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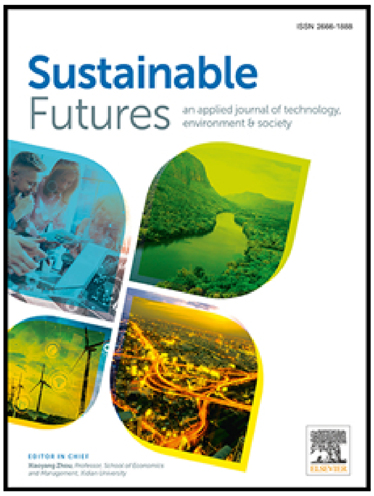

Build it and they will come? - a case study of a 'softer landings' approach in creating a low-carbon community

Jing Zhao , Rosemary Fieldson , Ozlem Duran

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Highlights

- Introducing ‘softer landings’ approach: a community-building oriented extended aftercare that creates behaviour change and energy reduction
- Main barriers and motivations to developing low-carbon communities and delivering SL framework for private developers are discussed
- A business model that uses ‘softer landings’ approach to drive demand-side market and promote business growth is presented
- Recommendations for this model to be replicated and upscaled and supported through policy and regulatory frameworks in the UK are presented

Build it and they will come? - a case study of a 'softer landings' approach in creating a low-carbon community

Jing Zhao[1], Rosemary Fieldson[2], Ozlem Duran[3]

[1] School of Architecture and Environment, University of West of England, Coldharbour Lane, Bristol BS16 1QY, UK, jill.zhao@uwe.ac.uk, corresponding author

[2] School of Architecture and Built Environment, University of Lincoln, Brayford Pool, Lincoln LN6 7TS, UK, RFieldson@lincoln.ac.uk

[3] School of Science, Engineering & Environment, University of Salford, 43 Crescent, Salford M5 4WT, UK, O.Duran@salford.ac.uk

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We declare that all procedures were performed in compliance with relevant laws and institutional guidelines and that the University of Lincoln ethics committee has approved them [No. 8983]. Informed consent was obtained from all research participants. The privacy rights of the participants were observed.

Abstract

This paper explores an emerging low-carbon construction business model through a case study of a low-carbon community supported by a private Small to Medium Enterprise (SME) in Lincolnshire. The study highlights the developer's extended aftercare and on-site support that has a focus on engaging residents in behaviour change and low-carbon community building (termed the 'softer landings' approach[1]). The research employs a mixed method approach, with multiple sources of data from in-depth interviews, a focus group discussion, and questionnaire surveys, as well as energy consumption data from Post Occupancy Evaluation (POE) on four projects over two development sites completed between 2016 and 2019. The findings suggest that extended aftercare and on-site support from the developer could cultivate a self-supporting low-carbon community that promotes peer learning and support, behaviour change, decreases energy consumption and leads to user satisfaction. The research proposes a model where the positive outcomes of the 'softer landings approach' could in turn drive the demand-side market for low-carbon dwellings, create further business opportunities for the developer, mitigate capital cost and resources invested in the extended aftercare, and generate business growth. Recommendations for this model to be replicated and upscaled through professional networks, and supported through policy and regulatory frameworks in the UK are presented as a constructive way forward in order to achieve the government's decarbonisation goals.

Keywords: Soft Landings; demand-side market; low-carbon community; behaviour change; POE; private housing developer

1. Introduction

The household sector contributes to more than a quarter of the UK's overall energy consumption and GHG emission, with space heating contributing to 62% of household energy consumption [1]. Decarbonising the domestic sector is central to achieving the Net Zero goals

[1] softer landings approach - a term derived from the Soft Landings Framework, used in this paper to denote a community-building oriented extended aftercare and on-site support.

set by the UK government. Research identified that as one of the key strategies set out to reach Net Zero goals, the government's Heat and Buildings Strategy [2] specified a range of policy mechanisms to decarbonise the sector mainly through a rapid scale-up of low-carbon[2] heat supply chains and an upgrade of measures to improve home energy performance ratings [3]. However, as pointed out by Cherry et al. [4], those energy efficiency-focused strategies have their roots in a techno-economic paradigm, focusing on economic benefit led by technological innovation, neglecting social and behavioural change required for the end users in order to transition into low-carbon living.

Amongst the housing stock, privately developed housing represents by far the largest share of housing development, sharing over 80% of all newly completed houses every year since 2015 [5]. Owner occupation remains the largest housing tenure in England and has seen a small increase compared to 2016-17. In total, there are 15.8 million households, representing 65% of all households in 2022-23. Ownership rates were highest in 2003 at 71% of all households [6]. Decarbonising the privately developed, owner-occupier housing becomes crucial in delivering Net Zero strategies at a larger scale that can make a significant difference to the sector decarbonisation.

Studies across different countries have shown that developers are key decision-makers in determining the extent to which low-carbon designs and technologies are implemented. Research [7] has pointed out that financial viability is the most critical concern for private developers to plan for low-carbon projects. Profitability and availability of incentives remain to be one of the biggest motivations for private developers to build sustainable buildings. Often, the focus of such projects is on energy efficiency. The higher premium of the sale price of those dwellings is promised to be offset by a guaranteed reduction in energy use. However, most

[2] Low-carbon in this paper, denotes 'net zero' or 'net zero ready' buildings in their operational phase.

low-carbon houses are marketed to the public without mentioning necessary behaviour adaptation in post-occupancy, for fear of deterring owner-occupiers that prioritising their established comfort and lifestyle over the benefits of low-carbon housing. The concern is that branding low-carbon housing as no different to conventional housing, i.e. requiring no behaviour adaptation, could lead to social resistance and a decrease in consumer demand for such housing typology when radical decarbonisation is needed to achieve Net Zero goals [8]. Research shows that the techno-economic paradigm has already led to a lack of care and support for the residents in the post-occupancy stage from the developers, where the residents were left with little means to adapt to low-carbon technologies (e.g. heat pumps [9]). As a result, dissatisfaction occurs when residents experience discomfort, or higher energy bills due to a lack of behaviour adaptation, energy systems control awareness, or any support they receive during the post-occupancy stage. Research has further shown that especially for private owner-occupiers, the lack of consumer interest [10], or users' misconception of low-carbon technology [11], hinders the progress of decarbonisation to a great extent. Consequently, failing to prioritise and develop effective support for residents during the post-occupancy stage could negatively impact the demand for implementing low-carbon housing.

