Innovations in Very Low Energy Retrofit Projects

Experience of Belgian exemplary projects

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ABSTRACT: More significant reductions in residential primary energy consumption and in space heating in particular, can contribute to achieving climate change and energy efficiency objectives. Project information from demonstration projects is now becoming available for highly energy-efficient renovation. By analysing selected Belgian demonstration projects with different building typologies, we tried to understand what innovations occur and how owner-occupants experience far-reaching energy saving innovations in renovations of single-family houses. Technological and social adoption drivers and barriers perceived by owner-occupants and architects were analysed by means of interviews and on-site visits. The research concludes that many technological innovations are available in order to establish an energy performance standard for renovation, but socio-technical and quality barriers remain. An opportunity is detected for the market entry of integrated concepts and social innovation. A research effort is still needed to cluster different innovations and to address socio-technical barriers.

Keywords: Renovation, Energy Performance, Innovation Adoption, Quality, Demonstration Projects.

1. INTRODUCTION

For newly built houses European and national ambitions prescribe increasing levels of energy performances, even including achieving the passive house standard, nearly net zero energy or carbon neutral houses. A large number of research papers report on the success of implementing very energy efficient newly built houses, for example passive houses ([1], [2], [3], [4], [5], [6]). However, a decrease of greenhouse gas emissions will not occur if no energy is saved through retrofit of the present housing stock. Within the European Union the total building stock is responsible for about 40% of the total primary energy consumption. Housing accounts for the greatest part of the energy use in this sector. Space heating is responsible for 57% of the total energy use of households in the European Union, followed by sanitary hot water production (25%) and household equipment and lighting (11%) [7]. Thus, renovating existing housing offers an important energy saving potential.

Nowadays, exemplary projects demonstrate that renovations can achieve substantial (up to five times and more) energy savings while improving quality, comfort and space experience [8]. However, for very energy-efficient renovation projects, particularly in Belgium, project information of first demonstration projects has only recently become available. This paper compiles the information and experiences from innovations encountered in these projects.

Drawing on project information and experiences, in combination with recent research developments, strategies can be defined for the further innovation diffusion of low energy housing retrofit in Belgium.

2. RESEARCH APPROACH

2.1. Context

The context of this research project was that low energy housing retrofit can be the pretext to a goal of sustainable architecture, in symbiosis with the environment, and to a global and general improvement of the housing stock, including its surroundings, interactions with the neighbourhood, its functions and organizations. For reaching these goals, it appears that low energy housing retrofit has to be placed in the larger context of neighbourhoods, towns and municipalities, stimulation of technological innovation and socio-economic development [9].

A previous project identified highly successful renovations through a network of national and international experts [9]. Relevant information considering low energy housing retrofit now needs to be developed and diffused in the form of published documents, files on the Internet and national workshops, and destined for different target groups. Especially innovations in highly successful renovation projects in Belgium need to be identified in order to study their impact on design, construction and performance of Belgian renovations.

2.2. Approach of the research question

The identification research started with an analysis of the Belgian building stock identifying characteristics of typical building typologies and ownership structure (owner-occupancy, private rent, social rent). Based on a statistical analysis of the Belgian building stock, owner-occupant single-family houses were chosen as a focus for research. One might discuss negative interactions between single-family houses and sustainability, but the aim of the research was to start from the existing buildings, using a building approach.

Following the statistical analysis, relevant Belgian exemplary renovation projects for the different predetermined building typologies were searched for. This search was guided by performance criteria: do the projects achieve substantial primary energy savings? Do they respond to other predetermined sustainability criteria? Further, the selected projects were analyzed in technical detail and owner-occupants were interviewed considering the owner's experiences with innovations. The selected renovation projects were analyzed considering energy performance, to provide feedback on the validity of including certain innovations in the study. This analysis can be found in [9].

