



Living in an Active Home: household dynamics and unintended consequences

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ABSTRACT

To meet UK decarbonisation and climate change targets, significant changes to existing and future housing stock will be required. The development of Active Buildings has the potential to contribute to meeting these targets. Active Homes, as a particular type of Active Building, alter how energy is produced, distributed and consumed, as well as how homes are designed, constructed and then lived in. Before occupation, Active Homes are designed and developed around imaginary users, yet residents do not always live in the homes in ways envisaged by developers. This paper draws on data from a qualitative longitudinal study involving in-depth interviews with Active Home inhabitants and developers across five UK case sites. Interviews elucidate how developers envisage future residents and their assumptions about how people will live. As the household is a particularly gendered sphere of society, three qualitative longitudinal case studies are then presented to explore the way gender interweaves with women's experiences of Active Home residence. Expert visions do not always fully encompass the gendered household dynamics of everyday life. Implications are drawn from how these Active Homes are experienced and lived in: what considerations developers can give to the design, controls and information that are more tailored to residents' needs.

PRACTICE RELEVANCE

This paper investigates the designers and developers of Active Homes, as well as the residents who live within them. The design of homes and the technologies they encompass have implications for the gendered dynamics of residents' everyday lives. Areas are identified where changes could be made in future developments. This includes providing information to residents about the operation of different technologies within the home, as well as how they interact with one another to impact the home's performance. The women in these case studies indicated a willingness to change their everyday energy practices, but wanted more information about their homes to maximise energy efficiency. Resident satisfaction will be crucial to the success of Active Homes, and insights from these early Active Home developments have important implications for wider rollouts.

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1. INTRODUCTION

Meeting UK decarbonisation and climate change targets will require significant changes to the existing and future housing stock. Active Buildings have been developed as one approach to building that seeks to address these targets. The characterisation ‘Active Building’ has been used to differentiate buildings with ‘active’ technology that produces, uses and exports renewable energy, from ‘passive’ buildings such as Passivhaus, which reduce energy consumption and emissions due to ‘*in-situ*’ energy efficiency properties such as thermal insulation and natural ventilation (Ionescu et al. 2015). However, current definitions of Active Buildings go beyond this, emphasising their ability to:

generate and store renewable electricity to meet their own needs and intelligently redistribute the surplus to other buildings and back into the grid.

(ABC n.d.)

(See also O’Sullivan et al. (2022) for an in-depth discussion.) Of particular interest to social scientists are Active Homes, which represent a potentially transformational innovation by altering how energy is produced, distributed and consumed, in addition to how homes are designed, constructed and then lived in. Such homes are expected to benefit residents by representing:

houses of the future, offering self-sufficiency, improved quality of life and a tangible economic payback.

(ABC n.d.)

Before occupation, Active Homes are designed with particular expectations of residents in mind. Existing research has highlighted how such expectations play a key role in expert visions of low carbon housing, ‘and will be crucial in shaping the future of UK housing’ (Cherry et al. 2017: 37). However, residents do not always live in the homes in ways envisaged by developers, which has implications for how the homes perform and are experienced. Therefore, it is important to consider both expert expectations of residents—particularly how these relate to design decisions that may subsequently impact residents’ everyday lives—and the experiences of Active Home residents themselves, in order to inform the successful development and rollout of Active Homes.

Important to understanding the experience of Active Home residence is a recognition of homes as spaces where everyday lives unfold, and as one of the most gendered spheres of society in most cultures (Tjørring et al. 2018). Women still have the largest workload in households (Gram-Hanssen et al. 2017), and gender is central to the performance of residential practices of energy consumption (Mechlenborg & Gram-Hanssen 2020), therefore paying attention to gender is important in energy research. The present paper refers to gender as the socially prescribed roles and behaviours culturally inferred from biological sex (Fathallah & Pyakurel 2020).

This paper draws on both expert and resident data concerning the experiences of designing and inhabiting an Active Home. First, a review of the existing literature is presented. The methods are then outlined and the data analysis is presented in detail. With relatively few Active Home developments in the UK to date, the paper draws on literature from multiple countries into relevant related concepts and experiences, which informed the research.

1.1 EXPERT VISIONS OF RESIDENTS

Whilst real-life examples of Active Homes are currently limited, albeit growing, existing research has considered the inhabitant experiences of smart homes. Smart homes incorporate internet-enabled appliances, facilitating remote control, monitoring and automation, but do not necessarily hold the capacity to produce and store energy or respond to electricity grid signals, as Active Homes do. Researchers have noted a gendered dynamic in the interest and adoption of smart home technologies, indicating that they appear to be less appealing to women (Strengers et al. 2019; Furszyfer Del Rio et al. 2021). One suggested explanation is that largely male smart home designers have neglected or undervalued the domestic responsibilities that often fall to women (Strengers & Kennedy 2020). Yet, it has been argued that trivialising the role of chore-doing is

problematic, given housekeeping entails decisions that impact national energy infrastructure (Johnson 2020). This failure to account for the gendered nature of everyday domestic practices may mean that residents do not engage with smart home technologies in ways that designers have anticipated, affecting their performance (Larsen & Gram-Hanssen 2020). Whilst smart homes may differ from Active Homes in certain respects, in the wider context of accelerating household interest in battery storage, electricity sharing and trading, and demand-response opportunities to better use the electricity they generate (Strengers et al. 2021), these innovative housing developments may further align in future.

