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Designing for the Future? Integrating Energy Efficiency and Universal Design in Belgian Passive Houses

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Designing for the Future? Integrating Energy Efficiency and Universal Design in Belgian Passive Houses

Energy efficiency and universal design in housing are high on policy and research agendas. Although in both domains there are policies and programs which aim to convince homeowners to adopt energy efficiency measures or universal design, they have had limited results and rarely take into account the impact on the other domain. Better integration could lead to more sustainable and appealing housing concepts to emerge, resulting in more effective policy. Currently there is scarce research that investigates the integration in private housing of energy efficiency and lifelong living, a physical outcome of universal design principles in housing. This research asks what energy efficiency and lifelong living measures are currently integrated by homeowners and what were the motivations behind the adoption? Nine owner-occupied, privately commissioned, single-family homes in Flanders, which are built to Passive house standards and have also implemented lifelong living measures were examined. Mixed methods were used for analysis including semi-structured interviews with homeowners, architectural drawings and video recording or photographs of a home walk-through. Inhabitants focused on the practical long term effect of their choices on their own families in parallel or above societal impacts of sustainability. It was easier for them to find information on energy efficiency than on universal design. The participants viewed the two fields as either unrelated or as parts of the same goal and so they saw no significant conflicts in their integration. Meanwhile indifference or path dependency from architects and contractors present resistance rather than facilitation towards residents' goals, particularly on universal design.

Keywords: energy efficiency; universal design; housing, adoption, case study

1. Introduction

Energy efficiency (EE) and universal design (UD) are two important fields addressing parts of the environmental and social pillars of sustainability. In housing research energy efficiency studies aim to find ways of reducing energy consumption at home, mostly taking an engineering and technological approach with recent shifts towards socio-technical and behavioural science perspectives. Universal Design has its origins in architecture and it is seen variously as a design approach (Mace, 1997), a process (Iwarsson & Ståhl, 2003), a paradigm (Ostroff, 2011), or as a design attitude leading to a design strategy (Herssens, 2013) which overall aims to create (housing) environments that can be used by everyone to the greatest extent possible. Universal design is based on the idea that a design which meets the needs of excluded groups, such as the elderly or persons with disabilities, will also improve the product experience of a broad range of social groups (Waller, Bradley, Hosking, & Clarkson, 2015).

As such, energy efficiency and universal design have enjoyed sustained focus in policy and research agendas at the international level (eg. the European Building Performance Directive and the UN Convention on Rights of Persons with Disabilities) as well as through policies, legislation, programmes, and incentives at national and local levels which aim to increase the uptake of EE and UD. However, their impact remains limited with equivalent major renovation rates in Belgium standing at about 0.33% (ZEBRA, 2018). These policies and programs also act in silos and rarely take into account their impact on the other domain. In research as well, EE and UD have been studied separately until recently.

1.1. Adoption of EE and UD

For the implementation of energy efficiency and universal design in housing both legislative enforcement and adoption incentives have been studied and used in practice (Kapedani, Herssens, & Verbeeck, 2016), although the fields have operated separately from one another. Legislation has been a driving force for implementation in buildings of both EE (such as the EPBD of 2002 and 2010) and UD (Ostroff, 2011). However, when it comes to studying voluntary adoption in private housing, energy efficiency and universal design research take different approaches.

In energy efficiency research the homeowner is considered as a consumer, a key decision maker whose barriers, incentives and decision making process must be studied. This has been done with both small and large studies, using qualitative and quantitative methods, in a variety of countries. One strand of EE research (eg. Poortinga, Steg, Vlek, and Wiersma (2003), COHERENO (2014) and Haines and Mitchell (2014)) take a rational economic perspective looking at the customer segments and suggest appropriate value propositions. Studies which explain energy efficiency adoption from behavioural and psychological perspective (Dugan & Connolly, 2013; Klöckner & Nayum, 2016) have become more prominent recently, as have socio-technical and social-practice perspectives (Bartiau et al., 2006; Gram-Hanssen, 2014; Wilson, Crane, & Chryssochoidis, 2015). In aggregate these studies reveal the complexity of factors influencing adoption of energy efficiency measures, such as comfort and lifestyles, which have little to do with the measures per se. The underlying argument is that policy and programs aimed at increasing adoption of energy efficiency need to understand better the homeowners and the surrounding environment of the home in which EE measures are implemented.

On the other hand universal design focuses on user-research and treats people as users whose role is to inform the designers and professionals towards making a better product. Although user research on both usability and adoption is rather common and part of the design & marketing process for consumer products and software, this is not the case for the built environment. Although products and services have different production processes and lifespan which can make UD adoption easier compared to buildings, both benefit from understanding people better. Case studies on universally designed buildings usually investigate the “how” to do it, such as best practices, rather than the “why”. This approach may be due to the fact that implementation of UD has focused on public buildings where the decision makers are (relatively) knowledgeable professionals. However it also implies that designers and researchers assume that a universally designed building would obviously sell itself and thus studies on incentives, barriers and decision-making processes of average homeowners are not necessary.