To select innovations in the detected renovations a focus was set on building skin (roofs, floors, walls, windows) and technical systems (space heating, water heating, electricity), and keeping in mind the used energy strategies (conservation, renewable energy use and efficient back up) and the obtained comfort (winter and summer thermal comfort, air quality and day lighting). On a project basis (project descriptions) these innovations were linked with aspects of decision-making (solutions that tie energy saving measures into other motivation parameters) and sustainability criteria, as defined in the International Energy Agency Solar Heating Cooling Task 37 Subtask D [8]. For more information about the statistical analysis and more detailed information per project (project files including a discussion on observed energy consumption, owner motivation and sustainability aspects) the reader can consult the web site www.lehr.be [9] or a previous paper on motivation in renovation [11].

2.3. Research method

On-site observations during and after renovation of selected demonstration projects were used as a means to collect information. To collect the necessary information on client motivation, building construction, energy use and user appreciation, specific interview sheets were developed and used.

The empirical data were gathered by means of interviews with owners, occupants and architects, both during renovation and after renovation, using a questionnaire focusing on perceived attributes of innovations, with both open and closed questions. In some cases, hard data were also gathered from measurements. The questionnaire addressed amongst other:

- Characteristics of the decision-maker: social and economical background variables of the interviewees (4 items).
- Felt needs and problems: general satisfaction (12 items), quality of housing (12 items), construction (11 items), installations (10 items).
- Possible barriers to adoption of innovation: Perception of heating/ temperature (35 items), air humidity (18 items), ventilation/air quality (71 items), health issues (11 items).

The group of interviewees always included the owner-occupant (who was also often the client) and often the architect, and in collective cases representatives of the occupants, social housing companies and controlling parties.

2.4. Limitations of the research

The paper presented here is limited in its scope and addresses only the emergence of technological and social innovations. The research further addresses the specific cases of the LEHR research project [9]. In these case studies, the cost of those renovations and how house owners raised the needed investment was not analysed in detail, thus excluding possible financial innovations. Also, the energy performance of demonstration projects was not compared between buildings, because of limited compatibility of calculation data, which were provided in different formats (energy performance calculations, energy performance certificates, PHPP calculations, energy simulations).

To complement the research findings, this paper uses literature review, and also practical findings from study trips in Germany and Austria, and work meetings and discussions (internet meetings) during the work of the IEA SHC Task 37 [8] and the LEHR project [9].

Building traditions tend to vary by region, and there can be social, cultural and institutional differences when comparing results with other countries, so this is an important limitation of the present study. The results are likely relevant for countries with a climate and building traditions similar to Western Europe and with emerging innovation development considering energy efficiency. The research is focused on the Belgian context, where the 'passive house' definition provides an opportunity for broadening existing market developments from new construction to incorporate renovation.

3. RESULTS

3.1. General results from demonstration projects

The chosen demonstration projects were deep retrofits of a building towards a residential building with improved comfort, taking into account substantial thermal insulation, avoidance of thermal bridges, and provision of air tightness of the building and mechanical ventilation with heat recovery. Passive house and/or sustainability principles were successfully introduced in the demonstration projects. Some architects placed a larger emphasis on sustainability sometimes resulting in lower energy performance. A success of the demonstration projects regarding energy performance was attributed to a combination of conservation measures to reduce energy demand; using renewable energy to cover much of this reduced demand; and supplying the remaining heat by highly efficient, compact conventional systems.

Depending on the building type, calculated and/or observed energy savings after renovation varied between 80 to 95%. In demonstration projects in the Brussels Capital Region - where a specific target value is set for subsidized projects - the specific heating demand is typically reduced from values between 150 and 280 kWh/m²a to < 30 kWh/m²a. In some cases in the Flemish, Walloon and Brussels Capital Region, a limiting value for space heating demand of 15 kWh/m²a was reached for the renovation of single-family row houses or semi-detached houses. It was observed that many projects used so called 'passive house technologies' in renovation to obtain substantial energy reduction ([9], [11]), although reaching a passive house standard was not often the direct goal. The results confirm findings from other countries that reaching the passive house target can be technically feasible and socially accepted, but whether the goal is reached will depend on the building typology, capacity and resources [8], [10].

While certain interviewees were optimistic about reaching a passive house standard in renovation, several interviewees-architects stated having difficulties with limiting the space heating demand to 15 kWh/m²a as design value. Especially protected facades and highly valued ornaments, as well as existing thermal bridges, appear to form aesthetical barriers with no suitable technological solution offered by executors. On the other hand, different interviewees working on large-scale renovations, expect that from the technological point of view, certain building typologies from the sixties and seventies can be relatively easy transformed to reach this target value.

