Innovation development for highly energy-efficient housing

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Abstract

Buildings account for 40% of EU final energy demand and policy developments like the Energy Performance of Buildings Directive are stimulating the innovation development for nearly zero-energy housing. However, businesses switching to innovative products for highly energy-efficient houses is a process that is poorly understood. To accelerate nearly zero-energy housing, all obstacles that currently restrict the distribution of innovation - experienced by end users, businesses and policy makers - must be defined and tackled simultaneously. These barriers and opportunities have been described in detail in a market study, three business innovation studies, three studies on end user experiences and three policy studies. These studies were recently assembled in a book.

The enterprise studies confirm that collaboration between companies is essential to innovation, even beyond the usual ad-hoc knowledge application and the individual collaboration during demonstration projects. One major obstacle is the transfer of the necessary technical knowledge and skills by the few pioneers to the other companies. Manufacturers, in particular, play a key role in the adoption of innovation and the transfer of new insights to small and medium-sized enterprises, which are a key target group for the market introduction of new concepts in the building sector.

Only a small group of occupants is interested in the energy savings and new forms of sustainable living. The study shows that end users can be motivated by low energy costs and improved living quality. They may be adequately satisfied with their homes, particularly with the high level of comfort.

The policy studies confirm that the government should play a more active part in getting energy-efficient housing off the ground, especially house renovations: the business community should be encouraged to develop more innovations which requires financial resources.

Manufacturers and suppliers switching to innovative products for ultra energy-efficient homes is not a standalone process of companies promoting technologies which consumers then use. Innovation is a diffuse process which must be approached from a policy perspective as well as the demand and supply perspectives.

Keywords: innovation, housing, low energy, passive house, policy
1. Introduction

The debates about climate change and security of energy supply, perceived opportunities for a ‘greener’ economy and policy developments like the Energy Performance of Buildings Directive (EPBD, 2010) have all revived interest in energy efficiency and related innovations. Significant potential has been recognised for reducing energy use through innovation, especially in such energy-intensive sectors as the construction sector, where a large part of the energy use goes to residential buildings. Achieving policy objectives related to climate change and energy will require significant carbon reduction in residential buildings, particularly with regard to energy demand for space heating. For this reason, this study investigated innovation opportunities and challenges related to the adoption of highly energy-efficient housing concepts, particularly passive houses, which largely reduce the demand for space heating.

Regarding the experience of limited diffusion of integrated design concepts in the previous decades, it is logical to consider whether we can expect enterprises, users and policymakers to move smoothly into this required transition. Some researchers (for example: van Hal, 2000; Femenias, 2004) have noted that, if we are not careful, we might remain in a demonstration phase with regard to sustainable housing without ever progressing into the mainstream market. On the one hand, the state of the art regarding available energy efficient technology solutions is already relatively advanced. On the other hand, the implementation of highly-energy efficient buildings is still at an early market development stage in most European countries, and it is proving difficult to diffuse integrated concept solutions beyond the demonstration phase (IEA, 2006; Rødsjø et al., 2010). Worldwide research by the International Energy Agency has revealed the strong influence of the passive house concept on the achievement of a market development of highly energy efficient housing (IEA, 2006; Rødsjø et al., 2010; Haavik et al., 2012).

In addition to differences between newly built construction and renovation, some countries (e.g. Austria, Germany, Switzerland) and regions (e.g. Brussels Capital Region, Vorarlberg Region) were found to be quicker than others (e.g. the Netherlands) are to adopt highly energy-efficient housing concepts (e.g. passive houses), as illustrated in Figure 1. Like the Netherlands, Belgium began relatively late with the adoption of the passive house concept, although it managed to develop its market more rapidly than was the case in the Netherlands. Given the author’s considerable experience with the introduction of passive houses into the market in Flanders, northern Belgium, it was possible to use these experiences to explore various questions related to adoption and diffusion.
This paper summarizes and discusses the main results of an extensive study (Mlecnik, 2013). The goal of this study was to develop a more general definition of barriers to and opportunities for the introduction and continued market development of highly energy-efficient housing concepts (in particular passive houses), in order to define recommendations for accelerating their adoption and diffusion. The empirical part of the study focused primarily on finding recommendations for the market for single-family housing in countries and regions in which the development of energy-efficient concepts is lagging behind. Innovation opportunities and barriers related to the promotion of highly energy-efficient housing concepts were investigated, in order to define pathways towards the elimination of barriers to their adoption and diffusion. This was accomplished through the empirical investigation of the viewpoints and experiences of enterprises (Part A), end-users (Part B) and government policymakers (Part C), in order to identify various factors that could lead to a rapid increase in the adoption and diffusion of innovative concepts (e.g. passive houses).