The Soft Landings (SL) approach has been a critical pivot point in understanding the importance of user behaviour in energy consumption and shifting the paradigm of decarbonisation in the housing sector from a purely techno-economic-based approach to a more holistic socio-technical approach. Developed through a combined effort between an architect and a research team at the University of Cambridge, the SL approach extends the responsibility of the developers and building professionals to a contractual aftercare period of 3 years beyond the handover stage to support the residents, learn and share feedback, achieving benefits to all parties involved [12]. SL is integrated in synergy with both BREEAM [13] and the Royal Institute of British Architects plan of work [14] and is well understood for other client sectors but not housing [15]. SL framework has been believed to reduce the performance gap, increase user satisfaction and further optimisation of building energy management [15, 16, 17, 18]. However, the SL framework is not a legal requirement, and due to the cost and complexity associated with the SL framework, it has not been used extensively [19].

Time and resource implications continue to be a critical barrier to the implementation of the SL framework and effective resident support. Questions remain unanswered, such as how to mitigate the time and resources expended, justify the cost-benefit in SL, and establish a sustainable business case in the private sector that can overcome these barriers. This is crucial for delivering low-carbon housing with reduced energy consumption, ensuring user satisfaction, and, most importantly, supporting residents in changing their energy behaviour during the post-occupancy stage.

2. Literature Review

2.1 Private Development of Low-Carbon Properties – Overview and Barriers

In the UK, privately developed, owner-occupied houses are often older and larger when compared with social and private rental sectors. Almost two-fifths of dwellings (39%) in the private sector were built before 1945. Among owner-occupied homes, 13% failed to meet the Decent Homes Standard [20].The majority of dwellings (87%) were in EPC bands C and D, with the most common band for owner-occupiers being band D (47%). Dwellings within the private sector are four times as likely to still have conventional gas boilers (8%) than those in the social sector (2%) [20].

There are nearly 2,500 active housebuilders and residential property developers in the UK, as of July 2023. Companies range from massive developers with national coverage, building thousands of units every year, to smaller, local developers [21]. The main drivers for private developers to venture into low-carbon housing have been summarised in four strands: financial (profitability and incentive); image (green certification and award/recognition); business strategy (market niche and operational advantage) and ethical (social responsibility, environmental responsibilities and risk of non-compliance) [7, 22]

From the supply side, several barriers are embedded in delivering low-carbon housing. Those include higher initial costs (e.g. increased consultants' fees, the unfamiliarity of the design team, and the cost of building assessment tools documentation) [23]. The acceptance of such costs increases with consumers' knowledge but decreases with developers' knowledge [24]. There is also a lack of policy framework for low-carbon housing standards and guidelines that can direct developers to aim for specific carbon goals [3]. For instance, the withdrawal of the Code for Sustainable Homes standard (introduced in 2006) and the scrapping of the Zero Carbon Homes target, despite the advice given by the House of Commons Environmental Audit Committee [25] have left developers with limited guidance on expected standards for low-carbon housing [26]. The lack of regulatory certainty discourages developers from making low-carbon choices in their developments, given a higher initial cost. A recent study commissioned by BEIS [27] identified the barriers and opportunities to the delivery of low-carbon homes at scale. The study suggested that housebuilders perceive they have little incentive to voluntarily develop homes that exceed required standards, with the exception being pilot scale research and development (R&D) projects [27]. However, those projects often lack support for scaling up [27].

Furthermore, non-cost barriers such as skills shortage in supply chain [7, 22], choosing low-carbon technologies (the variety of heat pumps and renewables) [28, 29] a lack of certainty about future requirements [27], and about whole grid electrification, and concerns about negative consumer attitudes have further complicated the decision-making process of delivering low-carbon housing [28].

From the demand side, commercial viability and expected returns, influenced by buyer demand or the lack thereof, present a significant barrier that hinders the push for more low-carbon housing [7, 22]. Research has stressed that one of the most important actions to promote sustainable building is the development of the awareness of clients about the benefits of low-carbon housing, in order to drive its implementation from the demand side [23]. A case study in Indonesia has shown that even though low-carbon buildings require higher capital costs, they ultimately benefit the owner with reduced maintenance costs and higher resale value [30]. However, the awareness and knowledge about low-carbon construction are still low amongst consumers.

Research has also highlighted several unintended negative outcomes associated with certain low-carbon houses. These include summertime overheating [27, 31], reduced indoor air quality [32], operational complexity, and a lack of consumer understanding regarding the appearance and use of the technologies. Additionally, potential delays and snagging issues, concerns about the maintenance of low-carbon technologies [27], and the occurrence of a 'performance gap' [33] resulting in higher-than-expected energy consumption, can all decrease residents' satisfaction and comfort levels. These factors can negatively affect their perception and attitude towards making low-carbon choices, further deterring potential buyers from investing in low-carbon houses, despite these negative impacts being closely related to how residents use these homes [33].

