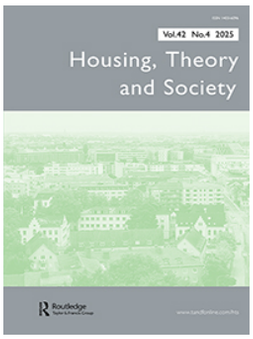

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"I Can't Imagine Living Anywhere Else": A Qualitative Longitudinal View of Low Carbon Home Residence

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ABSTRACT

There is an identified need for housing to decarbonize, yet new technical configurations of homes have implications for the everyday lives and relationships that unfold within them. Active homes, which can generate, store and export electricity, include a range of technologies that may be unfamiliar to residents and alter aspects of everyday life. With a small number of active homes in the UK, little is known about how people find life in these innovative homes and adjust to the combination of technologies that they encompass. This paper addresses an identified need for qualitative longitudinal insights from residents, foregrounding their lived experiences within these innovative homes. We highlight how the temporal perspective afforded by a qualitative longitudinal study is particularly valuable in elucidating the dynamic, evolving and relational nature of learning to live in an active home. We suggest that qualitative longitudinal approaches can offer new insights into resident experiences, of relevance to wider work on decarbonization transitions.

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Homes; lived experience; qualitative longitudinal; housing; heating; new build; low carbon

Introduction

To meet UK Government Net Zero greenhouse gas emission targets by 2050, the near-complete decarbonization of heating in residential buildings is required (CCC 2019), with an increasingly urgent need to transition towards a low carbon housing future (Cherry et al. 2017). A major aspect of this will be retrofitting existing buildings to improve energy efficiency and transition to low carbon heating systems, bringing extensive changes for customers (BEIS 2018). Retrofit is a pressing concern, as current buildings will make up around 80% of the 2050 housing stock. However, the development of new homes will also play an important role, given UK government's commitments to build 1.5 million new homes by 2029 (MCHLG 2024) and expectations that up to eight million new homes may need to be built by 2050 (CCC 2016). New homes are required to address demographic changes such as population increases, longer life expectancy and decreasing household size (Homes England 2024), as well issues with affordability associated with under-supply

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(Future Homes Hub 2025). It is generally much cheaper to integrate high-efficiency and low-carbon heating sources into new buildings than to retrofit those options to existing buildings (CCC 2016). As such, it is likely that a proportion of new builds will be active homes, encompassing highly energy efficient building designs and including energy generation and storage technologies, such as solar photovoltaic panels and domestic batteries, as well as low carbon heating systems. Developer hopes and ambitions for active homes include the aim to tackle pressing social issues, such as alleviating fuel poverty, as well as addressing construction industry sustainability and decarbonization targets (Shirani et al. 2022a).

Active or low carbon houses, however, are not just vessels for technology, but homes that involve personal relationships, expectations and experiences of residents (Goodchild, O'Flaherty, and Ambrose 2014), and research has shown how changes in heating technologies and the material structures of homes can change residents' everyday lives and practices (Brunsgaard 2011; Madsen 2018). Moving house has been widely explored as a moment of change or window of opportunity to encourage pro-environmental behaviour change (Bamberg 2006; McGuicken, Whitmarsh, and Toy 2024). Yet such approaches have also been critiqued for perpetuating individualistic notions of behaviour change. The word "moment" invokes a fixed before and after time point, when often it is more appropriate to think of ongoing processes of change (Burningham et al. 2014; Shirani et al. 2017) to consider wider problems of unsustainability through systems lock in (Henwood 2019). Instead, social practice theory (SPT) has been advocated within this area of work as an approach that moves beyond the individual (Hargreaves 2011) instead taking the practice or doing as the unit of analysis (Shove, Pantzar, and Watson 2012). SPT problematizes notions of an individual rational consumer, instead considering the collectively shared and routinized practices that individuals participate in based on norms of how to live a normal life, with energy consumed as part of these practices (Sovacool and Furszyfer Del Rio 2020). SPT has been utilized to demonstrate challenges with the flexibility of some elements of domestic energy use, which is fundamentally related to the rhythms of daily life (Blue, Shove, and Forman 2020), a consideration which may be overlooked in technical considerations of flexibility potential. Relatedly, differences between how developers envisage technology being used, and how people actually make sense of it in their everyday lives have emerged, with households developing workarounds to suit their own needs (e.g. Ozaki and Shaw 2014; Shirani et al. 2022b). These differences in actual versus intended use have implications for technological performance (Larsen and Gram-Hanssen 2020), resource intensity of homes (Hagbert 2016), as well as resident experience (Brunsgaard 2011).