Conflicting narratives regarding smart home residents, and users of smart grids and energy systems more broadly, have been identified, often within the same accounts (Dahlgren et al. 2020). Two dominant conceptualisations have been frequently discussed: an active public engaged with new technologies and a public envisaged as irrational and deficient in knowledge (Goulden et al. 2018; Cherry et al. 2017), respectively termed ‘resource man’ (Strengers 2013) and ‘indifferent consumer’ (Goulden et al. 2018). Such imaginaries highlight conflicting expectations of a passive role for consumers where technology acts on their behalf, alongside an active role where consumers take control of technology, energy and the environment (Strengers 2013). Despite various critiques of these binary archetypes, including from a gender perspective—given ‘resource man’ represents an archetypical masculine consumer (Strengers 2013)—they continue to be evident in expert accounts of residents (Cherry et al. 2017). However, existing research has highlighted how it is important to move beyond such narrow distinctions in order to provide insights into how residents engage with energy production possibilities (Strengers 2013, Winther et al. 2018), and the implications that this has for everyday lives.

Research by Dahlgren et al. (2020) into energy industry visions identified several claims about how people are expected to relate to technology and future technological change. One of these is the idea that opportunities for consumers to access and participate in the energy market by using new energy technologies will give rise to the engaged consumer and prosumer. This is relevant to Active Homes, which have the potential to change residents’ relationships to energy through the inclusion of energy-generation technologies such as solar photovoltaics (PV), which may require active administration (Hansen & Hauge 2017). Existing research into low carbon housing has highlighted potential tensions between expert expectations of residents and the experiences of residents themselves (Zhao & Carter 2020; Cherry et al. 2017). However, previous research into ‘prosuming’ households has largely focused on those who have chosen to install few or individual technologies, reflecting a sample who are energy-minded and engaged (Stikvoort et al. 2020). There is therefore scope for research that considers a wider variety of perspectives and experiences of life in innovative home developments in order to move beyond these binary views of residents. These insights from existing studies raise interesting questions for the present original work into Active Homes and whether potentially more active residents will be envisioned, either by developers or by residents themselves, and what implications this has for everyday life in the homes.

The ways in which future Active Home residents are envisaged may relate to the gendered character of technology development (Wajcman 2004). How technologies are integrated into daily domestic lives has implications for dynamics within households, potentially perpetuating asymmetric gender dynamics (Furszyfer Del Rio et al. 2021) and concentrating control of the home in the hands of the most tech-engaged household members (Nicholls et al. 2020). For example, Kennedy et al. (2015: 415) found:

a significant proportion of female participants described being digitally literate and competent users of digital technologies, yet were ‘disinterested’ or yielding to a male household member’s expertise when it came to digital technology-oriented decision-making.

This may contribute to an epistemic construction of men as confident ‘knowers’ or an authority on technology, with women more hesitant about expressing knowledge of or pleasure in technological control (Henwood et al. 2008). Similarly, Strengers et al. (2019) found that most

women were less tolerant of technology that was ‘glitchy’ or time-consuming, whereas men were more likely to persist with technical difficulties, even considering it a pleasurable hobby. One possible consequence of men’s greater involvement in ‘digital housekeeping’ (Tolmie *et al.* 2007) or technical maintenance is that more of the traditional or ‘physical’ housework falls to women (Strengers & Kennedy 2020).

1.2 DOMESTIC LIVES OF RESIDENTS

Housework or traditional forms of domestic labour are conspicuously absent from smart home visions (Strengers & Nicholls 2018), yet the use of domestic appliances to fulfil everyday routines and caring practices has important implications for energy use. Despite associations between masculinity and technology, domestic appliances are often associated with women—most particularly the washing machine (Tjørring *et al.* 2018). As Shove (2003) argues, laundry is routinely positioned as women’s work, with laundry-related responsibilities inextricably bound up with the reproduction of gendered identities. Beyond operation of the washing machine, laundry involves drying clothes to ensure they have the right smell, texture and feel, qualities which may be overlooked in smart home design (Strengers & Kennedy 2020).

Differences between men and women, both real and perceived, are also evident in the achievement of thermal comfort. Research suggests that women prefer warmer indoor temperatures and consider homely comfort more important (Hansen *et al.* 2019). This resonates with De Wilde’s (2021) research regarding heat pumps, where one installer described comfort as a ‘feminine concern’, noting that women found it difficult to adjust to cold floor temperatures following heat pump installation. In their interview study of households participating in energy-saving intervention measures, Carlsson-Kanyama & Lindén (2007) found that lower indoor temperature and fewer hot baths had a greater impact on women than on men. Beyond personal comfort, both heating and hot water play an important role in demonstrating care for others, a typically gendered practice (Shirani *et al.* 2017; Strengers *et al.* 2021).