This is reflected in the fact that only a handful of studies on adoption of UD in housing exist. Nunn, Sweaney, Cude, and Hathcote (2009) carried an inventory of present and desired UD features in private homes in the US showing a link between age & disability and the presence & desire of UD measures – in other words people think about UD measures only once they need them. An important theoretical study is authored by Steinfeld (2010) who has carried out an innovation diffusion analysis of UD and, among other ideas, proposes the linking of sustainable design movement with UD. It is based on one of the key principles of diffusion of innovations theory which states that adoption is facilitated when innovations are “bundled” together (Rogers, 2010). Steinfeld sees the two fields as very compatible in their philosophies but warns that such alliances also come with a cost and conflicts need to be dealt with - either with creative “win-win” solutions, or compromises would need to be made.

Studies on the adoption of the combined energy efficiency and universal design measures in housing are even more rare. Buys, Barnett, Miller, and Bailey (2005) looked at the perceived benefits from the perspective of residents in a demonstration project in Australia. They identified both EE related features (natural lighting and ventilation) and UD features (spaciousness and ease of access) that when incorporated “contributed most significantly to the comfort, liveability and enjoyment of Research House by the family" (Buys et al., 2005). The X-tender project which is part of the EnergieSprong (Energie Sprong, 2016) research in the Netherlands explores the feasibility of making a zero-to-the-meter home renovation for elderly with care needs. Its rationale is based on a reasonable “kill two birds with one stone” idea. However it starts from an energy goal, has a rather limited scope for lifelong living, and works with social housing landlords rather than private homeowners, all of which limits its relevance in the private housing context. The French company St. Gobain has developed a demonstration project called the Multi-Comfort House (Saint-Gobain, 2018). Several homes have been built which demonstrate that it is technically possible to build a home that is both highly energy efficient and universally designed. The “why” is implied in the title – the project focuses on the appealing comfort benefits of the EE and UD integration.

Although limited, these studies, in support of Steinfeld’s proposal, indicate that the lack of integration of energy efficiency and universal design is a missed opportunity. If “bundled”, more sustainable and appealing renovation concepts could emerge, leading to rising adoption and thus resulting in more effective policy. However, at the moment there is scarce research on how the integration of EE and UD works in practice.

1.2. Energy Efficiency and Lifelong Living

A literature review comparing universal design and energy efficiency research and practice revealed that there are substantial differences in the concepts, history, approach and implementation between these fields (Kapedani et al., 2016). This context complicates a merging of UD and EE both theoretically and in practice and indicates the need for clarification of terminology.

Energy efficiency is broadly the simple ratio of “useful output of a process” divided by the “energy input into a process”(Patterson, 1996). In housing that useful output is the provision of appropriate indoor environmental quality (i.e. light, temperature, humidity and air quality). Energy efficiency in this case is limited to the physical building measures that are intended to provide the required IEQ by consuming less energy, and does not consider occupant behaviour or other social or psychological factors impacting energy consumption at home.

When discussing building measures we must also differentiate between lifelong living and universal design. As mentioned earlier, the universal design concept is a contested and rather abstract one, but it is not the intent of this paper to debate the meaning of the term. Instead we make use of “lifelong living”, a term which can be seen as a set of concrete design measures which aim to make a home suitable for use during the inhabitant’s whole life. In other words, while universal design deals with characteristics of the design strategy, lifelong living is the outcome of a universal design strategy. It is focused on housing and based on universal design principles but with an emphasis on adaptability, therefore adding a time dimension. A more detailed discussion of lifelong living measures is presented in the next section. In Belgium “Levenslang wonen” (from Dutch: lifelong living) and “Meegroeiwonen” (from Dutch: home to grow with, or adaptable living) are terms used by Inter, a governmental organization, in promoting universal design in the Flanders region (Inter, 2017).

Alongside the theoretical investigations on combining energy efficiency with lifelong living in housing in view of future new-built and renovated homes, it is instructive to see how they are already combined in practice. Therefore, we present in this paper a study of nine passive homes with lifelong living measures which was guided by the following questions: Which energy efficiency and lifelong living measures are implemented by homeowners? What are the perceived conflicts and synergies in integrating passive measures with lifelong living one? In addition we wanted to understand the homeowners’ motivations. What are the reasons for (not) adopting particular measures? At a more general level, what are the motivations behind building a house with combined passive house and lifelong living concepts? In order to better understand the context around these motivations, background questions about previous knowledge of the topics and previous housing experiences are also relevant.

2. Methodology

The research presented below was done as a case study (Denzin & Lincoln, 2011; Stake, 1995; Yin, 2013) of nine new-built detached single family homes in the region of Flanders, Belgium. As is typical in Belgium, the homes are custom-designed and built for the owners with the help of architects and other building professionals. This meant that the owners/inhabitants had a very significant involvement in the design and construction process. The decision making power, a privilege of individual private clients, sets these cases apart from multi-unit, speculative, or social housing developments.

To the best of our knowledge there is no database or organization that has a list of homes with a combination of energy efficiency and lifelong living measures, or even with just lifelong living measures. Therefore the recruitment for study subjects was made through two Belgian networks focused on energy efficient housing: *Ecobouwers* and *Passiefhuisplatform* (recently renamed *Pixii*). A call via email and newsletter to the networks' members resulted in 18 responses which professed to having implemented both energy efficiency and lifelong living measures. After further email correspondence with the homeowners explaining the type of measures required to participate for the study and the study procedure, 10 participants agreed to be interviewed in their homes and to provide drawings and documentations of their home. One case, which was only marginally energy efficient, has been dropped from the enquiry in order to keep the focus on integration of passive house standards with lifelong living.