Research on material changes to homes has often focused on the impact of individual energy technologies. For example, how energy generation technologies such as solar panels shift a household's role from consumers to prosumers – both producing and consuming electricity (Stikvoort, Bartusch, and Juslin 2020). Studies have indicated that microgeneration led to prosumers changing behaviour to consume as much as possible of their own electricity (Palm, Eidenskog, and Luthander 2018) and also appeared related to willingness to time-shift practices (Gram-Hanssen, Hansen, and Mechlenborg 2020). Consequently, it has been suggested that living in a house with microgeneration could convey a greater understanding of energy production and consumption, although monitoring devices and feedback technology appear to play an important role in creating this increased awareness (Galvin 2020). However, existing research in this area has often

focused on those who have chosen to invest in technology, reflecting an energy-minded and engaged sample (Stikvoort, Bartusch, and Juslin 2020), and we know very little about other people's readiness to embrace new technologies such as low carbon heating (Sovacool, Demski, and Noel 2021). Existing research from an SPT perspective concerning smart home technologies has shown variation in residents' engagement with the technologies related to previous experiences and embodied competences, which appears to impact whether smart home technology is met in a reluctant, compliant, or committed way by users (Madsen, Hansen, and Larsen 2023). This shows similarities to other studies highlighting the relevance of familiarity with or knowledge of control systems for resident satisfaction with their homes (Zhao and Carter 2020). Some research has also illustrated how 'experiences of new technologies are not usually rational responses, where people weigh up risks and benefits of various courses of action, but are part and parcel of lived experiences, rhythms and relationships with people and objects, imbued with multiple meanings' (Ransan-Cooper et al. 2020, 1). Subsequently, detailed qualitative research that can elucidate these varied lived experiences may support a better-informed approach to policy making (Maller, Horne, and Dalton 2012) and implementation.

Few studies have considered resident experiences of living with a combination of technologies, which active homes involve. A notable exception is a longitudinal study by Hansen and Hauge (2017) concerning households in one community where a number of technologies, including solar PV, heat pumps, electric vehicle charging and energy management equipment, were installed simultaneously. Hansen and Hague note that prosumers recognized dependence on the sun, which necessitated rescheduling practices to make the most of their solar energy. Our Living Well in Low Carbon Homes (LWLCH) project, which we draw on in this paper, differs from that of Hansen and Hague in two important ways. Firstly, our participants were moving into active homes where technologies were already installed, rather than choosing to retrofit homes, therefore engagement with the new technology is likely to be different. This assertion is supported by research by Winther, Westskog, and Sæle (2018), which suggests that those living in ready-made houses with PV regarded the solar panels as part of a package and were less interested in the technology than individual prosumers who had specifically chosen to instal PV on existing homes. Winther et al. present a picture of those in the "ready-made" houses only lightly incorporating PV, monitoring and feedback technology into everyday life. Such findings are relevant for exploring active homes, as people express a range of motivations for moving to a low carbon home (Goodchild, O'Flaherty, and Ambrose 2014; Shirani et al. 2022b); therefore, high levels of energy awareness and literacy cannot be assumed. The second respect in which our research differs is that all homes in our study included battery storage. As Ransan-Cooper et al. (2020) note, there are currently very few studies of household responses to battery storage installation, particularly ones which consider changes in relationships to the technology over time.

QL Research and Lived Experience

Existing studies have identified the need for longitudinal research in relation to smart home technologies (Madsen, Hansen, and Larsen 2023) and domestic batteries (Ransan-Cooper et al. 2020), to add important knowledge to everyday life and consider whether behaviours and views of residents change over time. Specifically, Berry et al. (2014, 127)

note an absence of understanding "whether households actually enjoy living in net zero energy homes and feel comfortable interacting with the types of technologies and systems required to achieve that net zero energy balance." We argue that important to exploring and understanding the impact of active homes is the foregrounding of participants' lived experiences. In particular, we suggest that a qualitative longitudinal (hereafter QL) design is particularly well-suited to illuminating the dynamic nature of lived experience and can offer original insights into life in an innovative home.