The success of a renovation towards the passive house standard was also linked to ownership structure and inhabitants (the decision process and social characteristics of the actors), and the involvement of experienced companies in the building process, that already offer passive house related solutions.

To study technological innovations in the demonstration projects, a focus was set on the following retrofit principles [10], since these were commonly encountered in the demonstration projects:

• Minimized transmission losses: The building envelope has a very high standard of insulation – typical thickness for wall and roof insulation is around 20 to 40 cm. Typical windows will be triple-glazed or equivalent. Specific building details will reduce thermal bridges to practically zero.

• Minimized ventilation losses: Heat recovery in the ventilation system will reduce losses by about 80% while increasing both thermal comfort and air quality. A precondition for heat recovery is a high level of air tightness of the building envelope, minimizing losses from warm air leaking through cracks and crevices.

• Passive and active solar energy: internal heat gains (from people, lights, electrical equipment etc.) and solar radiation are typically taken into account in to the heating demand. In addition to passive solar gains, active systems like thermal collectors or PV-systems can be used.

• Efficient energy supply: Low energy retrofits have a very low heating demand but still need a heating system for the coldest winter days and a system providing domestic hot water. This remaining energy demand is typically supplied by very efficient systems like special heat pumps, high efficiency gas boilers or wood pellet burners.

• Overheating control: As a very high thermal comfort is one of the main marketing arguments in the development of low energy housing retrofits, overheating control is an important issue. Mainly passive measures like overhangs, shading devices, (e.g. awnings) are used. Measurements in pilot projects have shown that with these measures, passive houses actually suffer less from overheating than regular houses because the thermal insulation keeps the summer heat out.

3.2. Existing technological innovations

Many updates on traditional technologies (incremental innovations) have been detected in the demonstration projects. However, depending on the choice for ambitious energy performance targets, and regarding the motivation of owners to increase living space, radical innovations have also found their way in demonstration projects.

• Construction innovations

Novel insulation materials are being used in Belgian practice of low energy housing retrofit, like improved carbon filled polystyrene, polyisocyanurate, wood fibre insulation and cellulose insulation. Outside façade insulation systems - a well-known building method in other countries, but not very widespread in Belgium - have been used in several of the examined demonstration projects, especially for the insulation of the usually single brick back side façade. In some case inside thermal insulation was applied – also behind protected façades - but this required careful planning and investigation of possible risks. Innovations concerning inside insulation, encountered in Belgian demonstration projects, include the use of cladding systems with cellulose filling and vapor barrier with moisture control. In the research field hemp cement is being developed for thermal inside insulation. Floor insulation was often perceived as cumbersome: especially when the users already inhabit the house, they are not too keen to do the effort to break up a floor.

Demonstration projects show glazing with two or three glass plates with gas filling, air or mostly argon, and rarely krypton or xenon. Recently, also quadruple glazing has been introduced in Belgium for the market of inclined roof windows. Although inhabitants initially resist to change glazing because of pretended cumbersome intrusion, from the demonstration projects it was noticed that in practice replacement of full window frames can happen quite smoothly within the time frame of a few hours with only minor intrusion on the interior finishing. However, intrusion in the habitat area is usually experienced when workers have to be able to reach the back façades, usually through the building. A real challenge therefore lies in providing fast solutions for inhabited buildings, based on minor indoor intervention only. In this field, innovations were observed for prefabrication for large insulation thickness (see also IEA ECBCS Annex 50).

Energy efficiency of window frames is currently only a minor point of interest for architects. Observed benefits usually focus on better daylight entrance when old wide wooden frames are replaced with slim versions, and noise reduction because of the improved air tightness. In one project the architect proposed triple glazed window frames with integrated solar shading and two different tilt positions for winter and for summer ventilation (see Figure 1 left).

Thermal improvement of stained glass-in-lead windows was not yet available on the Belgian market, although it was observed in the Netherlands (see Figure 1 right). The single pane is carefully removed and integrated in a new frame in the factory. Usually this implies that clients can now open their windows, an improvement in air quality compared to the situation before renovation.