From the theoretical side, the available work focuses primarily on exemplifying, interpreting and developing the innovation adoption theory developed by Rogers (2003). As such, the study also provides a deeper understanding and conceptualisation of various issues that could lead to improvement of innovation theory, by using practical goals and real market, end-user and policy experiences as a laboratory. The traditional theoretical perspective of the enterprise or the customer as an adopter of innovation is expanded to include groups of enterprises and policymakers. Another theoretical challenge involves considering innovation theory beyond the level of individual technologies towards the concept level. The study challenged Rogers’ innovation diffusion theory to take more explicitly into account the experiences developed in other theoretical fields (e.g. construction innovation theory, enterprise network theory and environmental behaviour research).
2. Research approach

To structure the research in relation to the applied theories and key concerns regarding market development, the main research question was subdivided into three primary questions as follows:

*Which challenges and opportunities are related to the innovation adoption of highly energy-efficient housing concepts, particularly passive houses (main question), as observed from the supply side (Part A), the demand side (Part B) and the policy side (Part C)?*

Various issues related to technology innovation, business innovation and government policy were studied within the context of specific sub-questions, and pathways were suggested for the integration of highly energy-efficient housing concepts as innovations by analysing technological, societal and policy factors that can stimulate or hinder the diffusion of innovation.

Analysing demonstration projects involving single-family housing, the first part of the study identifies innovations that enterprises associate with passive houses and highly energy-efficient renovations. Innovation theory is then developed further within the context of the examination of a supplier’s innovation-adoption process, in order to explore systemic innovation opportunities. The path of collaboration between enterprises is then further explored for an emerging market (highly energy-efficient housing renovation). In addition, opportunities and barriers related to the transition from an innovator market to early adoption are examined, using the experiences of a passive house enterprise network.

The second part of the study addresses the viewpoint of the demand side. The first study in this part examines the innovation adoption experiences of end-users, based on post-occupancy evaluation research for various categories of newly built nearly zero-energy homes in the Netherlands. To ascertain the need for quality assurance and for improving passive house certification, the subsequent study then draws upon the experiences of end users with certified passive houses. To support the emerging market for highly energy-efficient renovation, the decision processes of owner-occupants regarding innovation adoption involving highly energy-efficient renovation are further examined.

The third part of the study aims specifically to derive lessons from European policies and policy initiatives that could stimulate the adoption of highly energy-efficient housing concepts. To this end, the first study in this part is based on the examination of the definitions of nearly zero-energy houses that are contained in the market and policies of European member states. A consequent study puts particular emphasis on the adoption of labels in governmental policy. In addition, opportunities for increasing innovation adoption through communication channels are explored, as exemplified by the activities of the previously discussed passive house enterprise network.
Several research methods are used to explore the issues mentioned above, depending upon the specific research issue being addressed. In addition to literature study, data are collected from existing Belgian and Dutch residential demonstration projects in order to identify innovations and end-user experiences in newly built passive houses, nearly zero-energy houses and highly energy-efficient renovations. Additional empirical data are obtained through questionnaires directed towards companies, end-users and policymakers, along with database and web searches, and interviews with demonstration project stakeholders (e.g. end users, architects and enterprises). Lessons are also derived from the author’s action-based experiences with innovation guidance for enterprises, the establishment of a passive house network and the development of a market for passive houses in Flanders, northern Belgium.

The general research approach is illustrated in Figure 2.

Figure 2: The three main components of the research approach, the main topics covered in each of the ten studies, the research input used in each chapter and the research output obtained from each part.
3. Challenges and opportunities for the adoption of highly energy-efficient housing concepts

This research has identified very important challenges to and opportunities for the innovation adoption of highly energy-efficient housing concepts, particularly passive houses, as observed from the supply side (Part A), the demand side (Part B) and the policy side (Part C), see Figure 3.