Given much domestic work is undertaken by women, it is important to consider how this relates to energy consumption patterns, in the context of efforts to reduce energy demand. Whilst research has indicated greater interest amongst men for data concerning energy consumption and production, including smart meters, the time shifting of practices to save energy is predominantly undertaken by women (Mechlenborg & Gram-Hanssen 2020). For example, Johnson (2020) describes how ‘flexibility woman’ was visible empirically in her research into demand-side response, as someone who had knowledge of family routines and consumption practices, and who made efforts to shift electricity consumption where feasible to generate system level benefits. Similarly, Carlsson-Kanyama & Lindén (2007) describe women increasing their domestic workload by altering laundry practices to achieve energy savings. This may also reflect a tendency for women to be more environmentally concerned and engaged in taking action to address climate change (Gram-Hanssen *et al.* 2017).

In the context of purported feminisation of environmental responsibility (Sunikka-Blank 2020), some research has indicated a greater concern amongst women about both cost and environmental implications of smart home technologies (Furszyfer Del Rio *et al.* 2021). This resonates with an ecofeminist perspective, which calls for critical examination of the appropriateness of technology (Romberger 2011), highlighting its potential ecological costs (Clark 2012). Beyond ecofeminism, others have offered critical discussion of instances where technological consumerism is posited as the solution to ecological catastrophe (e.g. Taffel 2018). Such reflections are often absent from smart home visions, given that the ‘smart utopia’ aims to perform a way of life mediated by and through technology (Strengers 2013). The pervasiveness of technological ‘solutionism’ (Morozov 2013), where technologies are positioned as the solutions to environmental problems, needs to be critically considered, as installing sustainable technologies in residents’ homes does not guarantee environmentally beneficial effects (Ozaki & Shaw 2013). Understanding how residents relate to these technologies and live in homes designed around them, as well as how developers envisage the homes, is therefore crucial.

2. LIVING WELL IN LOW CARBON HOMES

The Living Well in Low Carbon Homes (LWLCH) project incorporates five innovative developments across South Wales in the UK, enabling consideration of Active Homes built according to different principles. The case sites each have different home specifications, energy technology configurations, tenures and locations. However, common to all the developments is the inclusion of solar PV, intelligent battery storage, high levels of insulation and electric heating (either via underfloor heating or electric radiators). The LWLCH project is part of a broader social science work package that forms part of the Active Building Centre Research Programme.

The first strand of the LWLCH project research involves qualitative interviews with relevant stakeholders or experts such as designers, engineers, developers and registered social landlords (RSLs), to understand the impetus behind and process of designing the homes, what they hope the homes will provide and how they imagine future residents. The second research strand involves qualitative longitudinal interviews with residents to provide a detailed exploration of experiences over time. Residents are initially interviewed a few weeks before moving into their Active Home and twice within the first year of occupation, enabling consideration of their initial motivations for moving and expectations of the home, as well as their later experiences of residing in the homes. Qualitative interviews helped to provide in-depth understanding of participants' experiences, while a longitudinal approach with residents meant that participant accounts could be collected as biographically transformative experiences (such as moving house) were lived through (Miller 2015), enabling exploration of change over time (Saldaña 2003). Interviews are transcribed verbatim and coded thematically using NVivo software. In addition to thematic analysis across a single wave of interviews (as with the expert data), the qualitative longitudinal design enables diachronic analysis to be conducted, looking at individual accounts at different points in time to explore the meaning of changes in everyday life across participants' accounts (Shirani *et al.* 2017). Such longitudinal studies that explore the impacts of several technologies and how they interrelate are exceptional (Hansen & Hauge 2017).

Participants were sent information about the research via housing officers and sales advisors and were invited to contact the research team if they were interested in taking part. Subsequently they were sent more detailed information about the project and were asked to complete a consent form. Information was reiterated verbally prior to each interview, with the opportunity for participants to raise queries, before being asked to verbally confirm their consent. Thus far, eight women and 18 men participated in expert interviews, reflecting the male dominance of these industries, whilst resident interviews involved 24 women and 13 men. Participants ranged in age from their 20s to their 70s, and across the resident sample there were a variety of living arrangements, from single adults to family groups. Most resident participants were interviewed individually, but eight were participating as couples.

The following section presents data from experts. This is followed by the experiences of three female residents in detail. For anonymity, experts are referred to numerically, with 'M' or 'F' to indicate if participants were male or female, and pseudonyms are used for residents.

3. EXPERT PERSPECTIVES

As noted above, there are some commonalities between the studied Active Home case sites: all are low or zero carbon, all hold the capacity to provide grid flexibility, and all can be replicated or 'scaled up' to neighbourhood or city scales (O'Sullivan *et al.* 2023). However, Active Homes may be realised in different ways and developed according to different motivations, with decarbonisation not necessarily the primary aim. For example, other motivations include sustainable energy production, creating environments that improve resident health and wellbeing, enhancing connections to nature, alleviating fuel poverty, and sustainable resource use (O'Sullivan *et al.* 2022). Experts were interviewed from a range of specialisms, including architecture and design, project management, technology and engineering, policy, sustainability and resident liaison (e.g. sales, housing officers and customer service).