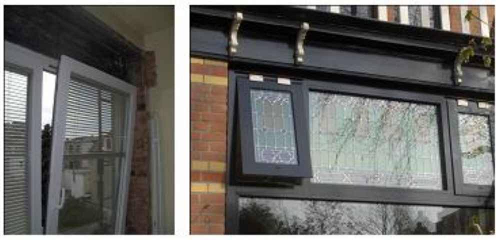

Figure 1: Left: Triple glazing with integrated solar shading and winter/ summer ventilation mode. (Renovation project Victor Driessensstraat, Antwerpen); Right: Renovation of glass-in-lead windows in a protected housing area in Rijswijk, the Netherlands: the glass-in-lead is carefully removed by the specialized manufacturer and integrated in a new frame.

• HVAC innovations

According to the popular definition, passive houses have to reach a target energy demand for space heating less than 15 kWh per square meter and per year. This definition makes sure that the heating demand can be provided by a small post-heater in the hygienic ventilation system, where as the ventilation system can be dimensioned purely for ventilation purposes. In theory thus the installed heating power should be less than 10 Watts per square meter. In practice it was noticed that a target demand of 30 kWh per square meter net surface and per year was already an important challenge for architects and building teams to reach in retrofit projects, thus leading to alternative indoor climate systems, often using passive house related components.

Gain of space was an important issue in most renovation projects. Electric post-heating systems are sometimes chosen because they require no boiler and no chimney. In the demonstration projects, clients preferred new types of post-heating, adapted to the low power requirement.

The retrofits towards passive house standard provided relatively simple space heating systems. Compared to traditional central heating systems, indoor climate systems often integrate space heating, hot water production, ventilation and heat recovery, and connection to renewable energy systems. Such integrated units are commercialized by suppliers as being much more compact and requiring less space and maintenance. If the client wanted solar renewable energy or biomass fired system, the architect sometimes consulted to attach a water-based storage boiler or ventilation post-heating system.

In low energy housing retrofit projects with no ambition to reach the passive house standard, usually more backup heating was provided then necessary, or some of the original heating elements were recovered. In some cases of central heating, conversion to low temperature and deletion of a few radiators provided an option. Radiators were sometimes removed where triple glazing and passive house level insulation was installed: the clients reasoned that surface temperatures would be high enough on those walls and windows.

A majority of low energy housing retrofit projects used mechanical ventilation with heat recovery, in some cases also coupled with ground-air heat exchanger to provide for some preheating in winter, but mainly to provide cooling in summer. Observed renovation projects with only mechanical extraction before renovation usually revised the extractors to reduce noise or to increase or reduce ventilation capacity. In some cases, clients were very creative with integrating mechanical ventilation in existing shaft or chimneys. Room based decentral ventilation with heat recovery was not used in the Belgian demonstration projects. Experiences in other countries show that such systems can offer the advantage that large ductworks can be avoided and nuisance to inhabitants can be reduced. Solutions exist that can be placed only by drilling a hole in the wall, or by integration during window replacement. Also solutions to integrate ventilation ductwork in the outside façade insulation were not yet observed as a means to have an integrated approach for low energy housing retrofit.

• Emerging clustered technology solutions

Low energy housing retrofit goes far beyond the current practice of renovation of the dwelling stock. Whereas most renovation projects are dealing with extension, modernizing and reorganization of the dwelling according to the changing needs, low energy housing retrofit provides an opportunity to introduce advanced and ambitious energy renovation concepts. From the demonstration projects it was experienced that clustered technology solutions can appear, for example:

• Thermal insulation of roofs + air tightness;
• Mechanical ventilation + heat recovery;
• Heat production + renewable energy;
• New glazing + new frames + airtight connection of frames;
• Thermal insulation of walls + window replacement;
• Prefabricated façade renewal;

and so on.

3.3. Remaining social barriers

The difficult adoption of innovations by architects and contractors involved in renovation was detected as an important social barrier. Three projects had owner-occupants who were motivated to achieve the best energy-efficiency solution, but had difficulties in finding suitable architects or contractors. In one case the owner even commissioned a specialized consulting agent instead of an architect to find the best available technologies.