A number of existing studies in the energy field and beyond have advocated illuminating "lived experience", a term which is often used as synonymous with qualitative research (e.g. Ambrosio-Albala et al. 2020; Cox 2023; Fox 2023). As McIntosh and Wright (2018) note, there is a strong tendency for the term "lived experience" to be used with little or no clarification about what it might mean or imply. Some have attempted to define lived experience more explicitly, although acknowledging the challenges in doing so (e.g. Abbott and Wilson 2015) but have highlighted the significance of practical knowledge of what works and conversely what does not work (Abbott and Wilson 2014). What we understand to be lived experience, then, incorporates individuals' practical and everyday knowledge, which is situated in a physical, political, and historical context (Ellis and Flaherty 1992).

In their work on the lived experience of climate change, Abbott and Wilson (2014; 2015) acknowledge a temporal dimension, including practical knowledge gained over time, which underlines the dynamic and evolving nature of lived experience. This temporal perspective challenges static assumptions about residents and their competencies, instead providing insights into how relationships with technologies may be constantly changing (Madsen, Hansen, and Larsen 2023). Given its dynamic nature, QL research in particular is relevant as a methodological approach to explore lived experience, partly through the ability to elucidate change over time (e.g. Horne et al. 2021). Some studies that use the term "lived experience" or are closely aligned to it, also highlight the importance of taking a relational approach that recognizes shifts in social relations over time, emphasizing the importance of linked lives (Bolton et al. 2023; Hargreaves and Middlemiss 2020; Middlemiss and Gillard 2015). QL research is well-placed to offer a relational perspective on energy demand, recognizing the centrality of relationships and understanding these in the context of infrastructure and the built environment (Middlemiss et al. 2024). Below we detail our own QL approach.

Methodological Approach

This paper draws on QL data from the Living Well in Low Carbon Homes research project (LWLCH), which formed part of the Active Building Centre Research Programme (2020–2023). The study received ethical approval from Cardiff University School of Social Science ethics committee. Given the innovative nature of the developments, there are only a small number of currently occupied active homes in the UK. However, more sites are under construction, and with large-scale housebuilders beginning to adopt active home technologies (Redrow 2023), such homes may become more ubiquitous in the future. Our LWLCH project involved 29 semi-structured interviews with key stakeholders related to five active home case sites in South Wales and QL interviews with 37 residents at three of these case sites over an 18-month period. Our stakeholder interviewees identified Wales as a particular locus of innovation in

housing development, partly down to financial support via the Welsh Government's Innovative Housing Programme, which makes case sites in Wales relevant for research attention. Stakeholder interviews have illuminated important variations in how future building residents are envisaged to interact with active homes, which have been considered elsewhere (Shirani et al. 2022a). In this paper, we focus on QL resident case studies to illustrate the process of learning to live in the homes. Adopting this intensive form of QL design (Wanat et al. 2024) provides an accumulation of lived experience data, enabling us to explore participant experiences in detail over a period of significant change. Interviews were conducted by FS and KO and lasted 60–120 min.

All project case site developments included high levels of insulation, solar PV, battery storage, electric heating (some via ground source heat pumps and some via electric radiators), electric vehicle charging, and all homes had hot water tanks. However, sites varied considerably in scale (from 15 to over 100 homes), design (from traditional rendering to timber cladding) and location. One site offered an in-house energy service, which involved the use of an app to manage household heating and hot water.

Information about the research project was distributed to all future residents of our case sites by housing sales teams or by Registered Social Landlords, depending on each site's tenure arrangements, with individuals invited to contact the research team if they were interested in taking part. Table 1 provides demographic details for our sample, the majority of whom described themselves as white British, reflecting the local population for each case site.

Initial interviews took place prior to occupation, to find out about current circumstances, motivations for moving and expectations of active homes. Second interviews were undertaken 3 months post-occupancy, to explore initial experiences. Third interviews took place approximately 12 month post-occupancy, enabling participants to reflect on the experience of active home living across different seasonal and weather conditions, which has implications for energy demand. The majority of interviews were conducted remotely using video conferencing software or telephone, with some 12-month interviews undertaken in person. Interviews were audio recorded and transcribed verbatim, and transcripts coded thematically using NVivo software, involving both a priori and inductive codes. In addition, we compiled QL case studies for individual households

Table 1. Participant demographics.