2.2 Occupants' Behaviour and Support

A recent review of POE literature [34] suggested that the focus of the field shifted from energy consumption to the interaction between people and the built environment. Li et al. [35] reviewed 146 POE studies conducted between 2010 and 2017, identifying that 50 of these studies pertained to residential buildings. They noted that POEs of residential buildings frequently emphasized the occupants' experiences and the utilization of facilities. Such a trend confirms the importance of the residents' role in lowering the carbon emissions of buildings. Even in energy-efficient housing, occupant behaviour could contribute to a maximum of 51% of variance in domestic heating consumption [36]. As the thermal envelope of low-energy homes becomes more efficient, the energy used by these homes will increasingly be associated with end uses other than heating. Failing to address the importance of low-carbon behaviour change could lead to a 'performance gap' [33], or 'the rebound effect' [37]. This occurs when energy consumption rises following the installation of energy-saving measures, as residents' behaviour changes adversely to align with the lower costs they encounter [38, 39]. A number of studies show a lack of occupants' behaviour adaptation in low-carbon residents [28], or their frustration that they had to actively adapt their behaviour to acquire comfort in what they assumed to be a house that provided comfort automatically [40, 41]. In contrast, research has also documented positive behaviour changes and subsequent positive feedback and high level of satisfaction in low-carbon communities [11], proving that if given appropriate support, residents are willing and able to make low-carbon behaviour changes [42]. However, a number of barriers are presented that prevent them from doing so. These include the residents' lifestyle and comfort practice [43], their technical know-how [44], the usability of the control interface [45] as well as the technical support available to them [11, 28, 46].

2.3 Supporting the Residents – A SL Framework

Adopting a SL framework is an effective way to support and engage the occupants in energy reduction and behaviour change, as well as to fine-tune the performance of the building and identify opportunities for future projects. Way & Bordass [12] have paved the way to implementing a staged SL framework within the standard procurement scope of service, including key interventions in 5 stages [47]. A limited range of research has investigated the challenges and barriers to implementing SL framework and POE, as an important part of the SL framework [48, 49, 50, 51]. Cost, time and skills [52], concerns for professional liability, as well as fragmented incentives and benefits within the procurement and operation processes [49], lack of agreed and reliable indicators [50, 53], exclusion from current delivery expectations, and exclusion from professional curricula [51, 53], as well as a lack of support from the government, or from peer learning [51], are some of the crucial barriers. POE studies on housing whether initiated by the occupant, developer or architects, are exceptionally rare. Moreover, there is a limited range of literature reporting specifically on occupants' support and engagement, especially on those to be implemented during stage 4: initial aftercare, and stage 5: years 1-3 extended aftercare. SL is expected to be led by the clients and funders, but the main barrier to adopting the framework is the added complexity and associated cost [19], especially the cost associated with stages 4 and 5, which is estimated to be between £30,000 and £60,000 [54]. At the same time, the current POE practice has been reflected upon in terms of its ability to feedforward. It is suggested that embracing early collaboration between end users and designers in the building procurement process could improve the effectiveness of POE [55].

What is still under-explored is the value of POE and SL to the development team, and if the benefits could outweigh, or mitigate the initial cost and resources implicated by the SL process. By conducting a case study of private developer-led low-carbon housing development, this paper argues that the non-monetary benefits resulted from a ‘softer landings approach’ - a term derived from the SL framework while taking a step further from the SL framework by emphasising a community-building oriented extended aftercare and on-site support provided by the developer - have created a path for a long-term financial gain and sustainable business growth.

3. Methodology

3.1 Methodological framework

This research is situated within a case study methodological framework, using a mixed method in its approach, combining quantitative and qualitative data to complement and triangulate the findings. The case study design did not intend to present quantitatively generalisable results, but the 'replication logic' [56] represented in this study can be shared in the wider context in the UK and other countries regarding developing low-carbon housing and providing aftercare.

Twelve households in two development sites (88 houses in total) by the same developer in the East Midlands were identified for this study based on a range of house types (construction of envelope and size of dwellings). This included two homes from each of three house types (bungalow, 3 bed and four bed each with similar envelope construction) on site 1, and two homes from each of three distinct development phases on site 2 which had very differing envelopes (terraced insulated concrete formwork, masonry and timber framed). From the range of property owners contacted, six were agreeable to taking part in this research (50% respondent rate). four of the households agreed to take part in the occupant behaviour interview (two participants dropped out due to health reasons).

The main data used in the scope of this paper are the semi-structured interviews with the developer and the residents (see Appendix A and B for interview questions). The qualitative data is complimented by energy consumption and PV generation data, and an energy behaviour and appliance use habit questionnaire survey. The interview design was guided by Grounded Theory Methodology (GTM) [57, 58]. Grounded theory entails an inductive process that is derived from the study of the phenomenon it represents. In this research, illustrative types of theories are acquired through literature review prior to data collection and are used to contextualise the proposed research [59] and form a basic 'sensitising concept' [60] and certain 'theoretical sensitivity' [58] for use in designing the semi-structured interviews.