Highly energy-efficient renovation is sometimes not perceived as interesting by the architect: tricky connections details require extra design work, and relative advantage to work in renovation is low compared to offers in new built construction.

Adoption problems by professionals occurred in passive house renovations, but also more 'easy' low energy renovations were sometimes experienced as cumbersome. Many owner-occupants stated that they had to check that the contractors were doing their job properly. Some interviewees experienced diminished comfort for a long time, because many rooms in the house were uninhabitable for months. Also, many contractors did not stick to the agreed time schedules. Some contractors were not familiar with measures proposed by the architect, such as extending a roof to connect to future wall insulation, and they had to learn by doing, a process of trial-and-error.

Several architects emphasized their concern considering the lack of an ambitious energy performance standard for renovation; others commented that reaching a predetermined energy performance after renovation can be difficult. Steered by client motivation architects often appeared to be social innovators in the demonstration projects, involving clients, new suppliers and motivated contractors in the design process to examine suitable solutions.

The LEHR study included inspection of technical details, measurements of indoor comfort after occupation and interviews with occupants of several projects in Belgium.

Concerning the performance of the indoor climate systems, owner-occupants were mainly concerned with winter and summer comfort, air humidity, temperature differentiation, acoustics and psychological and social preferences. Some interviewees recommended improving the user friendliness of indoor climate systems. Also, a good realization of (passive) cooling was considered a very important issue in low energy housing retrofit, in most cases solar shading was or became an essential feature.

In most low energy housing retrofit cases the interviewed occupants/clients were not aware of the existence of detailed dimensioning documents of the indoor climate system. In passive house retrofits the occupants/clients could provide a reference with a calculation with the passive house planning package PHPP. In some cases set points for air flows of the ventilation system were not installed. This led the owner-occupants to questioning the quality of the work of the indoor climate system installer.

4. DISCUSSION

Demonstration projects show how owners and occupants can take profit of innovations and advanced renovation concepts, resulting in a large reduction of the energy consumption while improving comfort levels in their houses. Specialized companies, contractors and engineers, developers and suppliers of construction materials and components for energy efficiency in existing buildings are now opening a very promising market. Care should be taken that a focus on sustainability parameters does not diminish careful examination of expected energy performance, and vice versa. Many innovations have been detected in demonstration projects and owner-occupants commented on benefits and problems. These issues should be regarded as opportunities for the development of adapted innovations. Also, other sustainability parameters and user's concerns can be integrated in new innovation development.

For low energy housing retrofit, like for most substantial retrofits, protection and renewal of construction is an important technological driving force. Thermal insulation and the implementation of ventilation measures can protect the construction from internal condensation and thus increase its life span. Minimization of thermal bridges and improved air tightness also reduces structural damages. Mechanical ventilation with heat recovery can contribute to a better air quality and reduction of moisture problems, while reducing ventilation losses. In fact, to cover all aspects, integrated solutions, such as the passive house concept, can be highly recommended.

A bottleneck for further application of nowadays used innovations can be the lack of education of professionals or access to information. Innovators who contributed to demonstration projects can help to spread information, skills and competences. The existing demonstration projects can serve as a starting point of information to reach innovating businesses, opinion leaders and other motivated clients.

In order to reach ambitious energy saving targets, a proper and sometimes innovative answer needs to be found for design issues - such as the bioclimatic design concept, the solar supply and protection, the thermal insulation, air tightness and ventilation, the systems, techniques, and renewable energies – but also for process issues like the detected problems of the building process, quality and control. The expected strong growth of the low energy renovation market probably requires the introduction of some form of quality guarantee, as in other consumption goods. In this framework, the role of the architect can consist of social innovation – for example steering building teams - and integration of technological innovation in an integrated approach. Further, if the low energy housing retrofit market is to increase, architects should be able to reduce the effort of coordinating craftsmen.