	Category	Number of participants
Age at I1	20–29	8
	30–39	9
	40–49	6
	50–59	10
	60–69	3
	70–79	1
Sex	Female	24
	Male	13
Household	Single occupant	8
	Couple	12
	Family	17
Tenure	Social housing	15
	Private sale	22

to document experiences through time, which involves a chronological reconstruction and synthesis of case materials (Neale 2021).

In the following section, we foreground three case studies, selected from our wider study for their explanatory power, offering insights into our broader research themes (Neale 2019). Case analysis offers a diachronic, through-time reading of the data, which enables wider processes of change to be anchored in and understood through the lives of individual participants (Neale 2021), with the depth of qualitative longitudinal data providing a relevant foundation for insights (Thomson 2007). We selected three case studies to represent participants at different lifecourse stages, with varying motivations for moving to an active home. These participant accounts also clearly demonstrate the relational context of their active home experience, with different relationships relevant to each case. While lived experience is inherently subjective and diverse, it can act as a window into instances of the *shared typical* (McIntosh and Wright 2018). Subsequently, we regard these individual cases as "striking" or "emblematic" cases (Neale 2021), which convey empirical insights illustrating wider patterns within the data set. In other words, while rooted in individual experiences, the cases also reflect issues that were raised across the dataset more widely. Participants are referred to using pseudonyms.

Case Studies

Jake and Holly – "A Step in the Right Direction"

This couple in their 20s was first interviewed after the birth of their second child, while living in an older terraced home that Jake had renovated. They described their primary motivation for moving as an additional bedroom and had looked at different new build developments. Having a new build was a high priority for Holly, as "*you just walk into perfection"*. While the size, location and price were important aspects of their decision to purchase an active home, Jake described how the "*crazy technology*" that was integral to the homes was "*definitely right up there*" as a deciding factor. Despite this, they expressed some disappointment about where the technology was situated, describing the "*massive battery*" located in the living area as "*a bit of an eyesore*", but felt that its visible presence would be a discussion point when others visited their home.

Holly was depicted as environmentally conscious, describing how her concern about climate change had increased since having children:

> It is the fear, I've got two kids and I just want 'em to be able to survive on the planet [laughs]. I know it sounds ridiculous but that is what I think it is for me, it freaks me out.

During their first interview, they spoke of efforts to live sustainably in their current home, such as installing solar panels and avoiding single-use items. In this way, the couple described themselves as different to others in their community, who they suggested were not motivated to make changes to their present lives relating to what they saw as long-term issues like climate change, partly due to financial constraints:

> climate change, as we all know it's probably not something we're massively gonna feel in our lifetime, it's our children's lifetimes, are they gonna suffer for it? But, you know, thinking 80 years ahead, but that doesn't help you with what's in your wallet today. And I think that's where people get, they move away from doing something then, (Jake)

The new active home, therefore, represented an affordable option for Jake and Holly, who also saw it as a step that they could take personally to address climate change. Despite their enthusiasm, Jake expressed concerns about the innovative nature of the development and particularly how any problems would be resolved, as he would not be able to address things himself in the way that he was used to doing. Jake indicated this uncertainty and potential inconvenience was something that they were prepared to contend with in order to be "*doing our bit for the environment*". Despite the anticipated advantages, the couple did not see it as a long-term home saying, "*I don't think it's where we'd want to live forever*" (Jake), suggesting that they expected to move to a more rural area for a different kind of lifestyle as their children grew up.

The couple moved in and had their initial post-occupancy interview during the winter, when Jake described his disappointment upon receiving a higher than anticipated energy bill:

> I was disappointed with the first bill, I didn't expect it at all . . . at the end of the day it's for a good cause as well like, if everyone's going greener then it's, it's obviously better like.

The couple raised similar issues in relation to hot water. Upon moving, they had found it difficult to get used to the hot water tank, often ending up without hot water when they wanted to use it and having to wait for it to heat adjusting their routines to accommodate this. Following initial annoyances, the discussion moved to frame the changes they had made due to more restricted hot water as beneficial for avoiding waste:

> HOLLY: I'm more cautious now of like running the hot water in the day. Like I'll make sure that I leave hot water in the sink if I know that there's gonna be more dishes or something.
>
> JAKE: Yeah. I was gonna say, if she wants a bath she'll say to me, "Jake, I'm gonna have a bath, have you had a shower today?" . . . We just know that, keep it spaced out if we both need a shower that day, one of us do it early in the morning and one of us wait an hour or two for the next one or whatever. You've just gotta be savvy with it like.
>
> HOLLY: And I think that when you get used to something like that as well it can really help you manage it. Cos obviously it's important for like us not to use too much hot water and stuff anyway.
>
> JAKE: Yeah, it's wasteful, innit?