Figure 3: The research defined the ‘innovation’ and studied its adoption by enterprises (Part A, four studies/sub-questions), end users (Part B, three studies/sub-questions) and policy (part C, three studies/sub-questions)

The study developed many answers to the main question by studying the issue from various perspectives. When addressing the main research question from the perspective of the supply side, the main conclusion is that multi-player enterprise collaboration plays a key role in the adoption of ‘concept’ innovation (e.g. passive houses). From the perspective of the end user, it can be concluded that the problems and positive experiences of end users should be used to guide further innovation. From the policy perspective, it can be concluded that increasing the diffusion of highly energy-efficient housing (particularly passive houses) requires an active role on the part of government policymakers with regard to the adoption of the innovation.

3.1 Multi-player enterprise collaboration plays a key role in the adoption of ‘concept’ innovation

Examination of the experiences of enterprises with innovations in demonstration projects reveals that an integrated architectural ‘concept’ innovation diffusion approach - like experienced during the promotion of passive houses - can stimulate enterprises to adopt a multitude of innovative technologies (possibly in clusters), services and systems as well as architectural innovations. One advantage of the passive house concept is that it can be easily
translated into generally recognised principles, which enterprises can relate to specific requirements.

Findings from the study indicate that, for the construction sector, suppliers can be important players for innovation adoption. The empirical research includes an investigation of a reference innovation journey for the adoption of the passive house by a supplier, thereby shedding light on the potential for systemic innovation involving various stakeholders, who supply the necessary competencies, expertise and resources. Led by the passive house 'concept’ approach, and with the help of an innovation agent, the supplier was found to start a formal structured risk-sharing innovation journey towards modular innovation as a vehicle for incorporating architectural and system innovation. This is in sharp contrast to the usual ad hoc generation of knowledge and loose actor collaboration found in demonstration projects, which usually rather results in incremental innovation taking place during specific project phases.

Project-related fragmentation, characterised by separate small and medium-sized enterprises (SMEs), each performing a fraction of a supposedly integrated project, was found to pose an important barrier to the development of passive houses, particularly for the renovation market. To counteract this barrier, it is essential to develop and cultivate a network around the proposed and actual ‘concept’ innovations. Given the specificity of the construction sector and the ‘concept’ innovations for achieving a high level of energy performance, it would be worthwhile to cultivate and develop specific innovation agents as intermediaries between suppliers and other players in the construction chain.

One particular challenge involves increasing the flow of necessary technical information, knowledge and project management skills from the frontrunners to the many less experienced implementing actors, most of which are SMEs, which form an important target group for the market introduction of ‘concept’ innovation in the construction sector. For example, in the case of the development of the Flemish market for single-family passive houses, small enterprises played the most important role in sparking radical innovation at the regional level, while large companies were slower to adopt innovation through incremental innovation, particularly given the financial and networking incentives that were in place and that targeted a larger market. The results identify the need to characterise, cultivate and develop enterprise collaboration in various subsequent innovation phases and transitions between phases. Business-to-business collaboration was found crucial to the development of ‘concept’ innovation in both the market-introduction phase and the early-adoption phase. Such collaboration can be facilitated by multi-player enterprise networks, in which various types of actors (e.g. architects, installers, contractors and consultants, as well as clients and knowledge institutes) can network and collaborate.

In sharp contrast to the market for newly built passive houses, the renovation market still has far to go with regard to the development of improved collaboration structures. A pool of experienced actors for implementation of highly energy-efficient housing renovation has yet to be defined, and adapted quality-assurance instruments and support schemes are needed as well. A major opportunity lies in finding market-proof structures for collaboration and
communication, in order to reduce the burden on homeowners, particularly with regard to alleviating financial burdens and burdens related to project management.

