriers.

	Belgium	Ireland
Financial	<ul style="list-style-type: none"> • Inaccessible land prices • Split incentive between social housing provider and tenant 	<ul style="list-style-type: none"> • Mortgage loan requirements • Loan to security scheme • Green financing benchmarks
Cultural	<ul style="list-style-type: none"> • Negative perception of small houses • Preference to traditional heating systems • Reluctance to move 	<ul style="list-style-type: none"> • Negative perception of timber-framed houses • Reluctance to change energy sources • “Not in my backyard” mindset
Legislative	<ul style="list-style-type: none"> • Allowable number of dwellings per plot 	<ul style="list-style-type: none"> • Individual certification scheme system
Technical	<ul style="list-style-type: none"> • Restrictive building regulations to small-scale living • Outdated social housing design requirements • Preservation of the universality of social housing designs 	<ul style="list-style-type: none"> • Restrictive accessibility and fire requirements • Limited level of involvement of housing providers in dwelling designs • Adoption of turnkey projects system

5. Discussion

The identification of overarching barriers validated by previous research findings led to the formulation of general recommendations also echoing past conclusions. Additionally, investigating context specific barriers allowed the formulation of more detailed recommendations and a more specific allocation of precedence within each potential recommendation. While recognizing the interrelations between identified barriers, corresponding recommendations are elaborated below following the categorization adopted throughout the paper.

5.1. Financial recommendations

On a general level, redirecting established schemes within financial institutions towards exceeding measures complying with basic building regulations could help in promoting green engineering. More specifically, within the Irish context, establishing a common benchmark for green financing ensures consistency between different financial institutions regarding providing funding. Within the Flemish context, recalling the split incentive barrier, increasing tenants’ rent could incentivise housing providers to invest in energy efficiency measures in their properties. To balance this rent increase a closed contract between tenant, housing association and external party could generate the investment from the savings on energy consumption. Another way is to negotiate lower rates with energy suppliers. Rent would include energy bills and the increase in rent is compensated by the decrease in the energy bill. Housing associations could also provide guarantees that living expenses would not increase for a certain period of time more than a common inflation rate [15].

5.2. Cultural recommendations

Since people’s perceptions were revealed as main barriers to the uptake of small, zero-energy dwellings, increasing the interaction between housing providers and tenants by providing and

obtaining constant feedback on energy efficiency and consumption could help improve them. This particularly applies to people's cost saving and spending perceptions. Constant support can also be ensured by assigning super-tenants; volunteers motivated to promote a change of attitude towards energy-efficient housing and facilitate the transition by demonstrating the actual various benefits of innovative dwellings when used properly. These super-tenants could also be easier to reach as neighbours and capable of solving potential minor issues [4,8,11]. To tackle people's habits as a barrier, workshops, trainings and demonstrations could be organized at an early stage to increase knowledge on new technologies, prevent their misuse, and limit maintenance costs. Moreover, organizing workshops on a neighbourhood level, informing and involving people could prevent third party objections highlighted in the Irish context. On a context specific level, another way to improve perceptions is to increase publicity campaigns that promote innovative, small and zero-energy dwellings. In the Flemish context, precedence would be allocated on promoting small dwelling sizes and in the Irish context it would be on promoting innovative building materials. This would help increase people's exposure to new dwellings types, designs, and materials and raise awareness on their various benefits.

5.3. Legislative recommendations

Informing housing providers on the latest innovations, their performance and outcomes could help in redirecting the business as usual mindset [12]. Moreover, increasing housing providers' level of involvement early in the design process could help ensure collaboration and good communication with designers, developers, and contractors for better overall outcomes. Within the Flemish context, redirecting land subdivision policy from parcel-based to area development with common public greenery rather than detached houses on large plots could help promote clustered construction. Also, considering long-term leasing of land instead of selling to developers could increase accessibility for housing providers thus encouraging the provision of affordable housing for specific target groups. In the Irish context, the traditional planning process could be revisited, specifically the system of individual certification. Within social housing, housing providers and local authorities could help promote innovation, energy efficiency and energy quality by including stricter tender requirements. Moreover, social housing design requirements could be revisited so that they promote innovative designs and specifically small-scale living for the Flemish context. Moreover, revisiting the tenant allocation rules by asking more details on household requirements during registration and redefining the selection criteria to attract people open to the active provision of feedback could prevent misallocation issues and an inefficient dwelling performance.

5.4. Technical recommendations

On a technical level, stricter building regulations and design requirements could help in promoting a zero-energy dwelling performance. To decrease the existing shortage of skills, education programs, trainings and workshops provided to contractors, builders and facility managers could help ensure the proper commissioning, installation, testing, certification, management, and maintenance of the new technologies, systems and dwelling designs. This could also contribute in limiting maintenance costs. Moreover, promoting innovative, zero-energy dwellings by documenting results and providing demonstrations would deliver the necessary information to housing providers and alleviate their uncertainties. This can be translated into having innovation champions in the industry and lead to an increased and improved marketability of the dwellings [4,6,10,12]. Within the social housing sector, ensuring the modularity and flexibility of dwelling designs could ensure the satisfaction of household requirements despite demographic differences. This can make up for the waiting list based random allocation of households and overcome the restrictions of universal housing design requirements.

6. Conclusion

This paper explores the barriers and drivers to a successful implementation and uptake of innovative, affordable, small and (near) zero-energy dwellings from the perspective of various housing actors in

two countries: Belgium and Ireland. On the one hand, the outcomes of this explorative study echo previous research findings despite the different time frames, objects of study, research scopes, and perspectives which implies validation. On the other hand, adopting a qualitative methodological approach through the conduction of focus groups allowed an in-depth investigation of context specific challenges revealing the peculiarities within each country. The identification of these contextual differences enables a better apprehension of the current situation in every location and allows a comparison and distinction of variations between them. This led to a better allocation of precedence when formulating context specific recommendations. In this way this paper demonstrates the importance of context specific investigations not only in the identification of barriers and challenges to energy efficiency innovations but also in the allocation of precedence leading to more effective recommendations. Although focus group-based findings are not straightforwardly generalizable, they can be used as strands for future research. Complementing the qualitative approach with a quantitative one could form an additional way of verification. Follow-up questionnaires asking respondents to rate identified barriers and drivers (pre-determined based on the focus group outcomes) could provide a numerical score describing the perceived significance of one barrier over the other [5,10]. When combined with follow-up interviews, new policies and technologies could be tested out. Inquiry into this is important for policy-makers and housing providers. Future research can adopt a mixed-method approach for a more exhaustive investigation leading to a more extensive context specific action plan which is much needed to accelerate the transition to zero-energy dwellings especially beyond 2020.

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