While the intention was to find houses that are merely more energy efficient than minimum regulations in Belgium, the recruitment channels used resulted in Passive-house-certified or Zero-energy homes. Effectively this means that the sample is relatively homogenous in terms of energy efficiency measures, while there is variation on the level and types of lifelong living measures implemented. As members of energy efficient housing networks, the homeowners are outliers in relation to the general population, which may have an impact on their motivations, particularly on energy efficiency. In Belgium masonry construction is typical for private homes. However, in passive homes timber framing structures are more widely used and this was reflected in our sample as well. The homes are typical in size for Belgium, but the large sizes mean that some of the challenges around implementation of lifelong living measures are not relevant for these homes. An overview of the case study homes is shown in Table 1.

Table 1. A summary of the nine homes used in the case study in order of year of construction.

Case	Year built	Size m^2	Household size	Household type	Notable LLL features	Notable EE features
B	2008	178	4	couple with 2 children		zero-energy
E	2009	129	4	couple with 2 children	column-free flexible interior	
A	2010	550	1	retired man, but up to 21 visitors on weekends		zero-energy, designed by engineer owner, masonry structure
I	2011	150	3	retired couple and child	top floor can be converted into a separate apartment	zero-energy
C	2013	198	5	couple with 3 children	top floor can be converted into a separate apartment	zero-energy
D	2014	380	5	couple with 3 children	large working space inside, ready to convert into 2 separate homes	
F	2014	200	2	retired woman with adult daughter	Flexibly divided into 2 separate apartments	Bought as "casco" in a passive-house project,

G	2014	180	3	couple with child		part of a group of passive houses, masonry structure
H	2014	169	2	couple	owner designed and built most of the house himself	zero-energy,

The data reported here were obtained from several sources of information used in concert: lists of potential measures, semi-structured interviews, a video or photo walkthrough of the home, and drawings and documentations.

Reference lists for energy efficiency and lifelong living measures were prepared in advance in order to have a consistent audit and comparison between the homes. In order not to make the lists overly extensive, too detailed and ultimately unwieldy, the scope for both energy efficiency and lifelong living was limited to those elements of a building which are linked to construction stage decisions and are difficult or expensive to change afterwards. So, for example, water taps have not been included in the lifelong living list but the location of electrical outlets and switches is.

The list of energy efficiency measures was based on the items outlined in Annex 1 of the Energy Performance of Buildings Directive (European Parliament and Council, 2010) as important in evaluating the energy efficiency of a building. These items were further detailed based on the practical building guide for nearly zero energy (NZE) homes published by the Flemish Energy Agency (Vlaams Energieagentschap, 2016).

The list of lifelong living measures is based on the measures, definitions, and structure of four similar but separate standards dealing with the subject: Inter's Levenslangwonen and Meegroeiwonen standards for Flanders (Inter, 2017), the UK's Lifetime Homes standard (The Foundation for Lifetime Homes and Neighbourhoods, 2016), and Australia's Livable Homes (Livable Housing Australia). They all tackle similar issues but with different focus, approach and level of detail. The list of measures assembled for this study is intended to bring together the medium level of detailed advice and measurability of Lifetime Homes and Livable Homes, with a descriptive approach and focus on flexibility and usability present in Meegroeiwonen standards. Flexibility is a key element of lifelong living which allows it to fulfil UD principles over time, thus broadening the scope beyond the one-size-fits-all approach pure accessibility standards.

Semi-structured interviews of 60-90 minutes with one, and sometimes two, household members were carried out in the subject homes. The semi-structured interviews were divided in three sections. The first addressed background topics of previous knowledge and experience with energy efficiency and lifelong living, with disability, and the participant's previous homes. In the second respondents were first asked open questions on the installed measured, followed by an item by item probing using the reference lists. In the final section of the interview participants were asked about their motivations, their objectives for the home, and any conflicts and synergies they experienced.

At the end of the interview there was a video-recorded walk-through of the house. Drawings, photographs and other documentation of each home were used when available to thoroughly check the presence of lifelong living and energy efficiency measures. In the analysis these sources of information were compared and aggregated to form the full picture of each home and its inhabitant.

3. Results

The results from the analysis have been grouped in such a way that they help to answer the research questions outlined above. First the installed measures are described accompanied by the reasons why certain measures were adopted or not. Their perceived conflicts and synergies are then discussed. This is followed by the higher-level motivations for choosing energy efficiency and lifelong living as goals. The context of these choices is elaborated by describing the participant's knowledge of energy efficiency and lifelong living and their previous home characteristics. Lastly their interactions with professionals such as architects and contractors are described. This topic was not part of the initial set of interview questions, but was mentioned repeatedly by most of the respondents as an important influence on the building process and final result, often negatively. Therefore we have included this information below.

3.1. Energy efficiency features

Table 2 summarizes the type of energy efficiency measures installed in the nine case study houses. Two groups become apparent: six homes which are both passive-house standard and zero-energy, and three homes which are passive but without renewable energy production. The latter group found the PV panels to be not yet cost effective, but would be happy to add them in the future.