Few experts made explicit references to gender when discussing how they envisaged people living in the homes, yet appeared to have clear ideas of what they considered desirable resident behaviours, which had gendered implications. Some experts felt that providing information to residents about how the homes operated was beneficial:

So users learn [...] they can see the screen and see oh, it's sunny and we're generating this much, let's stick something on, let's plug the car in. And if they can see the batteries are full, they'll probably want to try and empty the batteries so that they can put more in. [...] I think having the display screen, having something that connects people to their energy usage is really, really good.

(expert 1, F)

Yet others thought that in-home display screens were of limited use, with the residents caring more about 'outcomes':

[a]ll of the homes do have smart meters [...] what we don't particularly worry about putting in is the smart display [...] research on those tends to suggest that you ignore them within three to six months and so they don't have a long-term behaviour change impact [...] we just recognise that most people don't care about it, if brutally honest. So what they care about will be the outcome of when which room is at which temperature.

(expert 5, M)

This view that the residents were uninterested in the technology or could be overwhelmed by its complexity was in some cases used as a rationale for minimising resident interaction with the home's energy system, which was viewed as being more efficiently managed by experts:

[s]ome of them are struggling with the electrics, and how to work the solar panels. To be honest, there's nothing they really need to know [...] because it was set up to maximum efficiency, they didn't need to touch it [...] basically [instructions] said, 'Don't touch anything, leave it as it is, it's fine.'

(expert 26, F)

This echoes expert discourses elucidated by Cherry *et al.* (2017) of 'designing out' the role of occupants, who were seen as resistant to change. The view that residents were not well placed to operate the technology was also reflected in expert descriptions of residents' 'perverse' or 'mismanaged' use of the home's energy system, which largely related to domestic heating. This view could reflect an epistemic construction of the (largely male) designers and engineers as competent 'knowers' (Henwood *et al.* 2008) of technology as a masculine-coded artefact (Mechlenborg & Gram-Hanssen 2020), in contrast to perceptions of uninformed or disengaged residents. Residents were described as finding it difficult to adjust to electric heating systems, particularly underfloor heating. Whilst some experts explicitly noted that women preferred higher indoor temperatures, reinforcing the notion of comfort as a 'feminine concern' (as discussed by De Wilde 2021), most did not make gender distinctions and discussed residents' challenges with the heating system more broadly.

Changes to the material structure of houses, particularly heating systems, meant that residents needed to adjust to new ways of sensing thermal comfort and related everyday practices (Madsen 2018), no longer relying on being able to feel the warmth of a radiator. Yet on occasions where residents expressed dissatisfaction with thermal comfort, for example, because floors still felt cold despite the underfloor heating system, experts indicated that there was often little that could be altered. This suggests that despite embodiment being integral to understandings of thermal comfort, resident concerns for comfort were minimised and technical measures and performance were often prioritised by experts. Many experts suggested that if residents were informed of the most efficient way to do things, or advised not to continue inefficient household practices, this would encourage people to make changes. This was particularly evident in expert discourses around laundry:

[w]hen we talk about the low temperature heating system we do get some people who are, 'well, what about when I want to dry clothes? I normally just put them on the

radiator so how am I going to do that if I've got underfloor heating? Do I need to stretch them out on the [...] and that's when we have to say 'drying clothes on a radiator is a really bad idea, it's more expensive, it's not good for your home, it's not good for your health, it's not great for your clothes'.

(expert 12, M)

This requirement to change washing routines reflects a broader discussion within the expert interviews as to whether resident 'behaviour change' was viewed as necessary or desirable. Some felt that having technology 'behind the scenes' should enable people to continue existing lifestyles so that 'anyone could live in the homes':

[w]e don't want people to think that they can't touch anything [...] there's a combination of technologies there but most of it is working behind the scenes for them, they don't need to worry too much. And we also want to make sure that the people can live the way they want to live, rather than being forced to live in a particular way.

(expert 23, M)

Conversely, others thought that homes would prompt a different way of living:

[w]e shouldn't think that people need to heat up to what they have, and they need to act, and they need to live a little bit differently. [...] I think that we're hoping that that message will get translated in these properties and people will really realise that they need to, as well as just tuning their energy down, they need to also be, be aware that they can't keep it to a paradox of using more energy because it's cheaper.

(expert 22, M)

In contrast to decisions to keep the complexities of systems 'behind the scenes', some case sites sited technology in a prominent position, such as locating batteries in kitchens or hallways. Some experts felt like this would act as a 'surreptitious reminder' to save energy.