3.2 Overview of the Case Study Projects

The four projects in this study have all been designed to be significantly better than building regulations with low predicted operational energy use. They were completed and occupied between 2016 and 2019. The four studied houses include two very similar detached masonry homes, a semi-detached timber frame bungalow (most recently completed) and a terraced home using innovative insulated concrete formwork construction and passive solar design (which was on the first phase of the development completed in 2016). The homes all have constructed U-values better than regulation standards. They adopted radiant panel heating, air source heat pumps and mechanical ventilation and heat recovery system (MVHR), with hot water heated from direct PV installed on south-facing roofs. The details of the selected cases (including general information, energy use and occupancy information) are listed in table 1 below:

Table 1: Overview of the project (building fabric, service system and occupancy information)

	1A	2A	2B	2C
Construction	Brick faced masonry	Rendered masonry	Insulated concrete formwork (IFC)	Timber frame
Date of completion	2018	2019	2016	2019
Type	Detached 4 Bed	Detached 4 bed	Mid terrace 4 bed	End terrace bungalow 2 bed
Area m^2	176	171	161	91
Level	2	2	2	1
				
SAP rating and predicted energy	B rated (85)	A rated (95)	A Rated (97)	A Rated (92)
Airtightness m^3/h/m^2@50pa	3.55	1.82	1.9	0.98
Thermal Mass Parameter kJ/m2/K	804 (high)	830 (high)	252 (medium)	331(medium)
Annual Energy consumption reported	6179 1867	5835 3000	4994 2884	3713 3177

Mains and Solar (kwh)				
Annual reported emissions (scope 1 and 2) kgCO2e in 2022	1,194	1,128	965	718
Occupants	2	1	2	2
Age group	50-59 70-79	30-39	60-69	50-59
Occupancy pattern	Semi-retired working from home, caring for elderly parent	The occupant works from home, and regularly visited by their partner.	Couple semi-retired working from home	Working couple

4. Data Collection and Analysis

4.1 Summary of Quantitative Data Analysis

Smart meter displays are used by the occupants to collect energy monitoring data. Based on the period of occupancy, the meter reading period varied; e.g. 2A had data for 1 year (2022-2023) whereas 2C provided 3 years of data (2020-2023).

Overall, energy consumption was observed to have gradually decreased over time for the longest occupations, as illustrated in Figure 1. Energy usage of 1A reduced 15.7% between their first and second year of occupancy. Energy consumption of 2B increased in the second year due to the electric car they purchased. Despite this additional load, they reduced the energy consumption approximately by 10%. 2C saw a 1.3% reduction in the second year and a further 21.8% in their third year of occupancy. In more detailed comparison, 1A has the highest energy consumption: 15% higher than 2C. This energy consumption discrepancy does not reflect the difference in the footprint of the houses. For instance, 2C has a 48% smaller footprint than 1A. 2C having the highest form factor: 18% higher than 1A (and 38% higher than 2A) may be influencing the overall energy consumption.

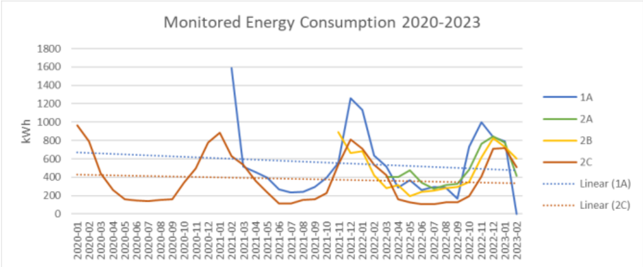

Figure 1 Energy Consumption 2020-2023; self-reported by occupants based on smart metering data

To understand the impact of occupant behaviour and energy use of appliances, an energy behaviour survey was conducted. The energy behaviour questionnaire survey were sent out in May 2022 prior to the residents interviews. These surveys included a series of questions on the occupants' ability to access energy meter readings, which household appliances are used and how often, stand-by practices, lighting habits in individual rooms and hot water usage frequency (Appendix C). The survey results provided insight into occupants' profiles and overall energy consumption in the lack of submetering data. The habit of using appliances can be seen from Figure 2. The majority of the appliances were used less than 4 hours a day, with the exception of a large fridge (2B), Electric fan in summer (1A), Electric heater in winter (1A) due largely to the presence of an elderly resident, Desktop computer (2A) due to working from home. The survey did not report any exceptional energy behaviour or evidence of rebound effect.

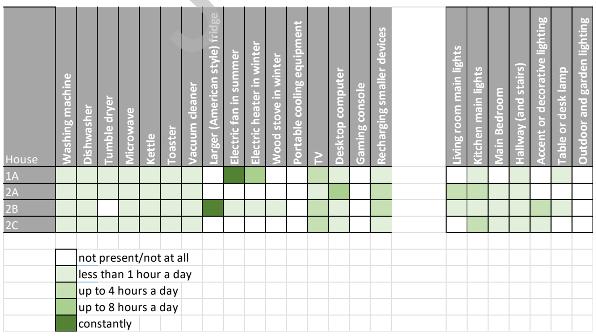

Figure 2 Appliance use habit of the four households

4.2 Qualitative Data Collection and Analysis

Interviews with the residents were conducted in July 2022 (Appendix B). Interviews with 2A, 2B and 2C took place on-site at the residents' homes, followed by a tour of their houses. 2B and 2C had both residents present in the interview. 1A, and 2A had only one interviewee each. Interviews with 1A resident took place online due to their availability.

All interviews were recorded and transcribed using either Otter.ai (in person) or Microsoft Teams (online) and checked against the recordings by the researcher. Each interview with the residents lasted between 1 hour and 1.5 hours. Transcriptions of each interview range between 3,600 words to 9,600 words depending on how articulate the interviewees were. As semi-structured interviews, the lengths of the interviews were expected to differ. Each interview had two researchers present during the session to take notes and ask follow-up questions.

The result of the preliminary findings (including the analysis of quantitative and qualitative data) was presented to all participants of this study (1A, 2A, 2B, 2C and the developer) in a debriefing session (Mar 2023) by two researchers. The session allowed open and documented discussions of building fabric, services and behaviour in the role of reducing energy consumption and carbon emissions. The discussions in this session were captured by two researchers using a mainly note-based and memory-based method [61], The notes and memos have been further coded by a third researcher. The data gained from this session provided further insights into the user's understanding of their own energy use, the design of their house, reflections on embodied carbon, the cost-benefit of low-carbon homes, and other related areas.