3.2 The needs and experiences of end users should be used to guide further innovation

On the one hand, enterprises need to innovative. On the other hand, they are more likely to find a market by responding to customer needs and expectations with their technologies, systems, services and architecture. Findings from the post-occupancy evaluation studies in this research show that potential residents have various reasons for choosing nearly zero-energy dwellings, with the energy costs associated with a dwelling being an important argument. The passive house requirements allowed clients to negotiate a well-defined target with executing parties. Nevertheless, a survey of end-user experiences in the Netherlands revealed that the choice for low-energy, passive houses or zero-energy houses was not very obvious from the perspective of the client. On the other hand, end users living in highly energy-efficient houses were quite satisfied with their dwellings, indicating a high level of comfort. These findings could be used as additional arguments in the promotion of such dwellings. One potential area for improvement involves the promotion of innovative renovation concepts towards owner-occupants. Factors that motivate owner-occupants to adopt highly energy-efficient renovation concepts include – in addition to structural improvement and increased surface area - the promise of improved comfort, a more general concern for the environment and improved health conditions.

The results of this research indicate that the demand side suffers largely from a lack of knowledge regarding available innovative concepts. With regard to the lack of knowledge, social strategies can be recommended (e.g. establishing peer-to-peer knowledge-exchange networks for owner-occupants, nurturing those networks with experiences from experienced owner-occupants, architects and contractors). In order to improve diffusion, the relative advantages and visibility of the actors involved should be addressed. The attractiveness of highly energy-efficient concepts, particularly for renovations, could still be increased by providing reference networks, suitable tools and significant economic incentives for both customers and executing parties.

One barrier to the adoption of nearly zero-energy houses involves the perception that such houses offer insufficient air quality and/or comfort in the summer, independent of energy category. Design deficiency (e.g. lack of shading or ventilation bypass) or technical deficiencies in the heating and ventilation systems could be linked to negative experiences. In addition, the simplicity and the user-friendliness of control systems were identified as being of the utmost importance. These experiences suggest opportunities for architectural and technological innovation.

Process innovation is also needed, primarily with regard to quality assurance during design and execution, combined with requiring the high level of energy performance of nearly zero-energy
houses. A post-occupancy evaluation study of certified passive houses in Flanders shows that current obligatory requirements for passive house certification (like those used in Flanders) do not always lead to positive appreciation of indoor temperatures, indoor air-humidity levels and/or noise levels. There is room for improving the requirements regarding cooling demand, the design and the installation of indoor climate systems, as well as for those regarding user-friendliness and information on building services (particularly mechanical ventilation systems). These recommendations can be discussed in the development of widely supported plans that aim to improve the general quality of building services in housing, indicating adaptations to regulations and building codes. Careful design and execution, including noise protection, sufficient air humidity control and odour removal strategies, are critical points for attention in relation to possible improvements in all housing categories.

In order to avoid negative end-user experiences, it is strongly recommended that inhabitants be provided with information in addition to that provided in the standard short introduction to the house. At the very least, this information should include operation manuals, although it should ideally include detailed instructions concerning the advanced systems they will encounter in the dwelling as well. Particularly for end users who are not involved in the building process (e.g. end users in rental housing), it is advisable to provide user-oriented technical information and/or training by qualified and/or experienced sources.

3.3 Increasing the diffusion of highly energy-efficient housing requires an active role on the part of policymakers

For the future implementation of national energy policies in Belgium and the Netherlands, the findings indicate that ‘passive house’ is an important and useful term, which offers market visibility and some level of policy acceptance. One important challenge with regard to avoiding market confusion is to ensure that definitions are clearly formulated and used consistently at all political levels (i.e. national and regional) and that they are compatible with the recast European Energy Performance of Buildings Directive (EPBD). Within this framework, government policymakers who are responsible for the development of energy policy should define and reward better energy performance for highly energy-efficient housing concepts (e.g. by using fiscal tools and an associated control system).

European states could benefit from integrating available labels in their implementation of the Energy Performance of Buildings Directive. Labels for passive houses have already been introduced as an option in many European countries, in order to introduce more user influence and to encourage market differentiation amongst enterprises. The diffusion of labels has benefited from the support of governments, banks, companies or combinations of these entities. Combining existing advanced labels (e.g. passive house) with the energy certificate scheme of the EPBD is recommended, although the way in which this should be done can be highly country-specific. National, regional and municipal authorities could further facilitate the adoption of labels through such actions as increasing their visibility in knowledge-transfer activities and by recognising the expertise of label providers. In addition, educational
programmes for specific target groups are needed in order to support the acceptance of related quality-assurance procedures.