In highlighting insights from these expert accounts, it is possible to see contradictions in the way experts envisage residents; with some expecting residents to make changes to their everyday lives in response to information about their homes, whilst others suggested the homes could be more efficiently managed by experts. These conflicting visions suggest a lack of clarity as to whether Active Home residents are expected to take an active or passive role in managing their energy use, which has implications for the kind of information offered to residents about their homes.

Experts did not frame their views in explicitly gendered terms, nor was there a significant difference in perspective between male and female experts. However, these expectations of how people will live within the homes have potentially gendered implications. In light of this, the focus now shifts to resident data and the impacts of expert decisions on the everyday lives and gender dynamics of households.

4. RESIDENT EXPERIENCES

This section presents case studies of three female participants to explore gendered experiences of Active Home residence in detail. The case studies illustrate the experiences of women who live at three different case sites, described below, and enable a detailed view of a range of experiences. The selection of participants with varying ages is to elucidate some of the gendered experiences associated with different life-course stages. The experiences of female participants are foregrounded, as they comprise the majority of the resident sample and women's greater involvement in domestic tasks is significant for energy demand reduction (Johnson 2020). The three women's cases have been selected from the broader sample to highlight relevant issues as they have good explanatory power, offering insights into the broader research themes (Neale 2019). These individual cases therefore act as illustrations of wider patterns within the data set, with the depth of qualitative longitudinal data providing a relevant foundation for insights (Thomson 2007).

Shannon, in her 30s, lived in a three-bedroom socially rented Active Home with her male partner (not interviewed) and children. The home was designed to produce a significant proportion of the energy required, including PV roof films, battery storage, air-source heat pumps and transpired solar collectors on the homes' cladded walls. Having moved there from a small, older property that was hard to heat, Shannon had opted for the property based on its size and location, but was hopeful that the active element of the home would mean an improved living environment, as well as reduced energy bills. Whilst Shannon was given information booklets explaining how to operate the different technologies in her home, some elements—such as the batteries—were located away from the home in a locked unit and she felt she had little understanding of how these operated.

Post-occupancy, Shannon was concerned about high electricity bills, but felt limited in her ability to make changes to heating because of her caring responsibilities:

I know some tenants on the street have said turn the radiators off. But if I turn my radiators off and we're really cold, what am I going to do, 'cause obviously with a one-year-old who's just learning to walk, you can't sit still under a blanket and put loads of layers of clothes on.

Some of the participants spoke about how they had an insufficient quantity or temperature of hot water during the first few months in their homes. In Shannon's household this resulted in her prioritising other household members and restricting her own bathing comfort:

I'm trying to shower so that [children] can have baths. And then it's in and out within five minutes [...] obviously with men and women it's different 'cause we've got longer hair to wash and [partner] will try to get in before me, so he has a warm shower, and then I'll just have barely lukewarm then, by the time we've all bathed and showered.

Shannon described making efforts to reduce energy use where feasible because of concerns about cost, such as reducing use of or using fewer appliances, and switching everything off at the sockets, suggesting that the responsibility for doing this was 'mainly me'.

Revisiting Shannon after 12 months of occupancy, she described how some of the problems with the home and technology, such as the hot water, had been resolved, but others were ongoing. She echoed the concerns of other residents that not having full information about how the homes operated made it challenging to understand the systems and where they were not working properly:

I don't understand [the batteries], I wasn't told about none of this. So, I couldn't agree or disagree with them because I'm not a technological person, I have difficulty sometimes reading [laughs] my phone.

Whilst Shannon described herself as 'not a technological person', she had been able to work out other technology within the home where adequate information had been provided. She had been responsible for controlling the difficult heating system in her previous home, but found that the simple control system in her Active Home meant that other household members could be involved.

Yeah, that's a lot easier because even [child] will say to me, 'Can I have some heating on?' then I'll say, 'Yeah you know what to do,' and it's just as simple as touching a screen and it's done, kind of, thing.

Moving to a new heating system had implications for other household practices. For example, in poor weather many residents were used to drying washing on radiators, which was no longer feasible with the small electric radiators in the new Active Homes that residents were instructed not to cover. This led to some residents making greater use of the tumble dryers that had been provided to all residents by the RSL, as Shannon describes:

Yeah the radiators you can only fit a pair of socks and a pair of boxers on them. [...] So the tumble dryer does get used a lot more because even though they put washing lines up, they ain't the biggest of washing lines [...] and radiators] ain't big enough.

Shannon's account shows a mixed picture of Active Home living. Lack of understanding about how the home operated and feeling unable to make compromises in some areas due to caring responsibilities led to Shannon expressing concern about her energy bills.

4.2 SOPHIE—TECHNOLOGY CHALLENGES

Sophie, in her 20s, was first interviewed when awaiting the move to a three-bedroom Active Home with her male partner (not interviewed). These homes were designed to be highly insulated with a combination of renewable energy sources, including ground-source heat pumps and solar panels, intelligent battery storage and thermal water tanks, as well as optional smart appliances. Residents were also able to sign up for an energy service, which aggregates energy production and storage across the whole development to manage resident comfort and respond actively to electricity grid signals, with the aim of providing low-cost low carbon energy to residents.