An important bottleneck is that in the current Belgian situation, the owner-client is often expected to start a renovation project, although he/she often has no experience. Architects can provide information, but they are often still not consulted for renovations. Instead the owner-client often receives information and impulses directly from contractors, media or DIY shops, which are often not well informed about available innovations. Most clients apply for additional technical and financial information from websites or on building fairs. However, they are often left with a lot of questions concerning the execution of their own project. Therefore it is important to facilitate contact with independent and trusted information sources, such as architects and consultants.

5. CONCLUSION

In our search for retrofit demonstration projects, we have examined different building typologies and detected a possible Belgian standard of an energy need for space heating around 30 kWh/m²a. Although this is twice the value for newly built passive houses, reaching this goal can be quite a challenge in practice for architects and clients. Demonstration projects show that such a high ambition level for the actors involved can be expected to result in better energy performance achieved. In contrast, when no specific energy savings target is defined for the renovation, guaranteed energy saving should not be expected as a result.

Although demonstration projects show several acceptable technological innovations – including combined technologies and even passive house concepts - increased quality and energy performance guarantee of the final renovation is both an opportunity to increase the market, as well as an item for further research.

Innovation in low energy housing retrofit is socio-technical in nature and the social component is currently often neglected. More rapid high-quality renovations with less technical compromises and with some energy performance guarantee are asked for by clients.

Interviewees perceived the following issues as particularly problematic, requiring process solutions where the architect might play a role:

• Many traditional craftsmen are unfamiliar with the innovations and not used to work together on whole building solutions;

• Many craftsmen are involved, often resulting in problematic coordination on site which can result in lower quality;

• Disturbance and required effort of the occupants and owners should be reduced.

To overcome these socio-technical barriers, a new project was started [12], based on the idea that compiling reliable information and combining innovative technologies on the supply side might provide a first step towards an integrated solution. In a second step, innovative whole building concepts should be considered leading to well-coordinated renovation modules with fewer companies involved. Finally, a ‘one-stop-shop’ solution could reduce burden for the client. Regarding quality and energy performance guarantee the architect could take up a role as coordinator from the demand side.

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7. REFERENCES

[1] E. Mlecnik, H. Visscher, A. van Hal (2010) Barriers and opportunities for labels for highly energy-efficient houses, *Energy Policy*, 38 (8), 4592-4603.

[2] IEA SHC Task 28. *Business Opportunities in Sustainable Housing – A Marketing Guide Based on Experiences from 10 Countries*, IEA SHC Task 28, ECBCS Annex 38: Sustainable Solar Housing, http://www.iea-shc.org/task28.

[3] M. Elswijk, H. Kaan (2008) *European Embedding of Passive Houses*, Final report IEE-SAVE project Promotion of European Passive Houses (PEP); ECN, the Netherlands.

[4] J. Schnieders (2003) CEPHEUS – measurement results from more than 100 dwelling units in passive houses, *ECEEE 2003 Summer study* – time to turn down energy demand, 341-351.

[5] J. Schnieders, A. Hermelink (2006) CEPHEUS results: measurements and occupants' satisfaction provide evidence for Passive Houses being an option for sustainable building, *Energy Policy* 34, 151-171.

[6] Passive House: Towards the volume market, proceedings of the conference Passive House ’10, Brussels, 3 september 2010, PHP, Berchem, Belgium, ISBN: 9789081118255.

[7] L. Itard, F. Meijer, E. Vrins, H. Hoiting (2008) *Building renovation and modernisation in Europe: state of the art review*, OTB, Delft University of Technology, The Netherlands, www.erabuild.net.

[8] IEA SHC Task 37 *Advanced Housing Renovation with Solar and Conservation*, http://www.iea-shc.org/task37.

[9] E. Mlecnik et al. (2010) Low Energy Housing Retrofit – final report, Belgian Science Policy, http://www.lehr.be.

[10] E-retrofit-kit (2008) *Toolkit for Passive House Retrofit*, http://www.e-retrofitkit.eu.

[11] E. Mlecnik (2010) Adoption of highly energy-efficient renovation concepts, *Open House International*, 35 (2), 39-48.

[12] ERACOBUILD project “One Stop Shop”, project partners: PHP, WTCB, VTT, Segel, DTU, http://www.one-stop-shop.org.