Fitting with the passive-house standard, the homes shared many of the same features such as very high insulation and air tightness levels, triple glazing throughout, mechanical ventilation with heat exchanger, rain water collection. Full height windows and sun screens were present on south facing facades to take advantage of solar heat gain. Eight homes had solar thermal panels for hot water which are backed up by efficient gas boilers, a heat pump, or an electrical boiler powered by PV. All homes had energy efficient appliances, although for cooking one used gas and one used ethanol. The mechanical ventilation, always coupled with a heat exchanger, also acted as the main climate control for heating and cooling for most of the passive homes.

Table 2. Implemented energy efficiency measures. Ordered from most to least efficient.

Case	Insulation	Windows	Heating	Hot Water	Ventilation	Energy Production
B	Passive level 40cm batt+EPS	triple glazing, hybrid frames, sun screens	one electrical heating pannel	solar thermal panels, condensing gas boiler	mechanical, ground-air heat exchanger	PV panels, EnergyPlus
I	Passive level	triple glazing, hybrid frames, sun screens	one electrical heating pannel	solar thermal, heat exchanger, electrical boiler for backup and kitchen	mechanical, air/air heat exchanger	PV panels, Zero Energy
H	Passive level 35cm	triple glazing, hybrid frames, sun screens	partial floor heating, solar thermal panels	solar thermal panels, wood pellet stove (as backup)	mechanical, heat exchanger	PV panels, Zero Energy
C	Passive level 48cm batt E=34	triple glazing, hybrid frames, sun screens	electrical radiators	solar thermal panels, ethanol condensing boiler	mechanical, ground-air heat exchanger	PV panels, Zero Energy
E	Passive level K=13 E=34	triple glazing, hybrid frames, sun screens	no system	solar thermal panels, condensing gas boiler	mechanical, ground-air heat exchanger.	PV panels, Zero energy
A	Passive level >20cm PUR	triple glazing, aluminium frames, sun screens	custom wood-pellet stove	Solar thermal panels, wood-pellet stove	mechanical, ground-air heat exchanger.	PV panels, Zero energy
F	Passive level	triple glazing, hybrid frames, sun screens	one electrical heating panel	electrical boiler, heat pump	mechanical, heat exchanger with heat pump.	none
G	Passive level 40cm	triple glazing, hybrid frames, sun screens	heat pump, radiant floor heating,	Heat pump, solar thermal panels	mechanical, heat exchanger with heat pump.	none
D	Passive level 35cmEPS	triple glazing, aluminium frames, sun screens	radiant floor heating, solar thermal panels	solar thermal panels, condensing gas boiler, small electric boiler for kitchen	mechanical, ground-air heat exchanger	none

Since these features are part of the typical passive house design it is difficult to extract motivations for individual features. The informants made the key decision to go for a passive house and the details were simply left up to the architects to decide. However, there were still some variations between these houses despite the overall homogeneity.

In a few cases a small electrical boiler was installed in the kitchen. The informants acknowledged it was a bit of energy waste, but the concern was overridden mainly for the convenience of instant hot water and in order to save water. Most had some form of backup heating such as an electrical heater in the living area which would be turned on for short periods of only a few weeks a year. Again, the convenience of instant heat was more important than the system's efficiency. Two homes did also install radiant floor heating, the water for which was heated by thermal solar panels, but they hesitated on whether they really needed a full heating system and installed it "just in case". Case A used an efficient wood pellet stove specially designed by the owner, as a fun personal project, which also served as backup for hot water.

Informant A had chosen for an automated system to control water and air heating, lighting, sun screens etc.. The informant conceded that it was complex and needed continuous tweaking but he enjoyed it because he is a trained engineer and had an interest in the systems of the home. The other informants opted for an "as simple as possible" strategy installing as few systems as possible and keeping those manually controlled. This approach is in fitting with the philosophy of the "passive" house, and as intuitive controls it is also an element in lifelong living. Informant F found even the mechanical ventilation system, which is present in all the homes and controlled from an electronic interface, too complicated to control effectively: "I always get it wrong. I'm not tech-savvy". However the other informants found it quite easy to "just turn the fan speed up or down". This may be because, unlike informant F, they had been more directly involved in the selection of the systems during the design process and seemed to understand their purpose better.

3.2. Lifelong living features

The informants were asked what kind of lifelong living measures they had installed, then further probed with a list of measures which was further checked against drawings and photographs of the home. Table 3 shows which measures were present (1), not present (0), or not currently present but is part of the adaptability plan for the house and it would be cost-effective and simple to install when needed at a later time (0.5). The grey rows highlight the measures with a value lower than 4.5, i.e. they are implemented less than half the time. The case studies have been ordered according to the level of lifelong living implemented.

Table 3. Lifelong living measures present in each case study home, the total number of homes that contain each measure, and the total number of measures per home. Score of 1 means the feature is present; 0.5 means the feature is planned for in the design, but not installed yet; and 0 means the feature is not present.

House Element	Requirement / Principle	A	I	F	H	G	B	C	D	E	Nr. of houses /9
Car parking & approach to entrance	wide enough or it should be capable of enlargement	1	1	1	1	1	1	1	1	1	**9**
	Level / gentle slope	1	1	1	1	1	1	0.5	1	1	**8.5**
Entrances	illuminated	1	1	1	1	1	1	1	1	1	**9**
	level access over threshold	1	0.5	1	0.5	0.5	1	0.5	1	1	**7**
	1000mm opening and 300mm nibs	1	0.5	1	0	1	1	1	1	1	**7.5**
	Weather protection	0	0	0	1	1	1	1	1	1	**6**
Doors and horizontal circulation space	convenient – min. 1000mm hallway, 850mm doors	1	0.5	1	1	1	1	1	1	1	**8.5**
	space for moving wheelchairs in kitchen, bathroom, & bedrooms	1	0	1	1	1	0.5	1	1	0.5	**8**
	Step + barrier free	0.5	0.5	0.5	1	0.5	0.5	0.5	0.5	0.5	**5**
Vertical circulation - stairs and lift	staircase wide enough so it allows for staircase lift	1	1	1	1	1	0.5	1	1	1	**8.5**
	hand rail fit for variety of users	0	0.5	0.5	1	0	0.5	0	0.5	1	**4**
	potential for lift through floor	0	0	0.5	0	0	0	1	0	1	**2.5**
All necessary spaces at entrance level	Living, kitchen & dining	1	1	1	1	1	1	0.5	0.5	1	**8**
	Space that is or has the potential to become a bedroom	0	1	1	1	1	1	0.5	1	1	**7.5**
	shower and WC exist or can be installed easily	1	1	1	1	1	1	1	1	1	**9**

Bathroom	Walls should be capable of firm fixing and support	1	0	0	0	0	1	1	1	1	**5**
	Accessible layout and barrier free sink, bath/shower	0.5	0	1	1	1	1	1	1	1	**7.5**
Flexible structure and layouts	Structure & wall materiality allows for *easy* functional adaptations	0	1	1	0.5	1	1	1	1	1	**7.5**
	Layout allows variety of uses with minimal changes	1	0.5	1	0.5	1	1	1	1	1	**8**
Hoist	Possibility for a hoist between bed and bathroom	1	0	0	0	0	0	0	0	0	**1**
Windows	Windows should allow people to look outside when sitting or lying	1	1	1	1	1	1	1	1	1	**9**
	Easy to operate	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	**4.5**
Controls, fixtures and fittings	Power outlets, switches & handles at correct height	0	0.5	0	0	0	1	1	0	0	**2.5**
	control system (eg. thermostat) reachable and intuitive to use	0	1	0.5	0.5	1	1	1	1	1	**7**
Maintenance	Finishings and layout allows for easy cleaning	0.5	1	1	1	1	0.5	1	1	1	**8**
	Ample and accessible storage & utility spaces	1	0.5	0.5	1	1	0.5	1	1	0.5	**7**
	Technical systems require infrequent or non-expert maintenance	0	0.5	1	0.5	1	1	0.5	1	1	**6.5**
Light	Ample natural light	1	1	1	1	1	1	1	1	1	**9**
Number of measures per house	**(28 possible)**	**18** **64%**	**18** **64%**	**20** **71%**	**19** **71%**	**21.5** **77%**	**22.5** **80%**	**23** **82%**	**24** **86%**	**24** **86%**	
		A	**I**	**F**	**H**	**G**	**B**	**C**	**D**	**E**	

As appears from the last row of Table 3, all homes had implemented or had built in the flexibility to easily implement at least two thirds of the lifelong living measures surveyed, and four of them had implemented over 80%. Overall these homes were designed with high attention to enabling a comfortable life for all members of the family over their whole life. Accessibility at entrances, horizontal and vertical circulation are the obvious elements to tackle when thinking of lifelong living and they were well thought through in most cases. However, as can be seen in the last column of Table 3, certain measures were not popular. The possibility for a lift through the floor required significant structural investment and could be replaced with a stair lift. Planning for a hoist from the bedroom to the bathroom was seen as too extreme a situation to plan for. This was true even in cases when the inhabitant had bed-ridden family members or believed they had a good chance of becoming physically disabled because of family medical history. In two cases the reinforced concrete structure of the ceiling and the layout allowed for a hoist to be installed, although it was not intentionally planned for.

Well-designed hand rails and appropriate location of switches and electrical outlets are much easier to implement but were rarely implemented. This was because of lack of awareness by both residents, who didn't know enough to ask, and professionals who didn't know or were not interested. Informant F commented: "We didn't know about [the location of electrical outlets]. It's the job of the architect to tell us." Weather protection at the entrance was slightly more popular but still lacking and for the same reasons as above. Architects and contractors were also part of the reason why most homes received 0.5 points on Barrier-free access. They did not know how to or were unwilling to change their normal practices to provide level entrances, an issue further elaborated in section 3.7. Barrier-free access was also in conflict with the high threshold door and window frames needed in passive houses, although window designs are continuously improving.

The operability of windows and sliding doors was an item where all the passive houses received half points. This is because the heaviness of full height windows with triple glazing meant that they were quite heavy and made it somewhat difficult to open and close. Their larger and deeper frames also hampered “barrier free” access. On these points the passive house standards can be seen in conflict with livelong living ones. However this same condition of heavy sliding doors was considered also positive by respondents who had small children because it meant that the kids couldn’t just go outside by themselves, thus increasing safety and peace of mind.

Ample natural light and windows which allow good views to the outside from sitting or lying position are both present in all the houses analysed. Although desirable and appreciated by the inhabitants, they were not their deliberate choices. Instead their presence is explained by the fact that passive houses in Belgium need full-height south facing windows in order to take maximum advantage of solar heat gain. The by-product is light and views, and an example of perfect synergy between passive house design and lifelong living.

Flexibility was also a very popular and effective strategy for realizing the ambition of a home to live in the whole life. Almost all homeowners had planned for easy changes to their homes by building a flexible structure, pre-fitting of electricity and water piping in strategic places, organizing the layout in such a way that a large home could easily become two separate living units or that all necessary living spaces could be placed on the entrance level. This would allow the residents to live comfortably now, and easily modify the home to be comfortable when the life situation changes.

3.3. Conflicts and synergies

There were mixed responses when informants were asked about points of conflict or synergy between lifelong living and energy efficiency measures. In some cases informants saw the two concepts unrelated and therefore did not mention any advantages or conflicts in the combination. In other cases the two were seen as parts of the same goal – planning for the future: "The whole concept fits because you design for the future".

After further probing some conflicts were mentioned. A common issue pointed out was the high threshold and heavy triple glazing windows and doors described above. Informant G however also noted the discrepancy, that the same feature is a conflict if you are elderly and a synergy if you have small children. Several informants remarked that they chose aluminium covered window frames because they are much easier to maintain, even though aluminium is less energy efficient than wood and has much greater environmental impact. Informant C pointed out that in principle wheelchair accessibility (in their opinion) means a larger house which costs more to build and to maintain, although this did not deter them since they wanted a spacious house anyway.

However, it seems that many conflicts and synergies were missed. The synergy between natural light, views and solar heat gain was not mentioned by the participants, even though natural light is an important factor for them, it is easily observable, and an architect could easily see the link. The conflict between natural light and views and the resulting higher heat loss from glass surfaces compared to a standard passive wall construction was equally unnoticed. High insulation also leads to thicker walls which allow for deep window sills which were used as shelves (marginally) improving usability. The protection from outside noise offered by the high insulation and air tightness in passive houses is arguably more important, but was pointed out by only one participant who lived next to busy road. Although participants were enthusiastic about the simplicity of needing just a fan (i.e. the ventilation system) to manage the whole home environment, they did not point it out as a synergy with the intuitive controls feature in lifelong living.

3.4. Motivations

During the interview, stated motives for adopting energy efficiency, lifelong living and the combination of the two were solicited. In most cases there was a general feeling that building an energy efficient home that works for you in different life situations just made sense. Informant D stated that it is “a natural way of building” and informant G wanted “just a house [where] to live your whole life”. Most informants mentioned “comfort” as one of the key aspects that was important to them during design and that they appreciated the most about their home now that they live in it.

“Peace of mind” was mentioned by three informants as a reason for becoming interested in energy efficiency and lifelong living measures. They wanted long term protection from energy prices, family changes, body deterioration, and maintaining long term comfort. In other words, they simply “don’t have to worry about it” (informant D). Several informants also believed that energy efficiency and lifelong living measures increased the value of their home or would help maintain it in the long term. Informant E wanted to “make a house that was still up to date in 20-30 years”.

More specific motivations for energy efficiency often had to do with environmental consciousness and saving money on energy costs. Some informants found the payback of measures such as photovoltaic solar panels too long and chose not to install them or only install a few. In two cases the state subsidies available at the time of construction pushed them to upgrade their ambitions from very energy efficient to passive-house. In contrast, informant A did not have environmental or economic concerns and was motivated by personal interest in the techniques and technology – they enjoyed the challenge of building a passive home.

Motivations for lifelong living measures were grounded in thinking about the future and wanting to live independently in the house for the whole life. They were often connected to previous experiences with disability, either directly or in family and friends. Informant C had a family history of MS and was afraid they would eventually get it as well. While informant I, a retired doctor, was "preparing for ageing" having seen many elderly people struggling to live in their homes.

Features that allowed for functional adaptability of the home, such as separating the house into two apartments or being able to easily make an extension, were motivated by considerations of family changes and future housing conditions for the children. Informant D was concerned with the rising difficulty of homeownership for younger people and wanted to make sure that their daughters (now in elementary school) would always be able to have their own home, next to the parents.

Tables 1 and 3 reveal that there is no relationship between the size of the house and the level of lifelong living achieved. The house with the lowest lifelong living score is also the largest (Case A: 550m2, 18/28) and the one with the most lifelong living measures is the smallest (Case E: 129m2, 24/28). The reason for this can be found in the motivations of the homeowners. Informant A enjoyed the technological elements of the house and lifelong living was mainly solved by just making spaces larger, almost as an afterthought. On the other hand Informant E was very focused on achieving high lifelong living and energy performance within their limited budget. This also demonstrates that, above a certain minimum dwelling size, achieving lifelong living and energy efficiency goals and is a matter of careful planning and design rather than budget.

3.5. Previous homes

The informants were asked details about their previous living arrangement and whether there was anything from the old home that influenced what they wanted to have, or to avoid, in their new home. In most cases the previous home had a strong impact on the design of their current home. Typically the previous homes were 50 years old or more and had no insulation which made them too cold and damp and this was something that the informants were keen to avoid in their new home. Informant E was excited to report that unlike their cold old home they now “use the same covers and bed sheets all year because temperature is so steady”, a co-benefit of passive homes.

Natural light was an often recurring topic. Many said they had very little sunlight in the old house and wanted to fix that in the new one. Informants E and G noted that they loved the natural light in their old homes and made sure the new home was even more bright.

Lifelong living issues were common with their previous residential experience and may have had a strong influence on the decision to adopt lifelong living. Several informants noted having too many steps, “even between bathroom and bedroom”, as an issue in their old homes that they wanted to avoid in the new one. Several informants reported issues with the layout and size of their previous homes. They were either too big or too small and the spaces were arranged inefficiently. Most informants stated that they decided to build new homes because the old ones were not adaptable enough and it was too difficult to achieve their passive house and lifelong living ambitions by renovating. Most of the new homes have included measures that increase functional adaptability.

Renovation of their old homes, compared to building anew, was considered too troublesome in terms of achieving their energy efficiency and lifelong living ambitions. Some of the informants were relatively satisfied with their old home but they “wanted to go further” and a renovation would limit them. Informant D had recently renovated their home but still decided to buy an empty lot nearby and build a new home in large part because it would allow them to achieve their full ambitions.

3.6. Previous knowledge

In general, knowledge on energy efficiency and lifelong living was limited before the informants engaged in the design and construction process. Most of them had some awareness of energy efficiency issues because "there was a lot of talk" about passive homes in the past years. In a few cases there was good knowledge of energy efficiency because of intense personal interest in sustainable building or because of related experience at work (one informant was an engineer and another worked as a sustainability advisor at the local municipal offices). Many went on to find information and to learn more about passive housing by searching online, attending information sessions, and visiting passive homes.

The situation with lifelong living was somewhat different. The term, although self-descriptive, was unfamiliar or "never heard of it" even in cases when the informants had some previous experience of disability themselves or in their family. This meant that they did not know what information to look for and just followed common sense. Informants C and G found some online information about accessibility, though not lifelong living, but did not recall where or from what organization. Lifelong living measures were more a result of informants thinking of the future and asking "what is important to me?". Passive house standards and methods are well documented, shared through specialized networks, and some architects and contractors are specialized on this type of construction. Whereas lifelong living, despite being intuitively named, is not as well disseminated so the homeowners had trouble explaining exactly what they wanted while the architects and contractors did not have the expertise to do it.

3.7. Architects and contractors: obstacles rather than enablers

Architects and builders were reported to stand in the way of implementing measures of lifelong living, energy efficiency or both. The earlier projects, when passive-house concept was still relatively new in Belgium, faced a lack of technical expertise from builders. The informant in case A confessed to using his engineering and project management experience to manage every detail of the builders' works. The owner in case H was so frustrated with the builder's inability to maintain passive house construction standards that he fired the builder soon after the structure was complete and finished building the home by himself. In the last few years builders and architects have emerged who are specialized in passive homes and energy efficient construction, making it much easier for more recent projects like cases C, F and G.

However, even recent projects could not rely on the architects to advise well on lifelong living. All cases faced indifference, lack of knowledge or outright opposition to their requests on lifelong living. In case C, the informant asked the architect for space in the plan where a wheelchair lift could be installed in the future. After some resistance, they found out during construction that the architect had instead designed a concrete shaft for a commercial sized elevator – a gross over-design that also failed their environmental goal of minimizing concrete use. In case G the architect designed what the clients asked him, but had no interest in lifelong living and made no contributions to that aspect of design. While Informant E reported going against some of the architect's advice because the architect was ”too focused on aesthetics” and too ready to compromise on lifelong living.

For contractors lifelong living details represented a departure from “normal” practice and so refused to build measures such a step-free main entrance and garden access. Path-dependency is notoriously strong in the construction sector and the homeowners did not feel secure enough to impose their will on the contractors, particularly without the backing of their architect.

4. Discussion and implications

Passive-house requirements are at a comparatively extreme level of energy efficiency standards in buildings and passive homes are still very rare in Belgium. Also rare, but difficult to quantify, are homes with a focus on lifelong living measures. So it should be emphasized that the nine case study homes discussed in this paper, which combine lifelong living measures with a highly energy efficient building, are by definition rather pioneering. As such, and in accordance with established practice in case study research, one cannot make direct generalizations to the larger populations. However, the type of measures included in the homes and the motivations and context described by the study participants reveal several future research paths and hold lessons for understanding the appeal and construction of more energy efficient homes that accommodate people during their whole life. Although the study took place in the Flanders region of Belgium, the results are applicable to other contexts with similar characteristics: high proportion of homeownership with many single-family homes, stable tenure, relatively large average home size, relative ease at commissioning a new home or significantly renovating an old one, and, more generally, homeowners who are emotionally invested in their home rather than seeing it as just an investment.

4.1. Passive house and lifelong living

As expected, previous residential experiences (positive and negative) as well as personal experience with disability and ageing impacted motivation for the combination of EE and lifelong living. These experiences are unlikely to be unique, so it would be valuable to explore how they can be leveraged with people who plan to renovate or build their home. Similarly, some of the underlying motivations mentioned above reveal paths for further research. The ecological, long term financial benefits, and innovation-mentality that motivated the passive house ambitions for these homeowners may set them apart from the typical homeowners in Belgium. However their more fundamental desires for long-term security and peace of mind, related to both energy efficiency and lifelong living, are topics that probably relate more to the typical homeowner.

The survey of EE and lifelong living measures shows that the small variations in energy efficiency measures between these otherwise homogeneous passive homes are connected to convenience and comfort benefits. The missing lifelong living measures on the other hand can often be linked to either the fact that those measures were considered too extreme, or more often to a lack of knowledge and awareness. This means that lifelong living can be improved even in these already well-performing homes with little or no cost if it was properly planned.

The informants pointed out only a surprisingly limited list of conflicts and synergies. It can be argued that many conflicts are resolved by architects and contractors behind the scenes and therefore go unnoticed by the inhabitants. Although some conflicts, like heavy windows & doors with high frames, are part of the passive house requirements and a compromise with lifelong living is needed. The synergy between natural light, views, and solar heat gain for example is rather present in the everyday experience of the house, yet went unmentioned nonetheless. As did the conflict of views and natural light with heat loss from the larger windows (even triple glazing) relative to a well-performing wall. In any case, we believe that it is a good sign that the informants do not perceive energy efficiency to be in conflict or synergy with lifelong living – it means they are open to persuasion. Well-informed professionals can resolve the conflicts and point out the synergies to someone planning to build or renovate their home. In other words "upselling" and expanding the focus of renovation can be an effective way of increasing the adoption of both energy efficiency and lifelong living measures, if the professionals are up to the task.

The potentially positive role of the designers, contractors and advisors as intermediaries in promoting energy efficiency is already being explored (eg. Owen, Mitchell, and Gouldson (2014) and (Janda & Parag, 2013)), although this is not the case for lifelong living. Conflicts are more easily seen and synergies are more easily created by professionals - if they are trained and interested in doing so. However the lack of knowledge as well as interest in one or both fields by architects, builders, engineers etc., was a recurring issue in our cases, which limits their positive impact. This points to a need for educational and communication programs and tools, particularly on lifelong living, for both, home owners (in order to increase awareness and demand) and professionals (so that they can build and advise properly).

4.2. Future orientation and comfort

A red line running through all nine cases described above is the informants' strong tendency to think deeply about their needs in the long term. It appears they have what Nuttin (2014) would call a strong future-time perspective. Whether it was expressed as "peace of mind" or as "just want to live here my whole life" this tendency to anticipate and actively prepare for the future was a key motivation behind the choice for combining low energy with lifelong living measures.

This is a reasonable approach to expect since, although energy efficient and lifelong living measures at home have some immediate benefits, the more significant benefits are felt in the long term. A series of studies have shown a link between the tendency for more future-time orientation, motivation and future behaviour (Aspinwall, 2005). Homeowners with a strong tendency for future-oriented thinking could be an important target group for homes that include both types of measures. Or otherwise, the future-looking tendencies of most people can be encouraged and appealed to in order to increase awareness and attractiveness of “future-proofed” homes. This may be easier to do in cases when people build their own homes and envision a stable tenure because they become emotionally as well as financially involved in the future of the house. Encouraging future-thinking may be more difficult in cultures where tenure is unstable and houses are seen as an investment or when homes are built as a speculative investment by a developer.

However, even in our case studies, there is a limit to how much future risk people are willing to consider. Some lifelong living measures, such as internal lifts, or hoists that could carry a physically immobile person from bedroom to bathroom are seen as too far-fetched or extreme to invest into.

On the other hand, comfort was repeatedly mentioned as a benefit by inhabitants, as well as being a stated goal of design decisions. Although it is possible to experience high comfort in a house that is not energy efficient, interestingly, comfort was associated with aspects of both energy efficiency and lifelong living measures, such as stable temperatures, air quality, lack of noise, ease of moving around the house, ease of maintenances, natural light etc.. This suggests an opportunity for exploring the concept of comfort as way of linking short term with long term benefits and thus creating a more broadly appealing argument for building an energy efficient lifelong living home. On this topic there is ongoing research on a comfort framework that combines aspects of energy efficiency and lifelong living (Kapedani, Herssens, Nuyts, & Verbeeck, 2017; Kapedani, Herssens, & Verbeeck, 2017). In a similar vein Kerr, Gouldson, and Barrett (2018) have developed a set of holistic narratives based on the experience of general home renovations as indistinct from energy efficiency.

4.3. Further research

These case studies contribute some practical evidence of the perceived benefits of integrating energy efficiency and lifelong living and for a shift towards a more inhabitant-centred approach in promoting adoption of energy efficient homes fit for people during their whole lives.

The knowledge gap is still large and this approach would benefit from further adoption research of the same type that has already been carried out for energy efficiency, which means larger qualitative and quantitative studies from both the technical as well as the design and social science perspectives. One research track in this direction would explore increasing demand by emphasizing the soft benefits of comfort and “peace of mind”. While this study took an inhabitant perspective, technical and ideological conflicts and synergies between EE and lifelong living measures need to be investigated also by taking into account the issues that architects and contractors would face in integrating these measures. Ways of helping home owners to identify and communicate their needs to professionals, and facilitation of communication between the two parties would also be valuable contributions.

The fundamental desire exhibited by our participants, of wanting a house to live in for the rest of their lives, sets up lifelong living and energy efficiency as either parallel tracks to the same goal or, in the best case, as two sides of the same “natural way of building” coin. Ultimately, this is an open invitation for policymakers, researchers, architects and others to join homeowners in their shared goal of designing for the future.

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