In order to further examine the development of low-carbon community from the developer's perspective, a third strand of the data - the interview with the developer took place at a later date online (Oct 2023). The interview was 1.5 hours in length, conducted by all three researchers with an agreed set of semi-structured questions (Appendix A) guided by literature and previous data analysis. The recording was transcribed in Microsoft Teams (12,400 words) and the transcription was checked by a researcher.

The processes of data collection and analysis in this research are carried out simultaneously, thus permitting a gradual increase in the theoretical sensitivity of the researcher. The qualitative data were coded in NVivo 14, firstly using an inductive process, which spontaneously created original codes the first time data were reviewed [62]. The coding followed the three-step process suggested in Grounded Theory: Open coding, Axial coding and Selective coding [58]. Constant comparative analysis and memoing were also employed to ensure the rigour of the data analysis procedure. Memos and field notes from multiple researchers during each interview and group session were also coded into the codebooks. The quantitative data from energy performance monitoring and questionnaire surveys has been coded using a deductive method into the residents' interview codebook (Figure3).

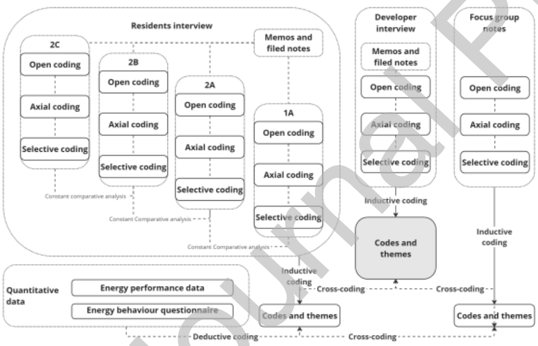

Figure 3 Diagram of multi-strand coding design

For purposes of this paper, the developer interview codebook was used as the main structure of the analysis. The main themes and percentage coverage can be seen in the following table (Table 2):

Table 2: Themes and percentage coverage of developer interview analysis

Themes	Percentage coverage
Codes\\D\\ Motivations	20%

Codes\\D\\ Barriers	28%
Codes\\D\\ Low carbon community building	23%
Codes\\D\\ Business growth	29%

The other two strands of codes and themes were cross-coded in a secondary and deductive cycle - each dataset was coded using the ready-generated codes from the first round of analysis to find commonalities and correlations. An example of cross-coding is illustrated below (Table 3). A complete codebook from the developer interview can be found in Appendix D.

Table 3: Example of cross-coding of three sources of data

Codes – developer interview (D)	**Cross-coding R(residents) interview and F(focus group notes)**	**Descriptions**
Codes\\D\\Low carbon community building	Codes\\R\\Community learning	Neighbours exchanging tips, Whatsapp group
	Codes\\R\\Developer support	Developer on-site support has been mentioned by every household, as a very positive and important feature.
	Codes\\R\\Motivation and ideology	Residents expressed that living in a low-carbon community motivated them to reduce their carbon footprint more, such as eating more vegan food and using less energy to maximise what the house can offer.
	Codes\\R\\Control behaviour\Behaviour change	Occupants' behaviour changed: put the washing machine or the oven on during the daytime to utilise PV generation, dry clothes indoors and change home attire.
Codes\\D\\Barriers\ Market demand	Codes\\R\\Reason to choose the house	Energy credentials are not the main reason to choose the house, but a positive input.
	Codes\\F\\Carbon low on priority	Occupants agreed that cost and comfort were the primary concerns once living in a home and carbon was a resulting outcome of those two criteria. This was the case even though they felt they were probably more carbon literate than typical homeowners.
Codes\\D\\Low carbon community building\Creating a community\Planning and design	Codes\\R\\Reason to choose the house	The general site ecology and the allotment have been mentioned as a good feature.
Codes\\D\\Motivations\The 'biggest sales team'	Codes\\F\\Promotion by residents	Several owners had shown their homes and promoted them to friends and family who were planning a renovation project.

4.3 Emerging Themes

The section is structured to show themes generated primarily from the interview with the developer, highlighting the developer's perspective, supplemented by cross-coding of the interviews with the occupants and the focus group. Relevant quantitative data that has been referenced in support of the analysis where appropriate.

Theme 1: Motivations in building a low-carbon community

In line with previous research [7], many motivations have been mentioned that drove the development of low-carbon housing, including financial incentives, commercial benefits and business opportunities, as well as personal and ethical values (*'do the right thing', 'address the climate crisis through better construction' (the developer)*). In this case study, the ethical value has been regarded by the developer as the main drive to get into what he termed *'sustainability space'* - an overarching term used by the developer to encompass 'sustainable construction', and 'low-carbon and energy efficient homes'. Whilst starting with their ethical value, the developer has effectively used the first-hand experiences gained from the development to generate commercial benefit and a sustainable business strategy. *'Creating low-carbon community'* became the vehicle to effectively deliver real change to mitigate the climate crisis.:

> *We wanted to make sure that we sit in the heart of Innovation around building not only low-carbon homes but very much focusing on building sustainable communities…So we, we see it as not just a, a process of trying to build efficient homes, […] where you don't actually end up with a community. You just end up with a series of properties. And what we're trying to do is to build properties in a way that they become a community. (the developer)*

One way to achieve the community-building aspect of the development in this case study is to provide long-term on-site support by the development team – a 'softer landings' approach. The motivations for insisting on delivering this are also multifaceted. From an ethical perspective, taking a long-term view and supporting residents to learn the new technologies in their homes was considered essential for the developer, to address the climate crisis from the bottom up ('*the change needs to come from community'(the developer)*). This support has been critical for the occupants to overcome barriers and difficulties in the post-occupancy stage, as echoed in the interviews with the occupants. Examples of such support included technical troubleshooting, operational advice on a boost button on the hot water supply (*'don't leave it on or you will end up with a massive bill' (the developer)*), retrofitting air-source heat pumps and/or infrared panels for winter comfort, as well as helping the occupants to choose the most cost-effective energy provider.