These discussions show that, whilst some elements of the home appeared inconvenient and more expensive than anticipated, Jake and Holly saw them as reasonable compromises for a "*good cause*" of reducing emissions, describing their willingness to time-shift practices. However, they also described becoming more conscious of energy use, because of the cost implications, and making more effort to switch things off. The couple were still getting to grips with the home and technology, expressing irritation with some features, such as the battery, saying "*it's a cool thing to show people when they walk in the house . . . But other than that literally it might as well not be there*." Despite these challenges, Jake and Holly were positive about their active home, describing it again as a "*step in the right direction*" although not a significant change.

The second interview indicated a potential shift in the way the couple saw their future on the site over a longer period than previously discussed, suggesting it was "a *nice thought*" that they would "*grow up together*" with other young families on the site in the

longer term. This was further evident by the third interview when Holly described how "*I can't see us moving, to be honest, like for a very long time, if ever*", as they were "*quite settled*". Taking place 12 month post-occupancy, the third interview covered experiences over different seasons and weather conditions, which had related implications for energy generation and demand. During this time, there had also been a marked increase in energy prices. Jake and Holly suggested that "*there was no better time*" for them to have made a move to an active home. They described how the significant financial savings they had made over the summer made a difference to how they viewed their active home, including the utility of the battery and its place in their house:

> JAKE: [o]ur battery done amazing this year. It's saved us so much money. Like, probably £500, £600 we sold back to the board over a few months. It was crazy. We didn't pay electric for about six months. We've only started paying electric in the last, what, two months, I think.
>
> HOLLY: Yeah. So as much as it might be a little bit of an eyesore, it can have its own bedroom if it wants [laughs]. It's staying.

The more positive picture of life in an active home when viewed over a whole year perspective had led to altered views of the benefits of the home's technologies, which Jake advocated to others:

> if anybody asks me where I live, it's one of the first things we're talking about, like, is the technology and the way the heating and the solar thing works.

By taking a longitudinal view of Jake and Holly's transition to active home living, we are able to see changes in their experiences as they learn to live in their home over different seasonal and weather conditions, which leads to altered views of their home's technology, in turn influencing how the home features in their future plans. Jake and Holly's description of themselves as motivated to act in the present to address climate change concerns and improve things for their children's future shows a different perspective to those who appear to struggle to make longer-term connections in the face of immediate pressures (Shirani et al. 2016). They also suggested that they were prepared to put up with some inconvenience, including time-shifting practices, for this wider benefit, which again differs from research that has illustrated participant concerns about new heating technologies being inconvenient (Thomas et al. 2024). However, for several of our participants, the "active" features of the home were less relevant to their decision to move, which led to different experiences, as we now consider.

Seren – "Working on Our Terms"

In her early twenties, Seren described the purchase of an active home as a first-time buyer as motivated by the location and new build, as she did not want to undertake renovations. Unlike Jake and Holly, the home's technology was not a significant element of Seren's decision to move. Conversely, she spoke of family members' concerns about the unfamiliar technology – which she described as "*a lot of new things, and big things*" – and uncertainty over how this would be maintained and repaired. However, Seren described how others had suggested the active home

technologies could result in savings, making the home a good option for her first responsibility for bill paying:

> but everyone kind of said, oh yeah, that is a good place to go and live, because the solar panels, and you would be saving a lot in your energy, and you know, if you haven't got the money to go and renovate a house, then this is probably, you're investing into something good here by having low energy.

Seren described herself as not a particularly environmentally conscious person and not currently motivated to make efforts to save energy, although anticipated this changing when she moved to her own home and had responsibility for bill paying. Instead, Seren spoke of "*investing*" in the home, expecting that the technologies would become increasingly appealing over time. For example, whilst not intending to use her EV charger, Seren was "*impressed*" at its inclusion as "*in the future I think that it will, you know, put the value of the house up as well*". Seren therefore anticipated the property to have a broader appeal in a few years' time, when she intended to sell it and move to an older property.

Post-occupancy, Seren, who moved in during the winter, initially described how *"everything's kind of easy in this home"*, with the exception of the app to control heating and hot water:

> we're still struggling with the app, we don't really understand it at all. We have phoned [energy service] a few times for them to explain, which they have. But I think it's just really complicated in the way of using it compared to, you know, a normal gas boiler. It almost doesn't make sense really, how you would save your money by keeping your heating on, and it's just getting used to that really.