Sophie described herself as environmentally conscious, attributing her initial interest to an all-female information and activism group:

I follow [...] a group on Facebook called 1 Million Women or something like that. And that's a lot about dealing with like climate change and the planet, and it's really interesting. [...] I came across them like by chance one day, and that's kind of what sparked my, like I'd always been kind of interested in the environment and protection. And that's kind of what got me thinking and it kind of went from there.

The choice to purchase an Active Home was described by Sophie as an extension of her environmental ethos and part of what she saw as an essential change to lifestyles in the future. This echoes the awareness and drive for change that expert 22 discussed above:

I think moving forward they're going to be a necessity. Like there's [...] not enough resources [...] and what we're doing to our planet is just terrible. [...] I never knew that homes could really be low carbon. Like I thought you'd have to buy a house and then do all that work yourself sort of thing. Which just seems like it's not feasible really. I don't know anything about any of that stuff. [...] I think it's a lot easier that they do come sort of already made.

Here Sophie describes Active Homes as an 'already-made' solution requiring less 'work' than retrofit, which makes it a more feasible option. Despite her enthusiasm for the move, Sophie felt that she did not fully understand how the home would operate, describing how her partner 'knows more about it than I do', but felt they would have a greater understanding once they had moved in. Sophie was enthusiastic about the house as offering an opportunity to live differently.

Post-occupancy, Sophie spoke about some challenges similar to those experienced by Shannon. For example, she described the water as being at an insufficient temperature for bathing, and had been told that this could not be altered, which had led to changes in her routine. Controlling her heating system via an app proved another challenge. An initial glitch with the software meant only one householder was able to use the app, and like other women in this research, Sophie spoke about how her partner largely did this:

I'm very technology challenged so I've, kind of, left most of that to [partner]. I have got [app] on my phone, but I don't really look at it because I just, phew [participant moved her hand over her head—indicating information went over her head], you know. [...] If [partner]'s not here I'm probably more likely to use the thermostat. [...] I just don't really want to accidentally change the schedule, I don't really know, like, exactly what I'm doing with it, to be honest.

This extract shows how Sophie had to rely on her partner to adjust the heating system or resort to manual control. Lack of engagement with the smart control system was about the technology not being user-friendly, rather than Sophie being disinterested or disengaged from energy use. Like the other women interviewed, she spoke of her desire for more information about the home in order to understand how it operated, which would provide more confidence in using the technology. Whereas Shannon's battery was out of sight, the visibility of Sophie's battery was a reminder of energy use:

I've got used to it [battery]. It doesn't bother me, and when I do see it, I do think [...] I wonder, like, how much energy's in there, whether we're, like, running off that or whether we're running off the grid. So it does make me think, yeah, and I think I just wish I had some more information about it because we don't really know a lot about it or what it's doing.

Alongside these challenges there were many positive aspects of Sophie's initial experiences in her new home: from surprise that she was able to dry laundry quickly without a tumble dryer or radiators because of the well-insulated warmth of the house, to the home's infrastructure enabling her to make other sustainable lifestyle changes, such as investing in an electric car. Sophie therefore saw her move to an Active Home as 'a massive step in the right direction' towards making her lifestyle more sustainable.

4.3 ROSE—A NEW START

Rose, in her 40s, had purchased an Active Home, moving alone from a large hard-to-heat older property. Rose's home was made using locally sourced timber and based on a low-tech concept. These homes also have solar panels and battery storage that can be monitored via an app, although the heating system, using electric panel radiators, cannot be monitored or controlled remotely. In her initial interview, Rose's husband figured prominently in her account of how she came to be environmentally and energy conscious:

[m]y husband was always much better about being very conscious about how much we consume [...] he basically kind of trained me to be aware of every time I switched the light on and always switch it off, never leave anything on when you walk out of a room. So he trained me very well in that respect. Sometimes it was irritating, but I'm very grateful to him for kind of making me really, really aware [...] just being very mindful of how much energy I consume.

When moving, rather than taking on a home that required a significant amount of work to retrofit, as with Sophie, a new build was seen as offering a low-maintenance opportunity for living more sustainably, given Rose's desire for 'greater simplicity'.

Although positive about the opportunities the house offered, Rose did have concerns about some aspects of the design, which she had raised with the developers. This included what she saw as insufficient consideration of impacts of some aspects of the home, particularly potential emissions and complexity from including high levels of technology, which she questioned the necessity of in an 'eco home'. Rose spoke in gendered terms about how she felt she was perceived by the developers:

I think [developers have] probably labelled me as a bit of a fusspot or a bit of a sensitive person. So yeah, so sometimes I cringe a little bit when I have to talk to them yet again about something. [...] I probably would have let my husband deal with all of that. [...] He was very strong and he was an engineer, he had all those kind of knowledge and I would have just let him deal with it and just shied into the kind of shadows.

Like others, Rose indicated a willingness to make changes to her routine in order to maximise use of renewable energy generated by the house:

if it does make a difference, then yes, obviously I would very much be looking to time the charging of my car or the putting on of my washing machine with when the sun shines

but was also looking forward to a home that required less work to keep warm.