In general, it is essential to nurture a high level of corporate involvement and collaboration, as well as quality assurance with regard to nearly zero-energy concepts. To achieve this goal, a broad range of potentially interlinked communication activities is needed, with high intensity of communication. This communication should be neutral, positive and peer-to-peer, addressing various customer and business segments. The availability and attractiveness of conceptual approaches to highly energy-efficient housing should be increased, particularly during the market-introduction phase. Neutral actors (e.g. passive house networks) can contribute to develop communication strategies and market infrastructure.

Very important is that customers and businesses are guided with appropriate information at each step of their innovation decision-making processes. Customer confidence should be enhanced, and perceived compromises should be eased by cultivating motivation, increasing availability, highlighting attractiveness and guaranteeing quality. To induce environmentally conscious behaviour, communication policies should focus more on exemplification (i.e. the effective use of experiences from demonstration projects), as well as on engaging, enabling and encouraging clients and businesses. In addition to targeting the development of customer demand, communication should be specifically directed towards the uptake of innovation by businesses. A set of coherent communication activities could be defined in order to realise the diffusion of innovation by focusing on behavioural change and by creating synergies to produce identifiable innovation outcomes. Specific competencies and resources are needed in order to guide companies in their innovation journeys.

4. Recommendations for further market development

To accelerate the transformation of the energy and housing market significantly, we should address all barriers to innovation diffusion and early market development simultaneously. Collaboration amongst all adopter categories in the elimination of barriers could be expected to result in successful market development for highly energy-efficient housing and renovation.

Various categories of important adopters were defined in Figure 3: enterprises (particularly groups of SMEs and suppliers), end users (noting the importance of owners and occupants) and policymakers (particularly for the development of energy policy and innovation policy). Throughout the various studies, three reoccurring important barriers for market development of highly energy-efficient housing emerged. These three barriers can be roughly summarised as ‘lack of motivation’, ‘lack of knowledge’ and ‘lack of competencies’.

The various studies illustrate that innovation adoption by enterprises for highly energy-efficient housing is not a stand-alone process in which enterprises promote and end-users adopt single technologies. Instead, this research reveals strong support for a ‘concept’ approach to innovation diffusion, in addition to drawing various connections between recommendations
from the supply side, the demand side and for policy development. In general, the continued use of collaborative strategies can be highly recommended. As indicated by the findings of this study, peer-to-peer knowledge exchange networks for owner-occupiers, architects and contractors or multi-player enterprise networks can be trustworthy players who can provide neutral information, networking opportunities and a system of appraisal. Networks and policymakers should now work together to develop an integrated master plan, focusing on the further development of quality-assurance systems and enterprise collaboration towards systemic innovation. Both networks and policymakers should seriously reflect on their communication strategies and respond adequately to enterprise demand for various innovation phases, as well as to end-user demand emerging from various market segments.

The cross-reflection generated two main recommendations for increasing the adoption and diffusion of highly energy-efficient housing concepts. These recommendations are directly based on various recommendations emerging from the studies.

1. Developers of innovation and energy policy should support specific change agents.

Energy policy and innovation policy should be integrated for the construction sector. Funded innovation agents should guide committed SMEs and suppliers. Funded change agents should guide potential adopters in each step of their innovation-decision processes. In some cases, these change agents could also combine their communication activities with positions as enterprise-innovation agents. At the same time, enterprise collaboration and multi-player networking should be stimulated.

2. Quality-assurance schemes for highly energy-efficient housing should be introduced or revised.

The quality of demonstration projects should be assured since benefits that are not related to energy should be used to persuade potential adopters. Notably, indoor comfort and the adequate performance of building services should be guaranteed and end users should be provided with detailed information. A system of appraisal for nearly zero-energy housing can be defined, for example using available passive house labels or related experiences. At the same time, an educational programme should be developed, particularly for highly energy-efficient housing renovation.

These recommendations should be implemented in order to eliminate barriers to innovation and to stimulate opportunities for innovation. In turn, this could accelerate the adoption of highly energy-efficient housing and the achievement of energy-policy objectives.
References