Despite explanations from their new energy service, Seren spoke of how she and her partner struggled to understand the low carbon heating system, comparing it unfavourably with the responsive gas central heating system she had previously lived with. With a higher than anticipated initial bill, Seren also expressed concern that the guidance to run the heating over longer time periods would increase costs but was following the advice of the energy company to see if this made a difference to bills. In this initial post-occupancy interview, Seren frequently used the word "*frustrating*" to describe her experience with the home and technologies, which were "*complicated*" and "*time consuming*" to try and ensure the house operated as she wanted. Describing the battery as "*that big white thing in the kitchen"*, Seren spoke about how she had become used to the noise but did not otherwise feel conscious of living in a low carbon home.

After a year of life in the house, Seren spoke very differently of her active home, describing it as "*amazing*". This largely appears to be down to a greater understanding of the heating system, with Seren describing how this was now "*working on our terms*", as well as realizing bill savings over the summer period.

> We have said as well, we probably wouldn't ever move from an electric house now to gas again, obviously, 'cause everyone's paying so much with them at the moment. So we have noticed a massive difference. And everyone says the same that goes to our house, just how cheap it is. And we've got used to the heating now with how it works and everything ready for the cold winter again now. So we know exactly when to put it on, how it works.

Despite positivity about the ease of the home, Seren described challenges in drying washing without having radiators or space for a tumble dryer, which led to a change in practices with her outsourcing laundry. However, her overall positive experience had led Seren to reconsider her longer-term plans, saying she could now never imagine moving – unless to a larger house on the same site. Seren reflected on how her views had changed over time alongside the lived experience of active home residence:

> It's opened my eyes to it because I didn't really think anything of this before. When I lived with my parents, I didn't know there was such a thing. I didn't know when I was even moving in here that that's the type of home I'd be moving into. I just did it for the sake of a new build. Didn't realise how effective it would actually be and how much we'd benefit from it. You know, in the first few months, I didn't really see the benefits either. And now towards the end of, you know, the year, after being here a year, I can't imagine living anywhere else. So it has just changed my outlook on the whole idea.

Seren's positive experience appeared to have an impact on how active home technologies were viewed by her wider relational network. For example, Seren described how family members were now considering installing solar panels in their own homes and how "*it has changed a lot of people's minds*". Despite these apparent benefits, Seren did not feel that she had become any more environmentally or energy-conscious since living in the home. Instead, Seren described how low energy use and bills had led her to consider other energy-demanding technologies, such as installing air conditioning, as well-insulated homes were very hot during the summer. This suggests a potential rebound effect, a topic extensively discussed in relation to energy efficiency, but where prosumers have rarely been the focus of attention (Dütschke, Galvin, and Brunzema 2021; Galvin, Dütschke, and Weiß 2021). Similar issues were evident in the account of our final case study participant, where relational influences had particular relevance.

Sally – "Being Greener for My Grandchildren's Future"

In her fifties and living with her partner, Sally described how she had sold a large, house that was "*most people's dream*" in order to move to an active home "*because of the benefits of the house*". Her experience differs from the previous cases as the active home credentials were "*the deciding factor*" to move given she was "*quite passionate about the environment*". These benefits for Sally were twofold; first, the home would use renewable energy and reduce emissions. This had become an important issue for Sally after her adult daughter – who she described as "*so green it's unreal*" – spoke frequently about the need to make changes to unsustainable lifestyles in the present in order to improve the situation for future generations. Secondly, Sally anticipated the long-term benefits of the home; "*I'm hoping by the time I retire that it's going to be economical to run as well as being good for the environment*", and that as a new build it would be low maintenance. In the light of this "*retirement plan*", Sally anticipated a long-term residence in her active home. Sally was vocal about the innovative aspects of the "*groundbreaking*" active home development and the wider impact she anticipated:

> I'm really hoping it's going to work obviously for more reasons than one. But on the environment, I think it's going to have a phenomenal effect on the environment. You know, this is the start of, I think, how building is going to become.