Post-occupancy, Rose was positive about many aspects of her new Active Home, but, like Sophie, spoke of challenges with controlling her heating due to lack of information about how the system worked, and a control mechanism that was not user-friendly:

I suppose that's the other thing about the house that I realise I hadn't fully taken into account. I've got to be much more savvy about my whole electricity side of things. I used to let my husband deal with that kind of thing and I didn't really think about it too much and now I'm realising I've got to be much more, pay much more attention—even than I am now, I think—to be looking at that app every day noticing. Like, it's really easy to leave the heaters on overnight 'cause the heaters are very difficult to programme. [...] I turn them on and off manually but that relies on my memory and there have been days when I've forgotten to turn them off and I wake up in the morning, come down to the kitchen and it's warm. And it's like, oh, shit [laughs], you know, that heater's been on all night. So that's not as user friendly as I would have liked it.

The home had been designed with radiators that could be controlled individually to allow for different levels of heating in different rooms or 'zones' of the house, with the idea that less frequently used rooms could be heated to lower temperatures, meaning the heating system would be more efficient. In practice, the lack of convenient central controls could lead to heating inadvertently being left on and therefore greater levels of energy use. Having to get to grips with complex control systems without sufficient information was a challenge, as Rose described:

It's not something I'm interested in, so I have to kind of make myself go and be interested in it.

Rose expressed surprise that her Active Home was not as warm as she had anticipated, which led to challenges with drying laundry:

The other thing I'm finding difficult still is drying clothes because I don't want to use the tumble dryer [...] there's nowhere indoors to really put an airer because my utility room is my front porch. So it doesn't feel right to put my things hanging up in the main front entrance of my house [...] it doesn't seem right in an eco house to have a tumble dryer, somehow.

Drying laundry was an unresolved problem for Rose, and like others, she felt that investing in high-energy-consuming appliances was counter-intuitive to life in an 'eco house'.

5. DISCUSSION

In this research, the experiences of Active Homes varied, and these case studies do not represent the experiences of the entire sample. For example, a minority of women were very engaged with technology and initiated its introduction and use within their households. However, the three cases presented here, whilst detailing the specificities of individual circumstances and life-course stages, highlight important issues that were raised by several women in the sample more widely. In focusing on these three women, the aim has been to elicit and demonstrate some patterns of broader significance (Yates 2003), which have relevance for other Active Home developments. Through conducting detailed, interpretive analysis of this kind, this research aligns with efforts to understand implicit, gendered assumptions and their unanticipated consequences.

Whilst few developers and their experts made explicit reference to gender in their expectations of residents, it appears that ingrained gendered assumptions (e.g. technology as a masculine-coded artefact best operated by experts outside the feminine context of the home) appear to influence views of Active Home design and operation. Although the women in the case studies described themselves as 'not technological', all had made efforts to understand and engage with the new technologies in their homes. This more hesitant form of knowledge suggests a temporal process at play in the gendered knowledge gap (Henwood et al. 2008), with opportunity for women to become technological knowers over time. In her account of the significance of gender (in)authenticity to create sociological insights into the reality of engineered, technological cultures, Faulkner (2000, 2011) gives centre-stage to women's felt sense of what passes as ordinary but (slowly) changing in gender-technology relations. Such work similarly generates subtle, in-depth understanding of the non-trivial consequences arising from gendered and gendering practices and dynamics of exclusionary cultures.

Nonetheless particular interpretive challenges are posed by the role of embodied experiences, knowledge and ways of valuing everyday home comfort in home technology appraisals. The embodied experience afforded by home heat technology is also a form of gendered epistemic subjectivity (Henwood *et al.* 2008). Both these aspects of gender–technology relations were brought into view in the way women expressed not only feelings of discomfort but also intertwined this with making judgements as carers who were confident as knowers and incipient technology practitioners. Attentiveness to the role of such embodied knowledge alongside an emphasis on the importance of technological measurements of performance has the potential to further elucidate gendered household dynamics.

Analysis of expert interviews indicated a lack of clarity as to how future Active Home residents were envisaged, with some expecting resident behaviour change, whilst others favoured minimising resident interaction with technology in order to manage the home more efficiently by external experts. Despite describing themselves as not technological, all three women discussed here had made efforts to learn about the technology in order to better understand their homes and use energy more efficiently. This appears contrary to developers' assertions that residents are uninterested or disengaged with the way the homes work and suggests an appetite for Active Home residents to take an active role in managing their homes and energy use, which has implications for information provision. The women sought information themselves, but where they were unable to find answers—such as Shannon's confusion about how her battery worked—this could lead to concern about energy use and its impact on bills. Where compromises over comfort were made, the women spoke about being the ones to make these, but where such compromises were not seen as feasible because of their impact on caring practices, concerns about energy use and its impact on bills could overshadow the experience of Active Home living for some residents.