To cross-reference with the residents' interview, all four interviewed households showed general satisfaction towards their home environment in terms of thermal comfort and energy reduction in comparison to their previous experiences. They have reported that their knowledge about their house has increased, even though some residents are more technical-minded than others. The residents have learned a set of control routines that enable them to optimize the indoor environment, including an increased awareness of the maintenance needed such as cleaning filters of MVHR and washing solar panels. All of the interviewees showed awareness of energy use but exhibited different levels of awareness. 2C, for example, keeps a manual log of energy consumption to keep track of their energy use. This learning curve and increased learned energy-saving behaviour have been reflected in the energy consumption data, representing a gradual downward trend in energy use observed in 1A and 2C who inhabited the dwellings for a longer period. (Figure 2). Interviews with the residents also reflected the shift in the residents' mindset where living in a low-carbon community motivated them to reduce their carbon footprint more, such as eating more vegan food, and using less energy to maximise what the house can offer (Table 3).

From a commercial perspective, making sure that the occupants are satisfied with the level of comfort, information and support they expected is a business strategy to drive the demand-side market in the long-term, using feedback from the residents to showcase their practice. The residents became the *'biggest sales team' (developer)* that can be marketed to new customers. This has also been echoed in the interviews with the residents. All occupants have mentioned the developer's on-site support to be a very positive and effective way to help manage energy use and comfort and commanded the extended aftercare provided by the developer:

> *[…normally developers] have a two-year warranty period whereby [this developer] will just [say] it's not a problem[…] (2C occupant)*

Furthermore, supporting the residents in resolving post-occupancy issues also gave them advantages to secure future service-related contracts (*why would they want to buy [all sorts of services] from somebody else [going forward] if they can buy it from me? (the developer))*. This also gives them the advantage of creating a niche market in their business strategy with their experiences embedded in it.

Theme 2: Barriers to developing low-carbon housing and post occupancy support

The interview with the developer highlighted two main areas of barriers to implementing sustainable construction or developing low-carbon homes. One of the main barriers is legislation, as articulated by the developer, reflected in three strands: firstly, an expected level of build standard (e.g. an energy performance standard such as Net Zero) needs to be established in building regulations to create a level playing field for all private development. The lack of legislative certainty affects the competitiveness of high-quality development, as well as the preparedness of the supply chain. The interviewee has elaborated on the example regarding the withdrawal of the Code for Sustainable Homes standard.

> *[…] it was about setting that vision. Uh, giving time for the supply chain to get itself aligned behind that vision and then hitting the, you know, alleged legislative button and saying right 2016, that's when everything kicks in and by that time you've got your supply chains aligned, you've got your technologies developed and you're ready to go. And unfortunately, pulling the pin on all that and then[…] the scale of it is not there to be able to roll it out nationally. (the developer)*

More importantly, the developer noted that providing post-occupancy support, or extended aftercare, and creating a low-carbon community has time, cost, and resource implications that are not currently addressed by legislation. Even though adopted by the RIBA Plan of work, and reflected in the Government SL framework, this has not been made into a mandatory requirement, or provided with an effective support mechanism from the policymakers. The extra cost associated with the initial aftercare and extended aftercare (1-3 years) in particular, is a critical barrier to developers or funders when implementing post-occupancy support.

Another major barrier is the lack of market demand, caused by the value of a house being given to location, square footage, or furnishing levels, rather than carbon emissions. The lack of consumer-side demand echoes previous research [7, 22, 23], and is reflected in the interviews with occupants in this study. Comfort and cost are still at the core of consumers' decisions in choosing a new home. None of the occupants chose their homes specifically for their low carbon credentials, they agreed that cost and comfort were the primary concerns once living in a home and carbon was a resulting outcome of those two criteria.

Moreover, the developer commented on the difficulties in scaling up the supply chain, and the challenges and pressures placed on contractors to grow in size and upskill their employees. However, as explained by the interviewee, as a small company, they have been building relationships with a network of skilled suppliers that can deliver the required expertise in small-scale development, where both parties grow their experiences through collaboration.

Theme 3: Using 'softer landings' to create a self-supported community

The community-building is achieved through a careful design and planning strategy (creating communal spaces within the development site), giving residents ownership of the development (making residents shareholders of the communal areas), and delegating one of their employees as the community manager *'to ensure that those communities grow and engage with each other, support the self-supporting' (the developer)*. The role of community manager has been especially beneficial to the occupants as reflected in the interviews:

> *[The developer] has now appointed a manager, Service Manager [name]. And he's brilliant. He's great. Because he understands all the systems, how they were built, etc. […] (2C occupant)*

> *And the site manager [name] did come and show us the basics and you know, he only lives around the corner. If we need any more assistance, he's really good. (1A occupant)*

Furthermore, the developer has elaborated on a '20-60-20' model they used in facilitating the growth and autonomy of the community. The '20-60-20' model (Figure 4), adopted by the developer, denotes an estimated proportion split of the engagement level of all occupants in a newly-developed community. The 20-60-20 principle has been used commonly in management theory, often connected to people's behaviour or choices [64].

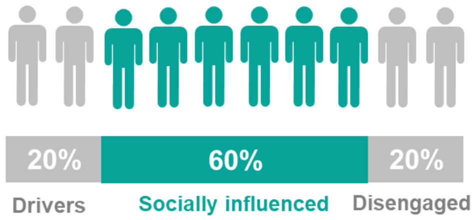

Figure 4: the '20-60-20' model after [6].