Post-occupancy, like Seren, Sally "*struggled*" to get used to the heating, describing it as "*horrendous*" as it operated over longer periods at lower temperatures and the underfloor heating gave a different kind of heat than radiators. Initial faults had also resulted in overheating in some areas. Sally described finding the home less responsive or easily adjustable in regard to heating and cooling than previous homes, which led to some workarounds that Sally felt somewhat contradicted the efficient ethos of the development:

> The houses are so well insulated, it's boiling here … I'm often for opening the windows, which doesn't really justify the environmentally friendly.

Whilst trying to navigate the new heating system, Sally spoke of support from developers and energy service and how bills were being monitored, while outstanding issues were addressed, which meant she did not yet have an accurate idea of energy costs. Since moving in, Sally had made changes to the property, including purchasing a hot tub and contemplating garden heating, although acknowledged that the latter "*does defeat*" the home's energy and emission savings and was likely to be seen as problematic by her daughter, whose views and values had been influential in Sally's decision-making.

> Yes, it did cross my mind a lot and what I was thinking was because I've got a zero-carbon home with solar panels and ground source heating that I wasn't doing as much bad for the environment … I'm not actually using anything that's bad for the environment by using it. But, yes, I did think about it and I was thinking is it the right thing to do? Is it wrong? I thought, well, ultimately I've still got to live.

Like Seren's contemplation of air conditioning because of the homes' low energy use, Sally justifies having high-consuming appliances through the use of renewable energy, highlighting how efforts to live more sustainably are balanced against objects that provide enjoyment and meaning (Groves et al. 2016), as well as comfort.

Twelve months post-occupancy, Sally described rarely needing to use the app as her household had found a comfortable routine and adjusted the temperature via the thermostat when necessary. Whilst Sally spoke of the bills "*getting better*", she suggested she had not saved as much as anticipated because they had run several fans throughout the summer, with the home becoming uncomfortably hot during a heatwave. Despite these challenges, Sally commented "*I love my house*", feeling that the set-up was "*perfect*". Whilst Sally described at times feeling that she would prefer to return to a conventional house, by 12 months she felt differently, articulating a longer-term desire for active home technologies; "*I would have to have solar panels and ground source heating still*." Although positive, at 12 months Sally suggested that she was still getting used to her home, particularly adjusting to a different heating system. As with Seren, Sally described how running the heating over longer periods seemed counter-intuitive, but had resulted in low bills:

> it's still new, you know. I mean for the last 50 years I've had gas, or however long I can remember it's been gas. And, you know, it's always been quite instant in, in relation to what we've got now. And there is that niggling part of me, as if, well if it was off longer we'd save more money, you know, my bills would, you know, be less. But I mean I can't really grumble for my bills. I mean I pay … so much less in comparison.

In contrast to some of the comments made in her earlier interviews, at 12 months Sally described herself as "*quite cautious*", changing how she undertook some tasks in the home.

> I'm probably more environmentally friendly that way. And again, [husband] would shower, leave the shower running for me and I could be 10 minutes before I get in, the shower's been running … But then it was a combi boiler so it didn't matter, cos the water was there. We wouldn't do that now.

This cautiousness coincided with receiving more information about energy use, enabling Sally to pinpoint usage of specific appliances, following which she disconnected her hot tub. Whilst Sally was positive about solar PV and ground source heating, she felt that in some respects the home design did not go far enough. For example, Sally spoke of how she would like the homes to include water recycling as "*that would have been, I think, the total package*" and described plans for her own rainwater harvesting.

Sally spoke of family relationships as continuing to be significant in both everyday and longer-term choices. For example, she described the influence of her daughter and partner "*rubbing off*" in her choice of garden planting to improve biodiversity. Sally continued to see active homes as an important way of taking action that would benefit future generations: "*I do think it's important. I mean it's important for my grandchildren and my future grandchildren. And, you know, if we don't do something I, I just think it might be too late*." In this way, like Jake and Holly, Sally highlights the importance of acting in the present for longer-term future benefits.

Discussion

As lived experience is inherently temporal (Neale 2021), relating to practical knowledge gained over time (Abbott and Wilson 2014), a QL research approach is particularly valuable (McIntosh and Wright 2018). The temporal perspective afforded by our QL data collection is illustrated in both residents' changing perceptions of their active homes over time – from initial dissatisfaction to a more positive view by 12 months – and in how anticipated futures are imagined and change in response to present experiences. Two case studies illustrate concerns about longer-term futures for children and grandchildren as an important motivation for making changes to everyday lives in the present. Sally, Jake and Holly described moving to an active home as an action they could take to reduce their own energy and emissions because of the broader societal benefits of "*going greener*". Consequently, their perspectives differ from those who find current pressures make it difficult to maintain connections with perceived long-term concerns, such as climate change. By foregrounding these perspectives, we can consider how choices for everyday living are not necessarily incompatible with addressing longer-term environmental concerns (Shirani et al. 2016), which has implications for other low carbon and energy system transitions.

