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Review

A multi-case study of innovations in energy performance of social housing for older adults in the Netherlands

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ABSTRACT

With the ageing of population in Europe, the housing stock needs to meet the demands of older occupants, including an increasing demand for energy efficiency. As collective entities, Dutch social housing associations are among the frontrunners in achieving the energy and comfort goals of the European Union and the national government. This paper presents a number of case studies from the domain of social housing for older people from The Netherlands. The cases presented focus on the baseline conditions, the interventions conducted, the financial aspects and the involvement of stakeholders. Implications and recommendations for the design and retrofitting of housing, as well as the process of improving energy efficiency and comfort in practice, are discussed on a supranational level.

Contents

1. Introduction

Europeans are living longer than ever in history, because of the economic growth and advances in hygiene and health care. By the year 2020 around 25% of the population will be over 65. The increasing group of older people poses great challenges in terms of creating suitable living environments and appropriate housing facilities. Apart from the construction of comfortable and accessible

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dwellings (van Hoof et al. [33,34]) [1–3], there is an increasing need for energy-efficient and sustainable housing [4]. Actions in a field of energy efficiency are often driven by policies dictated by supranational authorities. The world's latest policy in that sphere is the Paris Agreement that directly influences sustainable development. In Europe, the highest potential for the reduction of CO_2 emissions lies in the housing and transport sectors [5]. In the Netherlands, residential buildings are responsible for about 9% of CO_2 emissions, and the Dutch Government has a long history in encouraging energy conservation in the built environment [6]. In order to meet the European Union's target of a 20% improvement in energy efficiency by 2020 it is forecast that the annual European investments in the energy-efficient renovation of the building stock should increase from 12 billion euro in 2014 (~30 € per capita) to 60 billion euro in 2020 (~150 € per capita) [7]. In October 2014, the European Council agreed on the 2030 climate and energy policy framework for the EU setting an ambitious economy-wide domestic target of at least 40% greenhouse gas emission reduction for 2030 [8]. The European Commission's "Clean Energy for All Europeans" proposals include the renovation of Europe's buildings in the light of a clean energy transition. The package also contains several measures aimed at protecting the most vulnerable consumers.

There are large differences in the energy efficiency of the existing building stock, including the dwellings occupied by people aged 65 and over. Energy strategies are easiest to implement when new construction takes place, and when energy-efficient solutions can be integrated into the design. Apart from the quality of the building envelope and occupant behavior, being able to upgrade the energy performance of existing buildings depends largely on the ownership of real estate. In the European Union, there are large differences in the ownership of housing. Older people can either be home owners, or tenants of commercially rented dwellings, or homes that are rented out by social housing associations. In Northern Europe, a large number of older adults live in institutional aged-care facilities, including nursing homes. Depending on the ownership of the home, older people can implement energy-efficiency measures themselves, or in collaboration with a landlord or social housing association. In case of social housing, and a generally older housing stock, measures to improve the energy efficiency of housing may have a relatively larger impact on the purchase power of older tenants as financial resources are lower than that of younger counterparts or private home owners [1]. van Hoof et al. [1] have identified that many older adults, and their younger counterparts alike, spend a large amount of their incomes on energy, and, therefore, the need for a reduction in energy consumption is desirable, without any negative effect on comfort and well-being inside the home. There is no single value that can describe a share of expenses on heating or cooling in relation to average pension of retired persons, as these figures depend on the purchase power of individuals in different countries. In many member states of the European Union, older cohorts deal with limited financial resources and form a substantial section of the low-income households.[1] The aforementioned European Commission's "Clean Energy for All Europeans" proposals provide the foundation stones for achieving energy efficiency in the built environment and opportunities for improving the purchase power of older people in relation to energy expenses. Housing Europe, the European Federation of Public, Cooperative & Social Housing, will have to account for this new set of EU energy legislative proposals on housing.[2] This organization stressed the problem of affordability of refurbished dwellings as well as social acceptance of the acceleration of renovation investments.[3]

Achieving energy efficiency in the built environment addresses another policy area, namely that of combatting fuel poverty and improving the affordability of housing. Kolokotsa and Santamouri [9] presented a state of the art regarding the energy demand and indoor environmental quality of low-income households in Europe, in which the term energy poverty was used to describe a situation of a household not able to satisfy socially and materially the required levels of its energy services. There are many strategies against energy poverty in the European Union [10], and depending on purchase power and home ownership, taking steps to improve the energy efficiency of equipment and homes is a viable option. About 10% of the Dutch population deals with fuel poverty, in which the energy bills are too high given the household income.[4] Depending on climate conditions or technical standards the cost of energy used by households varies all over the world. However, in the case of Poland, the average cost of energy resources per household reach approximately 20% of the average pension. Additionally, electric energy costs (which are used not only for cooling but other purposes as well) cover about 7% of the average pension [11,12]. In Australia, it is estimated that older people pay between 10–20% of their household income for energy (gas and electricity), which is to be used for cooling, heating and cooking [13,14]. According to Nibud, the National Institute for Family Finance Information, the average gas use for flats and terraced housing in the Netherlands ranges from 940 to 1310 m^3, which amounts to € 66–88 per month.[5] This gas use encompasses gas used for cooking, heating one's home and for heating water for showering and bathing. The minimum net basic pension in the Netherlands for single-person households is about € 880, which means that at least 8% of the income is spent on the gas bill. The figures do not provide a first glance on the purchase power of older people in an all-electric scenario, in which electrical systems are used for heating and cooling. However, those expenses could be reduced, for instance, by the implementation of appropriate and energy-saving systems in the built environment [15,16].

As it is the housing experts and building services engineers who can help achieve energy efficiency in homes of older people, it is important to see how such strategies take place in practice. This paper focuses on the domain of social housing for older people, and presents a number of best practices on energy consumption and sustainability from The Netherlands. First, we provide an outline of the social housing association that implements a number of projects related to sustainability in the built environment. Thereafter, we describe three case studies in terms of the goals of the project, its organization, costs and profits, and involvement of -and effects on- end-users.

2. Profile of Habion

The Netherlands has a long tradition and history of social housing, providing housing to people with limited financial resources. Habion is a social housing association specialised in housing for older people in need for care and services. There are only a very few of such specialised housing associations, of which Habion is the second largest in the country with a total of 4847 housing units

[1] In the Netherlands, the cohort of older people is the richest in society. According to Statistics Netherlands, the average net income of a single person aged 65 years and over was € 23,000, and that of a couple of the same age cohort € 40,000. https://www.cbs.nl/nl-nl/nieuws/2017/10/ontwikkeling-inkomen-en-vermogen-65-plussers-na-95.

[2] http://www.housingeurope.eu/section-10/energy.

[3] http://www.housingeurope.eu/resource-319/energy-and-housing-in-2030-looking-behind-the-targets.

[4] http://energiearmoede.nl/.

[5] https://www.nibud.nl/consumenten/energie-en-water/.

in aged-care facilities and nursing homes, 5797 dwellings for ageing in place, and an additional 625 units including shops, garages and parking lots. The association is active in 71 out of 388 Dutch municipalities. The average age of the residents is 80 years. About 88% of the units of Habion are rented to people as social housing units. The average rent of a dwelling was € 575.42, and the overall rental income totalled M€ 73.1 in 2016. The mission statement of Habion is: "All frail older people a secure and comfortable home!" This assignment entails more than just providing shelter, it also means providing comfort, a purpose and meaningful activities, and considering aspects of sustainability and safety and security [17].

The activities of Habion are focused on maximizing the 'good life' for older residents, even when support and care becoming necessary. Apart from investing in real estate, Habion invests its means in the atmosphere, social interaction, liveliness, accessibility and comfort. New construction considers the diversity of future residents, which are entitled to comfortable, safe and secure housing. Habion actively monitors the different and changing needs of seniors over time. Even if needs and wishes changes over time, housing should keep its value and should remain a flexible and sustainable character. By working together with local providers of healthcare, a continuum of housing and care can be delivered to the tenants.

In 2016, Habion invested M€ 28.4 in the creation of newly constructed dwellings and the conversion of former aged care facilities into single unit housing: 205 units in total. About M€ 12.4 was allocated for maintenance. The returns on investment of Habion are used only for the general interest of public housing, with a focus on financial continuity in the future. In 2016, Habion witnessed a number of important events, namely a number of transformation projects in which former aged care facilities are transformed into new living communities for older and younger tenants, which still offer amenities for the provision of healthcare but have a different focus. The quality of housing, community and living together prevail over an institutional model of care. This means that old real estate is re-used and retrofitted, also in terms of installing new building services throughout the premises. This is part of the sustainability strategy as included in the association's mission statement. The general tendency in the Dutch care sector is that buildings have an average functional life span of 30–40 years, and thereafter, disposition or demolition takes place due to an increased frailty of the older residents.

3. Habion and sustainability

Habion has included sustainability in its extended mission statement, on the basis of people, planet and profit. For Habion, this means 'building together', 'a minimal use of resources', and 'flexible buildings'. In collaboration with (future) residents, partners in healthcare, other suppliers and the local community, Habion develops and redevelops its real estate portfolio (Fig. 1). The re-use of structures and materials is a foundation stone in these processes. Other key words are energy-neutral buildings; circularity ('Habion no longer demolishes buildings; but reinvents them'); and smart technologies.

The average Energy Index – a Dutch index in use since 2015 for social housing associations which influences the level of the rent – of Habion's portfolio is 1.58 (Energy Label C). A further improvement of this index is foreseen in the future, and is part of the active mission of the association. In the long run, the Energy Index of the portfolio is expected to come down to 1.41 at most (Energy Label B). In order to limit hindrance to its occupants, Habion chooses to improve the energy performance of a building at the moment of new construction or renovation. Overall, the measures takes should not only improve the Energy Index and the sustainability of a dwelling itself, but also contribute to the comfort of the tenants and minimising the cost of living. A study by Milieudefensie [18], a Dutch environmental organization, ranked 25 of the larger social housing associations in The Netherlands in terms of sustainability of the real estate portfolio. Habion ranked among the best scoring Dutch social housing associations, and was given the qualification "good". Habion achieved a number of 304 so-called label steps per 1000 dwellings in 2015.

Fig. 1. Reinventing existing real-estate through extensive retrofitting of old property with involvement of the local community in order to create home-like environments. The concept of Extended Living at De Benring was launched in 2016 after a long process of involving tenants and the wider community. The figure shows a view of a communal kitchen area and living room.

In 2016, a number of initiatives in the domain of sustainability were commenced, namely:

- All residents received a letter from a supplier of green energy only (Woonenergie company). About 2.5% of the tenants applied for this green energy package.
- In various locations, Habion facilitated the establishment of a building lease to install solar panels on roofs of real estate that is part of Habion's portfolio by other parties.

In previous years, Habion facilities participated in an energy competition, and thermal energy storage systems have been installed in numerous premises. The next sections deal with an analysis of the energy competition, solar panels, and thermal energy storage systems.

3.1. Energy competition

In the Netherlands, costs for care and costs for housing in aged-care facilities used to be part of a single financial arrangement. In aged-care facilities, older residents and care organizations are now obliged to pay for their own expenses for housing, and, thus, also for the utilities. In 2012, Habion investigated the quality of its portfolio, and this analysis showed that the institutional care facilities showed a large potential for energy savings. Habion has formulated goals for sustainability, which are based on the strategic starting-points of controlling costs of housing, and being economically profitable. Parallel to setting these goals, Habion started to engage in dialogues with societal partners in order to kick-start concrete sustainable initiatives that would lead to lower costs for energy. In a time of rising rents and pension rates that remain on an equal level, cutting down on energy may be a way to both be environmentally responsible and save on scarce financial resources. In 2012, the energy costs were about 25% of the total costs of housing, or € 150 per month. Being able to save about 10–20% per month

Table 1
Details of solar panels, and overview of yields and costs.

Location	Number of solar panels	Type of solar panel	Time taken to raise funding [weeks]	Minimum investment per 'solar part'[€]	Number of bonds sold	Financing involved [€]	Number of participants	Estimated output [kWh/kWp]	Estimated production of energy during first year [kWh]
De Benring	512	512x CSUN 255 Poly, 255 Wp	6	25	6400	160,000	119	872	114
De Molenhof	300	300x REC – REC265PE	3	25	4000	100,000	136	886	70
't Kampje	480	480x REC – REC260PE	1	25	6000	150,000	206	904	113

Fig. 2. Energy Battle. Residents, care professionals and the social housing association work together in reducing energy use in the built environment by competing against other nursing homes and aged-care facilities in The Netherlands.

equals an amount of € 30, which can be substantial when one's pension is low.

Therefore, Habion has participated in the so-called Energiestrijd Zorghuizen[6] (∼*Energy Battle Care Homes*), together with Dutch sustainability organization Urgenda,[7] and Meneer de Leeuw (∼*Mister Lion*).[8] The goals of this Energy Battle was to create awareness among tenants concerning the costs of energy, as well as change people's behavior, doing things together and with enthusiasm (Fig. 2). The main goals were the reduction of CO_2 emissions, the control of costs for housing and living, and increasing comfort and indoor environmental quality. The Energy Battle is a competition between aged care facilities on energy savings. Every year, residents and staff battle from December 21st to March 21st (start and end of the winter season), by monitoring their energy consumption and by finding out who did best in terms of energy savings. Habion stimulated the participation in the Energy Battle because of the goals it set out in terms of sustainability and affordability by paying half of the participation fees (€ 2.000). In the winter of 2014–2015, a total of 38 aged care facilities joined the Energy Battle, of which six were Habion locations. In mid-2015 these aged care facilities together managed to cut down € 200.000 on the utilities bills, which amounts to a 16% cut in energy consumption, without a negative effect on perceived comfort according to the participants and without pre-investments. The winner of the battle managed to save a staggering 55%, which amounted to € 20.000 for 70 residents. Or, on the individual level, € 286 per resident. Habion and Urgenda calculated that for the 76 care facilities Habion had in its portfolio, over M€ 1 could be saved. For all 1900 long-term care facilities in The Netherlands, annuals savings could between M€ 20 and M€ 40.

In fact, all participants of the Energy Battle were winners, and each one of them managed to save energy, and thus, costs.

[6] www.Energiestrijd.nl/zorghuizen.

[7] The Dutch Urgenda Foundation aims for a fast transition towards a sustainable society, with a focus on the transition towards a circular economy using only renewable energy. It works on solutions for this transition, including for example the introduction and realization of 'energy neutral' houses and the acceleration of electric mobility. http://www.urgenda.nl/en/.

[8] Mister Lion is an Amsterdam-based lab for societal change. Mister Lion organizes local and transnational innovation communities around sustainability issues and has expertise in co-creation and transition management. Mister Lion's work includes interventions in regional development, urban mobility, urban climate mitigation, energy saving, youth employment, international cooperation, refugee shelter, healthcare and civic participation. http://www.meneerdeleeuw.nl/abroad/.

Fig. 3. Solar panels on top of De Benring premises in Voorst, The Netherlands.

Fig. 4. A large-scale heat pump installation in the basement of one of the premises of Habion. The design of sustainable energy systems in the built environment also includes having sufficient space available for the placement of technological equipment.

Some triggers for participating were straightforward: participation as such with co-residents and doing things together (or active engagement and interaction), having the feeling to participate in a 'feel-good' and 'do-good' programme, and having the financial benefits of lower energy bills. Some of the successful solutions were the application of a set-back mode for collective heating installation, the reduced use of lighting in shared spaces, separate day and night modes for air handling units, and a check of the controls of central heating installations. The most important lessons learnt were that apart from creating awareness and behavioral change, it was fairly easy to save on energy for heating without sacrificing the perceived thermal comfort.

The Energy Battle initiative has inspired other aged care centers in the Netherlands to follow the path towards energy efficient lifestyles among older residents. The battle has stimulated Habion to engage in a project involving the large-scale installation of solar panels.

3.2. Solar panels

Together with the Dutch sustainability organization Urgenda, Habion started the initiative Zon Op Zorg *(~Sun on Top of Care)* in order to install solar panels on as many aged care facilities in the Netherlands as possible. Through the help of the joint crowdfunding website www.zonnepanelendelen.nl[9] (~*sharingsolarpanels.nl*), anyone can be a co-owner of a solar panel that is to be installed on top of an existing or new care building. Habion provides its rooftops for the project. Habion itself is not involved in the ownership of the panels or the generation or distribution of the electricity, and thus, limits financial risks run by the association. Together with tenants and www.zonnepanelendelen.nl three crowdfunding actions were started to install solar panels onto Habion's rooftops. The interest in society to participate was substantial: in the first project, it took six weeks to receive sufficient funding, in the second about three weeks, and in the third project just over one week. About 1.300 solar panels have been installed at three sites: at De Benring in the town of Voorst in 2015, and at De Molenhof in the town of Zwolle and 't Kampje in the town of Loenen aan de Vecht in 2016 (Fig. 3, Table 1,). About 20% of the investment is funded through a national scheme for stimulating green energy solutions. The total reduction in CO_2 emissions amounts to 127,000 kg per year. With new projects on the way in eight Habion facilities, the future reduction will be even larger at an estimated magnitude of 549,000 kg per year.

The predicted return on investment, with a term of 16 years, is predicted to be 3.5% on average per year. This is much higher than the current interest rates for Dutch savings accounts which are around 0%. Residents and non-residents can invest in the crowdfunding actions. The project offers potential to invest in green energy solutions. Residents and people living in a limited radius of the building are given priority in buying bonds as investments per bond are limited to € 25 only. This would even allow people with very limited financial resources to participate. Bonds can also be transferred when passing away. The tenants of the Habion facilities themselves are benefitting from the Zon op Zorg project as well, through the concept of the Green Wall. This wall displays the amount of energy generated, and contains plug sockets that can be used free of charge in order to charge the batteries of mobility scooters. The overall services costs can be lowered as some of the energy generated is used to power the lighting in the shared spaces such as corridors. A small amount of the revenues are used to fund activities of residents, preferably so-called 'green activities', and this amount is kept by the manager of the building. The solar panels are thus not primarily installed to achieve behavioral changes among tenants.

3.3. Thermal energy storage systems

Since 2008, a number of premises owned by Habion make use of thermal energy storage systems: six in total (Fig. 4). Every year, thermal energy storage systems provide about 9500 GJ for heating, and 1.700 GJ for cooling together. Traditional ways of heating and cooling would require about 310,000 m^3 of gas, and about 265,000 kW h of energy. This amounts to approximately 675,000 kg of CO_2. The thermal energy storage systems allow for a reduced use of gas (~115.000 m^3) and energy (~846,000 kW h). Together, these systems contribute to an annual reduction in CO_2 emissions

[9] https://www.zonnepanelendelen.nl/project/debenring/project-update/zon-op-zorg-van-start.

of 80,000 kg. In combination with the use of 100% green energy, this reduction is about 595,000 kg per year.

The thermal energy storage systems are used for low-temperature heating inside the dwellings. Older tenants were not involved in the design or installation of thermal energy storage systems, however, comments regarding the operation of the systems and the effects on (thermal) comfort are collected through a system of object managers. These comments can be divided into two categories; effects on energy bills and thermal discomfort. The type of heating system installed in the dwellings is a floor heating system. Many of the older tenants have problems with the operation of these floor heating systems. Tenants stated that they were used to the conventional method of heating through radiator panels. These panels provided instant heat. In the case of floor heating, the provision of warmth takes longer, and the system itself is switched on continuously in a low mode. The most frequently files complaints concern the operation and cost of operation. It is often said that the system 'does not work'. The floor heating is a rather slow and inert system (it takes about 2–3 h to heat up), and therefore, it is important to leave the system in operation without being switched off. Over time, the number of complaints has become lower, as tenants are getting used to how to operate the radiant floor heating and how to handle the inertia of the system in comparison with more traditional methods of heating. Outsourcing of the total maintenance of the building has also led to a faster and more adequate handling of complaints, which, in turn, is expected to lead to a further reduction in energy use as the operation of the thermal energy storage system is coordinated better.

Another complaint concerns the utilities bill and cost of energy. By an incorrect use of the system (switching it on and off), the bills are high, partly because of Dutch legislation (*Warmtewet* ~*Heat Law*[10,11]). This law come into force on January 1st, 2014 in order to protect people with collective heating systems, including district heating, from excess energy bills by setting a maximum prize. In case of such systems, one can effectively speak of a monopoly on energy, and resident cannot choose a supplier freely on the liberalised Dutch energy market. Still, the investments in the thermal energy storage systems and their maintenance need to be paid back. In addition, tenants tend to compare the energy bills with the neighbours. Large differences in bills lead to complaints with the social housing association.

4. Discussion and conclusions

The three case studies presented above are an illustration of how sustainability in the home environment of older tents of a Dutch social housing association can be achieved at different levels of user involvement. In the following sections, we look at the case studies from the perspective of investment opportunities and the potential for behavioral change, and how these findings can be used for practical valorization and utilization.

4.1. Investment opportunities

In the Netherlands, there is a great potential for investments in sustainability in the built environment, in particular, for healthcare facilities. Recent market explorations by ABN AMRO [19] bank have studied the status of the Dutch healthcare real estate in terms of sustainability performance, and the related requirements for change and need for financing. The total surface area of real estate in long-term care is about 22 million m^2. As this surface area is vast, the bank advises to focus on real estate with an average age between 6 and 15 years old. The premises are adequate in terms of user-friendliness and health, but do not yet exploit all potential for energy conservation. The bank also estimates that about 5–10% reduction in CO_2 emissions is possible by a change of behavior of the occupants, for instance, by tuning the need for lighting and heating. The main solutions for energy savings lie in the installation of LED lighting systems (with sensors to detect the presence of people and availability of daylight), solar panels and heat pumps, which comes at a cost of € 185 per m^2. This leads to a potential reduction in CO_2 emissions of over 60%. ABN AMRO further estimates that for the total long-term care sector, M€ 900 suffices to make real estate sustainable. The payback period would be less than 10 years [19]. In addition, Bedir et al. [20] defined the influence of lighting and appliance use on electricity consumption in Dutch dwellings, and identified determinants of use, through regression analyses of data gathered through questionnaires completed by 323 occupants in the Netherlands. The research showed that duration of appliance use and dwelling and household characteristics are important predictors in models of electricity consumption. Moreover, improvements to the energy efficiency of dwellings should not lead to social exclusion. Due to the concept of eco-districts [21], it is possible to combine socially diversified neighborhoods [22] in order to connect a large number of opportunities in different housing areas. As a result, renewable energy produced at one place could be shared with other buildings in a surrounding area. Solutions to optimize investments in renewable energy are already known in relation to urban development planning [23,2,3], and, therefore, it is just a matter of political decision making to implement such tools in practice.

4.2. Opportunities for behavioral change

Apart from the Energy Battle, the cases described do not directly lead to major behavioral changes among tenants. The installation of sustainable energy systems as such does not lead to more "green" behaviors. According to van Middelkoop et al. [6] people are not easily convinced of the need to take measures to improve the energy performance of their houses, even when financial benefits outweigh the costs. In the Netherlands, both owners and tenants (50–70%) support government policy on energy performance improvements to existing homes. Nevertheless, people also have strong feelings of autonomy regarding their homes. Van Middelkoop et al. [6] explored the decision-making process of households for implementing energy saving measures to their homes. They describe a model in which policies impact not just the household and dwelling characteristics (physical context), but also the social context, behavioral processes and preferences, convictions and values of home owners and tenants. This, in turn, leads to investment behaviors, including the implementation of energy saving measures, and their depth, as well as daily behaviors.

Mills and Schleich [24] established relationships between measures of household energy use behaviors and household characteristics, using a dataset comprising 5000 households in 11 European countries. Households with young children are more likely to adopt energy-efficient technologies and energy conservation practices and place primary importance on energy savings for environmental reasons. By contrast, households with a high share of older adults place more importance on financial savings, and have lower levels of technology adoption, energy conservation practice use, and knowledge about household energy use. Vassileva et al. [25] evaluated the effects of the different ways of presenting feedback used for different households groups. The monthly income is amongst the most influential factors determining electricity consumption although only in high and low income groups. The analyses of the consumption patterns showed that the major

[10] http://wetten.overheid.nl/BWBR0033729/2017-01-01.
[11] https://aedescms.getbynder.com/compact/?mediaId=D2C0A039-7A09-411B-939F1B15FDD3C35D.

variations can be found between individual households rather than households groups. Therefore, we consider that individual and specific feedback (personalized for each household according to different preferences, characteristics and needs) should be provided to the households instead of generalized tips and information applicable to all households. Gordon-Wilson and Modi [26] studied the older consumers' overall green behavior, and whether their level of greenness can be explained by their personality. According to their study, which was based on subjective self-reports of older consumers in the UK; the openness personality trait to be positively linked to green behavior, whilst the extraversion personality trait is negatively related to green behavior. Although the level of green behavior increased with older consumers' age, this did not reach significance. Walker et al. [27] stated that the market for home energy products is currently large and growing. They identify two main types of products for the ageing population: home energy monitors and automated energy systems, which are installed in dwellings in order to help save energy. Sadly, Walker et al. [27] also identified a number of serious usability issues which prevent these products from successfully accessing the market place.

4.3. Opportunities for smart home technologies on behavioral change

Another technological solution for sustainability that is emerging are so called smart metering, consumption-feedback systems, in-home displays and smart thermostats. These systems are expected to increase user knowledge whilst improving comfort, safety and the ability to cope with increasing costs of energy in the residential sector [28–30]. These technologies address people's energy-related behaviors. Such behaviors have two implicit dimensions, namely the behavior itself and the associated energy consumption [31]. Barnicoat and Danson [29] noted that is it important to understand older people's behaviors regarding energy and technology use, as they are usually living on low incomes and are at risk of fuel poverty. Their study revealed that participants showed little knowledge of energy efficiency of home or appliances and the cost of energy was relatively unknown. In all, there is a lack of awareness of the changing energy technologies with little evidence of peer pressure or other drivers to change behavior. Vilches et al. [32] argued that for those living in fuel poverty, their utility cost is already low (as they cannot afford to pay the bills), so retrofitting the building will not have much impact on their already low utility bills. In line with conclusions by Walker et al. [27], Podgornik et al. [30] concluded from their study on the consumption feedback and other complementary energy services provided to low-income households, that it is important to customize information and efficiency indicator. As the implementation of smart technologies target behavioral change among end-users, a process called norm activation has to be activated for new norms and considerations to enter the conscious decision-making process. Through this process, occupants become aware of the relevance of their behavior and its relation to energy consumption, the possibilities to sustainably influence personal behavior and the environmental issues associated with energy consumption.

4.4. Conclusions and recommendations for other social housing associations

Habion shows that real estate that seems functionally outdated can still be useful. As the older people in our societies are growing increasingly older, this demographic development calls for more and better dwellings in order to provide adequate and sustainable housing. The case studies have shown that energy efficiency in the built environment is not merely a task for engineers, who, through their designs, can develop or redevelop energy efficient buildings and building services. The Energy Battle has shown that substantial energy savings are possible in existing buildings without the need to retrofit. All that is needed is the active participation of tenants and the willingness to change their behavior and lifestyle. Financial incentives are important, but are not the main driver behind participation and change. This approach can also be tried by private home owners or other cohorts of tenants, including office workers. The crowdfunding initiatives have shown that by dividing large investments into smaller bonds, more people have access to energy friendly projects. Participants can benefit from ready-made arrangements for investment, the social housing association manages to improve its image as a sustainable housing partner through leasing its rooftop space at low financial risk, and the tenants themselves benefit from the availability of free energy and the possibility to invest some of their limited savings into a green energy project. The crowdfunding actions have demonstrated a substantial willingness among tenants and in society to invest in green energy, partly because of the return on investment. Investors contribute to both financial and societal returns. Many older people participate by buying bonds. This enables them to leave something for their (grand)children: a better world, bonds, and financial revenues. Again, the trigger to participate lies in the group or community approach to making a building energy efficient, and, in case of external participants, without having to worry about installing solar panels on the own rooftop. The thermal energy storage systems can only be installed in newly designed buildings, but require a significant amount of training among tenants (as well as behavioral change) on how to operate the systems in order to maintain indoor comfort without increasing the costs for energy. Although substantial reductions in CO_2 emissions can be achieved, the costs of installing thermal energy storage systems are large.

Habion is working hard to achieve an annual reduction in CO_2 emissions of over 1 million kg per year, by making its real estate more sustainable, and thus improving the market value of its portfolio. When transforming healthcare real estate, sustainability and energy producing building services technologies should be an integral part of the strategy. Sustainability means business, and can be at the basis of collaboration between social housing associations and the building services sector. Chain partnerships can lead to mutual benefits, in which real estate for older people and the behaviors of the residents can contribute to the goals set out for a sustainable society.

Overall, the case studies show that older people renting property from social housing associations can be motivated to save energy in daily lives through both active involvement (as was the case in the Energy Battle and by investing in solar panels), and passive involvement (use of green energy and making use of sustainable energy systems in their own home). These investments are financially viable, and with the right amount of guidance and training do not have to go together with a loss of comfort or well-being. At the contrary, older people can contribute to sustainable goals set out by national governments and save money on utilities bills which they can spend on other things. Fuel poverty cannot be fully eradicated by the programmes illustrated in the case studies, but a purchase power improvement of several hundreds of euros seems possible as the problem is seen in combination with cutting down on electrical energy use. This is of particular important for single-person older households, who are financially worse off than couples or people benefitting from adequate pensions, and who lack the opportunities on the labor market to improve their financial situation. The Dutch case studies show that sustainability programmes in the built environment may even (slightly) improve the purchase power of older people, which -in an international context- may be one of the solutions to combat fuel poverty.

Statement of conflict of interests

Joost van Hoof is a board member of Vastgoed Zorgsector, and member of the supervisory board of Habion.

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