In this case, according to the developer's experience, 20% of the occupants are fully engaged with the community-building process; 60% of them appreciate the benefits but are less active; The last 20% are either completely disengaged or are disruptive to the process. In understanding the mix of priorities and engagement level of the occupants, the developer devised strategies to effectively engage the 20% 'drivers', while focusing on delivering benefits to the 60% so they '*come along the journey'*.

This 'community building' theme has been reflected in the interviews and focus group discussions conducted with the occupants. A learning curve was identified by all occupants. Not all occupants learned control of the house by reading instruction manuals. Trial and error, neighbour exchange and community learning were prominent in their behaviour adaptation during post-occupancy. This echoes previous research where community-oriented learning was observed [65, 66] .

> *There's a WhatsApp group as well. For [community] and everyone has the same or very similar kind of kit. So there's often Q&A going on there and nobody told us about this.[…] (2A occupant)*

Striking a balance between encouraging the occupants to take ownership and making sure that the occupants feel supported is considered by the developer to be crucial in creating a low-carbon autonomous community whilst effectively managing resources in the SL process:

[…] really, you know every developer wants to get away as quickly as they can from development because it just chews up resources when people keep coming back to you. And it's the same for us. We still want people to take ownership of the House. […] There will be things that get knocked and broken and you know that you've got to you do have to get that clarity with people. But you also want them to feel supported. And I think that that's the element that we're trying to bring in. (the developer)

One indication of the effectiveness of the 20-60-20 principle, in this case, is reflected in the participant respondent rate; 50% of the sampled households agreed to take part in the study, and two of them dropped out in the middle due to health reasons. The high engagement rate positively reflected the top 20-30% of the drivers in the community. In one of the community centres with shared equipment and facilities, it has been recorded that about 80% of the residents have engaged with the initiative. Furthermore, a growing number of residents in the community have opted for electric vehicles (estimated at 20-30% to date).

The following table summarises the motivations, barriers and the developer's 'softer landings' approach to creating low-carbon communities:

Table 4: Summary of motivations, barriers and 'softer landings' approach from the interviews

Motivations	**Barriers**	**'Softer landings' approach**
• Ethical perspective – bottom-up approach '*the change needs to come from community'* • A business strategy to drive the demand-side market in the	• Lack of regulatory parity • Cost and profitability • Supply chain scaling up • Lack of market demand	• Create community space as a 'focal point' in design and planning • Giving residents ownership of the development • Dedicated community manager

long-term - - satisfied users as sales team • Secure future service-related contracts • First-hand experience - learn from POE to aid future development	• User dissatisfaction and misperception of low-carbon housing • Lack of a physical focal point in the community • Lack of engagement from residents (or encounter of 'disruptive' residents) • Time and resource implications in delivering SL	• '20-60-20' model to facilitate the growth of an autonomous community • Balance support and empowerment • Use residents' experience to feedforward business growth to scale up the community-building

Theme 4: Business growth

Even though the main motivation of this developer in building low-carbon housing is driven by an ethical value, rather than financial viability, a big proportion of the interview with the developer has revolved around their business growth. Under this theme, the developer elaborated on their business model currently in transition into a B-Corp organisation, giving employees ownership of the company. As has been noted by the developer, this transition is not unlike their effort to engage and empower the residents to take ownership of the community. Their business ethos is consistent through the business's operation and production. The experience gained from developing and managing low-carbon communities has equipped the developer with the insight and confidence to create autonomous low-carbon communities. It also provided strategies to engage residents in taking ownership of their community, thereby reducing the additional time and resources required during the extended aftercare process. At the same time, this allows residents to become a marketing force, drive the demand-side market, help to secure future clientele and service-related contracts.

In reflection on the developer's motivation, the commercial benefits brought by the success of building the low-carbon community as well as their ethical value are both critical in driving the growth of the business. The developer explained their future ventures, including building 'intentional communities' such as 'Veganville' – a group of residents dedicated to veganism and related sustainable lifestyle; exploring new low-carbon material such as Hemspan® bio wall insulation [67], and new building standard advocated by AECB (Association for Environment Conscious Building, [68].

4.4 Triangulation and Validity

The research design incorporated (a) method triangulation, (b) investigator triangulation, and (c) data source triangulation to develop a comprehensive understanding of the studied case, and to test validity through the convergence of information from different sources [63]. The coding was processed by a single researcher due to time and resource constraints. However, the finalised codebooks have been checked by the other two researchers to ensure that the themes and codes reflect the collected data.

Internal validity

The research design has proposed the collection and integration of multiple sources of data from multiple researchers using varied methods. The nature of the research has determined the qualitative interview to be the primary source of data, with other relevant sources of quantitative data proving their necessity. The techniques used in coding the transcripts and writing memos enable the researcher to reflect on the subject matter as well as the operational measures as the study progresses. The employment of a second cycle of coding and cross-coding of qualitative datasets from four strands of qualitative data ensures a robust generation of themes and theories. Given the same selection of samples, the same case study can therefore be repeated with the consideration that the timescale and any changes to have occurred in the household will need to be noted as different.

External validity

The comparative analysis method offered by Grounded Theory allows for the simultaneous testing, construction, and refinement of the theory's new qualitative and quantitative data strands. These criteria ensure that a substantive theory can be generalised. It is important, however, to acknowledge time and resource limitations, as well as the theoretical sensitivity level represented by the researcher, in terms of the potential that exists for not fully reaching the point of theoretical saturation.