Most participants were positive about the design, layout and finish of their Active Homes across the different case sites. However, some felt that there was a lack of consideration for how routine household tasks would be accomplished; most notably washing and drying laundry, a task largely undertaken by women. Where homes are not designed in ways conducive to accomplishing these tasks, residents experience frustration, which impacts upon their experiences of and satisfaction with the homes. Rose's case illustrates how some residents were alert to aspects of their home that appeared to counter the energy-efficient ethos. This highlights the way Active Home developments need to pay careful attention in both the design and information provided to residents as to how practical everyday tasks can be accomplished, which may be of particular significance to female residents in light of the gendered dynamics of household labour. Without this, potential reliance on high-energy-consuming devices could undermine performance targets and claims of energy efficiency, as well as countering perceptions of sustainable living.

Active Homes were seen as a more convenient 'ready-made' solution to sustainable housing than retrofitting older homes, which both Sophie and Rose suggested that they would not know how to do and would be concerned about being 'ripped off'. However, this convenience was not always manifest in the way residents controlled the technology within their homes. For example, whilst individually controlled radiators may facilitate temperature zoning, the increased mental load of managing multiple devices rather than a central control meant participants such as Rose found they were more likely to inadvertently leave the heating on. Additionally, overly complex control systems may be subverted if not experienced as user-friendly.

This paper highlighted some challenges experienced with Active Homes, but participants also spoke of many benefits. For example, despite some initial technical troubles, Sophie was positive that her Active Home offered an easy way to live sustainably, prompting other lifestyle changes such as the move to an electric vehicle. This indicates that where Active Homes can facilitate everyday domestic tasks and are not experienced as overly complex, they have the potential to play an important role in the transition to more sustainable lifestyles.

Several areas have been identified where Active Home design may impact upon everyday lives, with potentially gendered implications. Drawing on data from both experts and residents, some practical steps are highlighted for developers to address some of these issues. First, by providing information to residents about how individual appliances, technologies and control systems work, but crucially also about how the various elements of the home interrelate. This could reassure residents about the operation of electric heating systems, help to identify faults and aid residents in understanding where changes to everyday practices could improve energy efficiency. Failure to provide information in the belief that homes are more efficiently managed by experts does not mean that residents will not try to seek this information themselves or make changes to their energy use based on erroneous assumptions. Information should be provided both in a form that residents can refer back to and through practical in-person demonstrations that illustrate how the homes and technologies work together.

By providing more information to residents, developers could help to challenge constructions of technology as a masculine artefact and enable women to become technological knowers as well. This depends on giving recognition to the ways in which women's contribution to technology design and its unintended consequences in home living spaces can have singular value and importance. Information provision is likely to present only a partial solution, as information may be selectively interpreted or disregarded. However, it could play an important role alongside an ongoing relationship with developers to provide practical support and advice as residents learn about their homes over time. Providing information in a timely way and at different time points over the pre- and post-occupancy period could therefore reflect the temporal process of learning to live in an Active Home, and potentially better support opportunities for women to become technological knowers over time.

Despite describing themselves as 'not technological', the three women discussed here all made efforts to gain knowledge about their homes and the technologies they encompass. The willingness to make changes in their everyday lives in order to use energy more efficiently that was indicated in the women's accounts was also evident more widely across the sample. Therefore, providing information about, for example, the best time to use or charge appliances to maximise use of renewable energy would appear to be welcomed by Active Home residents.

Second, more thought should be given to how the design of homes facilitates or hinders the accomplishment of essential daily practices. Two of the women's accounts presented here indicate the frustrations experienced in relation to drying laundry. Ensuring that homes have adequate space, layout and heating for such everyday tasks could therefore contribute to greater resident satisfaction with the homes. Similarly, attention should be paid to domestic control systems, as overly complex or impractical systems for controlling heating or hot water may be subverted by residents because they are not user-friendly, rather than because residents are uninterested or disengaged. For example, like other residents in the same development, Rose indicated that she would like a single control mechanism for her heating system rather than relying on individual radiator controls, which was seen as burdensome for the occupants. Consideration should also be given to the amount and complexity of technology included and to explaining the rationale for this, as residents are alert to apparent contradictions to the energy efficient ethos of their homes.

The present research identifies changes over time, contrasting participants' pre-move expectations with initial and longer term post-occupancy experiences. The authors' ongoing work will consider the extent to which initial technical teething troubles—such as the issues with the heating control app that Sophie encountered—have longer term implications for residents' experiences, and why understanding the gendered dynamics of everyday domestic lives is important in meeting socio-technical challenges. Wider environmental benefits will not come about by glossing over practicalities, but understanding how social lives are caught up in technical shifts and epistemic transitions to align positively with transformative change. The present study highlights the necessity of future research that engages with residents over time to provide a dynamic understanding of experience. Exploring residents' perspectives in detail will enable relevant insights to be offered to inform wider development of Active Homes and the policies that support such developments.

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COMPETING INTERESTS

The authors have no competing interests to declare.

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The data that support the findings of this study are not publicly available due to containing information that could compromise the privacy of research participants.

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