In addition to understanding lived experiences as temporal, we have highlighted how they are relational (Middlemiss et al. 2024), illustrated in different ways across our case studies through reference to linked lives. For Jake and Holly, the need for additional space for their family in the present and concern for their children's longer-term futures prompted their move to an active home. Woven through Sally's account were instances of her daughter's influence "*rubbing off*", illustrating the relevance of this relationship for

her own views. For Seren, the location of the home close to her family and friendship networks was fundamental to her decision to move there. Seren's relational networks were also present as both influencing and influenced in her account, moving from initial concern about the technology, to contemplating their own installations following Seren's positive account of active home living, indicating a potential ripple effect amongst wider relational networks. Our work supports contentions that research that takes a relational approach can add greater depth of understanding (Thomas et al. 2024) and give important insight into how people respond to innovative developments, which can lead to more appropriately designed policy support (Middlemiss and Gillard 2015).

Conclusion

Our discussion of three case studies illustrates the value of a temporal perspective afforded by a QL research study in elucidating the dynamic, evolving and relational nature of learning to live in an active home. In doing so, we address an identified gap in the literature for longitudinal research that explores the lived experience of low carbon home residents (Berry et al. 2014). Our data demonstrates how participants' views changed over time in relation to their experiences of living in the homes, with perceptions of active homes both in the present and longer-term futures altering across the interviews. We have elucidated how these changes relate both to the variation in active home performance across different seasonal and weather conditions and broader contextual changes, such as energy price rises. We therefore suggest that QL case studies have particular value in elucidating lived experience, which has been recognized as important for informing policy and practice (Middlemiss and Gillard 2015) and advocate the utility of this approach for future work exploring decarbonization transitions.

Whilst all our participants could be regarded as early adopters of active home technologies, there was substantial variation across the sample in the extent to which the "active" aspects of the home were part of the decision to move. This variation may partly explain the different ways in which participants initially described and experienced the technologies, with some finding this more problematic than others. For example, Jake and Holly spoke of benefits to the more restricted hot water system such as helping them to avoid waste. The diverse motivations of our sample expand the discussion beyond those who are technically minded and engaged to explore a broader range of experiences in these innovative housing developments. In this way, our case study insights illustrate differences to Winther, Westskog, and Sæle's (2018) findings of "ready-made" home residents "only lightly incorporating" technology into everyday life as our participants indicated preparedness to make changes to practices. Further work that challenges assumptions about early adopters could add greater nuance to efforts to optimize the benefits of low carbon homes.

Evident in our case studies is the way participants referred to their new active home technologies in relation to prior experiences with other technology. For example, running heating over longer periods seemed counter-intuitive for cost savings when participants were used to gas heating systems that operated differently. Sally indicated some uncertainty about this approach, describing how "it's still new", suggesting after a year of occupancy participants were still learning about how to use their homes. This problematizes conceptualizations of moving home as a moment of change for behavioural

intervention, instead reflecting change as an ongoing process (Burningham et al. 2014). Experiences with hot water were also related to prior experience with instant hot water from a combi boiler, with having to wait for hot water initially seen as a backwards step (Shirani et al. 2024). Our findings here correspond with previous work drawing on SPT which highlights how the "rucksack" of previous experience and embodied competence is important when approaching and learning to live with new heating systems (Madsen, Hansen, and Larsen 2023).

Despite their different motivations for moving to an active home, all participants described how they were seeking a new build. For these, and other, participants in our sample, new builds were seen as low maintenance and generally more efficient than older properties, helping to avoid the expense and inconvenience of renovation work. Whilst retrofitting buildings to meet energy efficiency targets will be crucial for meeting net zero decarbonization targets, policy commitments to housebuilding (MCHLG 2024) and identified needs for additional housing (Future Homes Hub 2025; Homes England 2024) mean that new homes will also play a role. Subsequently, it is important to consider the reasons people express a preference for new builds over retrofit and how lessons from early innovative housing sites can inform future developments.

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Data Access Statement

The data supporting 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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