5. Discussion and Policy Implications

The barriers the developer encountered echo a number of previous research, both from the supply-side (e.g. higher initial costs [23], a lack of regulatory certainty [3, 27], skills shortage in supply chain [7, 22]), and the demand-side (e.g. lack of buyers' demand [7, 22], technical support available to them [11, 28, 46]). Faced with those barriers, the case study demonstrated a bottom-up approach to mitigate some of the barriers by supporting the residents in post-occupancy stage. It revealed the positive influence of the developer's support and community learning on resolving snagging and maintenance issues, sharing technical knowledge, decreasing the performance gap that contributed to residents' dissatisfaction as mentioned in previous literature [27, 33]. It further echoed findings form previous studies that residents are willing and capable of making low carbon choices and behaviour changes if given sufficient support [42].

By utilising a 'softer landings' approach in developing low-carbon communities, the study showed an example of creating a positive, self-sufficient loop (Figure 5) that feeds forward to aid his business growth, securing future service-related contracts and creating a demand-driven market.

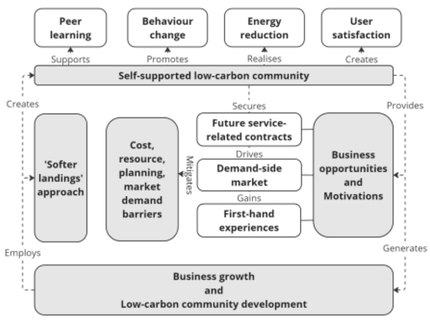

Figure 5: ‘Softer landings’ positive feedback loop

The close partnership and mutual growth between the developer and the owner-occupiers built in this case study also echoes the review that concluded the positive effect of dialogues between property owners and developers on capacity and awareness building, setting more ambitions for future development [70]. In creating community space as a ‘focal point’ in design and planning, appropriately balancing the support provided to the residents (such as on-site support, and a dedicated community manager), and the provision for the residents to take ownership (using the ‘20-60-20’ model), the developer has allowed the organic growth of the community, whilst optimising the time and resources incurred in the extended aftercare process.

The study resonated with several key findings from BEIS’s Building for 2050 study [27]. It confirmed that the demand for low-carbon homes would likely increase if developers market them with details of features and running costs, and provide post-occupancy support to ensure they perform as promised. It also stressed the importance of the need for developers to tailor and resource the handover process for low-carbon homes, so residents understand and operate their homes efficiently [27].

This study has shown an exemplary case of a developer’s bottom-up approach to providing extended aftercare in low-carbon community development by focusing on long-term value and business growth. However, one developer’s enthusiasm and a novel business model could not ensure the Net Zero goals set for the whole nation. This example addressed some of the time and cost barriers in delivering SL framework mentioned in previous literature [49, 52, 54] by demonstrating the potential benefit and value gained through applying the SL framework. But other crucial legislative, regulatory, educational, and assessment barriers [50. 51, 53] need more top-down interventions to address, The lack of legislative certainty and regulatory requirements reflected in this research and previous studies make a strong case for policymakers to take action. Without a regulatory framework, it is unlikely that Soft Landings framework and POE will become a common practice, let alone the 'softer landings' initiative shown in this study. The research calls on policymakers to regularly review building regulations and ensure long-term legislative certainty, parity, and commitment to enhancing building energy performance through the POE and SL framework. It also recommends developing reliable indicators for measuring success. Additionally, incorporating SL and aftercare costs as a compliance requirement within the regulatory framework will encourage continuous monitoring and support for residents during the post-occupancy stage. Additionally, the findings from this research highlight the need to upskill the supply chain in delivering SL framework effectively, so the small scale business model in this case study could be amplified to a national level.

6. Conclusion, Limitations and Future Research

This research has shed light on barriers and opportunities in decarbonising the private housing sector through a case study from a socio-technical perspective. It has underscored the crucial role a private developer can play in decarbonising residential properties and establishing low-carbon communities, by providing extended on-site aftercare, or, 'softer landings' approach. The focus has been on energy reduction strategies that revolve around the community of owner-occupiers, rather than merely enhancing the energy efficiency of individual dwellings. The result of such an approach demonstrated a range of changes in the residents with increased energy-saving behaviours, a good understanding of consumption deriving from building services and unregulated equipment and devices, and the use of adaptation methods in managing overheating. The triangulated energy data further suggested that the occupants had effectively improved their home energy management over time.

The ‘softer landings’ approach encouraged the residents’ shared learning as a community. The positive result indicates that effective behaviour adaptions supported by ‘softer landings’ approach could magnify the benefits of low-carbon housing, reduce energy consumption; increase user satisfaction, therefore assist in driving the demand market towards a demand-oriented low-carbon housing industry. The case study has also showcased a business model that addresses various supply-side and demand-side barriers while fostering the development of low-carbon communities. A further quantitative approach focusing on economic analysis in the future to build a business decision-making model would be beneficial to private developers in creating and supporting low-carbon communities. Additionally, the regulatory uncertainty and a lack of government guidance remain unaddressed and under-studied. Further research is needed to explore supportive mechanisms that could assist the scaling up of this model.

We recognise the existence of a number of limitations within this research. Generalisation from use of a single case study with one developer and two development sites limits comparability. The scale of the business and its rural location could also impact the applicability of findings and lessons learned from this case study. Quantitative findings of post-occupancy evaluation are reported in a parallel paper, which if read in conjunction, will aid the understanding of the research. Future research into the applications of SL and resident support with a wider range of developers, design professionals and building managers will further testify to the findings of this research.

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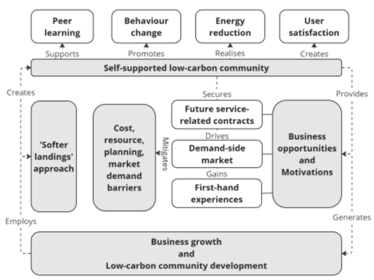
Graphical abstract



Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: