sustainability

MDPI

Article

Role of 'Community Spaces' in Residents' Adaptation to Energy-Efficient Heating Technologies—Insights from a UK Low-Energy Housing Development

Sonja Oliveira * and Elena Marco

Department of Architecture and the Built Environment, University of the West of England, Bristol BS16 1QY, UK
* Correspondence: sonja.dragojlovic-oliveira@uwe.ac.uk

Received: 10 January 2018; Accepted: 15 March 2018; Published: 23 March 2018

Abstract: Advanced energy-efficient heating technologies are often integral to low-energy home design, practice, and policy. The expectation is that technologies designed to lower space-heating energy use may also contribute to better performing buildings and a comfortable indoor environment. Too often, though, it is found that residents do not use technologies as intended due to multiple socio-technological phenomena. Whilst increasing efforts have been made to better understand residents' social engagement with energy-efficient heating technologies, there is a lack of evidence that takes into account the wider context of a housing development. This paper draws on residents' experiences across 40 dwellings in a recently completed low-energy residential development in the United Kingdom (UK). Implications of the research are twofold. First, the study contributes to a better understanding of the emerging roles, motivations, and expectations that a 'community' has for residents living in domestic low-energy environments. Second, there are implications for design professions to take account of the potential effects that specific external collective spaces such as playgrounds, allotments, and gardens can have on the ways that residents adapt to new technologies within their home. There are also implications for international energy policies on low-energy housing, specifically in relation to energy efficiency technology adaptation and learning.

Keywords: community; comfort; energy efficiency; housing; low energy architecture

1. Introduction

In the United Kingdom (UK), there have been increasing efforts to improve energy efficiency in the residential sector, particularly in relation to space heating, which is viewed as contributing to over a quarter of the country's carbon emissions [1]. Efforts include policy initiatives such as the Climate Change Committee 'White Paper' [2], as well as research commissioned by the Department of Business, Energy, and Industrial Strategy [3–6] to better understand how and why particular heating technologies such as heating controls contribute (or do not contribute) to energy efficiency and carbon emissions. However, advanced energy-efficient heating technologies, designed to enable lower energy use in homes, are reportedly contributing to unintended increased energy use and uncomfortable indoor environments [7]. Policy measures regarding space heating have also historically—both in the UK and the European Union (EU)—largely been based on energy-efficient heating technology improvements, more efficient energy generation, and generation from renewable and nuclear sources. The context of the technology, including the type, location, and climatic constraints of the home, as well as the age, condition, and occupancy patterns within the home are largely under represented in both policy and practice. Also, the potential contribution from behavioural change is largely unexplored in UK energy policy.

Studies on resident behaviour and interaction with energy-efficient heating technologies report that apparent technological deficiencies such as complex interfaces, lack of user friendliness and poor functionality principally contribute to poor or no use of technologies, leading to a lack of comfort and increased energy demand [8,9]. In addition, particular design and construction practices such as installation methods, handover approaches, and a lack of communication between developers and residents as well as designers' attitudes towards energy-efficient design [10], have been highlighted as contributing factors. More recently, understanding how to measure and isolate the effects of a particular technology, such as heating controls within a system of technological efficiency measures, have meant that there is inconclusive evidence as to their efficacy in reducing energy use in homes [3,4].

Studies on heating practices have suggested that social perceptions and cultural attitudes towards "meanings associated with a home" influence how residents engage with particular energy-efficient heating technologies. Devine-Wright et al. [11] analysed how older adults engage with new energy-efficient heating technologies post-installation, suggesting heating practices were influenced by pre-existing meanings associated with the "making of a home". Whilst some scholars have focussed on interactions with particular energy-efficient technologies, such as controls, others have emphasised the need to study technologies as constituted within meanings of culture, spatialities, technologies, and bodies [12]. Fennell's [12] study of heating enables a greater understanding of the relationship between heating and culture, spatialities, technologies and bodies. In her ethnographic study conducted in Chicago public housing, she found that heating technology was intertwined with class and race dynamics, politics and the bureaucratic regulation of a common sensory regime. Whilst existing research has been helpful in contextualising energy-efficient technologies within societal perceptions of the home and heating, there has been a dearth of research examining how residents engage with such technologies within a housing development and the wider community, rather than just within a home.

The purpose of this paper is to examine how residents in a recently built innovative large low-energy housing development in the UK have engaged, learned, and adapted to energy-efficient heating technologies. In particular, the paper aims to explore the experiences that residents reflect upon from their initial expectations related to moving in and living in their home as constituted within a housing development. The paper did not try to focus on understanding thermal comfort parameters, though it is acknowledged that this is a comprehensively developed literature. In particular, the focus is on residents' motivations and expectations, whether buying or renting a home, and approaches to learning how to engage with new energy-efficient heating technologies in order to reduce energy use and provide a comfortable indoor environment. The housing development studied is promoted as a beacon of low-energy community living, winning a host of social innovation and architecture awards. Though the findings primarily consider energy-efficient heating technology, the literature review and discussion sections draw on a broader scope of work concerning residents' experiences of a range of energy-efficient technologies in the domestic sector as appropriate. The following sections discuss the key literature on the topic of residents' experiences of adaptation to energy-efficient heating technologies and community engagement in energy-efficient issues more broadly. This is followed by an outline of the methods, findings and a discussion and conclusion section.

2. Energy-Efficient Heating Technologies as Constituted through Culture, Spatialities, and Intermediaries

The purpose of the following section is to discuss residents' experiences with heating technologies rather than issues of thermal comfort or comfort more broadly, although it is recognised that these research domains overlap. A growing body of research has suggested that how well a home performs is dependent on many issues, including the ways that residents experience the use of energy-efficient technologies such as heating controls. Controls and their usability have been a topic of an increasing number of discussions specifically in low-energy homes, where there may be a number of advanced heating control technologies installed. Their intended designed role is sometimes based on

"learning" residents' routines and habits, and adjusting heating modes based on individual lifestyles. Despite likely energy savings, a growing number of studies have found that residents often override programmed features [13]. A large-scale international review carried out for the UK Department for Business, Energy and Industrial strategy for both the UK and overseas has outlined the key issues brought about by heating controls [14].

However, problems with controls have mainly been discussed through a technical lens [15]. Studies suggest that the growing complexity of confusing interfaces, inconvenient locations within homes [9], poor functionality [16,17] and issues with slow or no feedback [18] all contribute to difficult or unintended use. In addition, research has begun to highlight some of the social and cultural difficulties in communication between users and designers, including poor handover practices, a lack of knowledge amongst users, site managers, contractors, and designers [19,20] and at times a lack of interest in improving current practice across the built environment [10]. Also, a number of studies have suggested that particular research methods used, such as questionnaires, tend to overestimate users' understanding of controls, thereby at times ensuring socially acceptable responses [21,22].

In low-energy developments in particular, users tend not to make adjustments to controls due to complex technology or unfamiliarity, leading to uncomfortable conditions in indoor environments [20]. In addition, low-energy housing developments often include separate controls for different services, further complicating the management of homes [21]. For some scholars, key difficulties lie in poor handover practices and often very complex manuals [23]. Stevenson and Rial [23] suggest that difficulties lie in poor knowledge and understanding, which can be found across the design team. When discussing the post-occupancy survey carried out for the Sigma house, Stevenson and Rial [23] observed how housing developer's representatives were not always familiar with the more complex controls, referring the user to the induction guidebook.

Researchers have made a number of recommendations to improve handover processes, enhance the design of control interfaces [9] and enable better habit-forming practices in order to provide energy-efficient management of indoor environments. It is still too early to fully appreciate the effects of some of the recommendations, the extent to which they are taken up and how they make a difference.

2.1. Resident Behaviour and Interaction with Energy-Efficient Heating Technologies

Whilst an established area of research has focussed on improving the usability of controls, recent work by Hellwig [24] suggests that greater attention needs to be placed to exploring perceptions of the environment "being controlled". The environment can include broader social and cultural issues, as argued by Fennell [12], whose study of heating enables a greater understanding of the relationships between heating and culture, spatialities, technologies and bodies. In her ethnographic study conducted in Chicago public housing, she found that heating is intertwined with class and race dynamics, politics, and the bureaucratic regulation of a common sensory regime. Using a similar approach, Cupples et al. [25] discussed heating as constituted within national identities and notions of masculinities. Embedded widespread and common practices of using log burners and open fires to heat homes, despite leading to significant air pollution in Christchurch, were found to be deeply tied to notions of "bearing the cold" and cultural identities linked to the colonial past. In an earlier study, Wilhite et al. [26] also highlighted the importance of cultural meanings associated with a "cosy" home in residents' choices of temperature settings in various rooms, as well as a means of demonstrating "love for the family".

Hards [27] discussed ways that domestic energy practices reflect status and stigma, noting how the adoption of wood-burning stoves—defined as "positional goods"—in the United States in the early 19th century was a form of conspicuous consumption. Hards [27] suggested that energy consumption is both a way of conferring status, through conspicuous consumption, or stigma, through a person's inability to conform to societal norms with regard to energy consumption. The mobilisation of different forms of capital, including social, economic, cultural, and symbolic capital, is important here in both establishing one's status position as well as avoiding stigma [27]. Devine-Wright et al. [11] suggested

that perceptions of cosiness in a home occupied by older adults led to the installation of wood-burning stoves and fake fireplaces, despite the installation of highly efficient low-carbon heating technologies.

Barr et al. [28] also suggested that the broader context of environmental behaviour needs to be considered in relation to technology and habits. Mills et al. [29] analysed energy-efficient technology adoption across a large dataset of 5000 households from 11 European countries. The findings discussed the cultural differences between countries despite the similar policies in place, with Eastern European countries showing a lower level of adoption compared to Western Europe. DeMeester et al. [30] conducted a simulated study in the Belgian context, suggesting insulation levels in a home influence lifestyle and heating practices, making the fabric of a home of greater influence than occupancy. Hitchings et al. [31] also argued that environmental behaviour is entangled with "locally distinct adaptation cultures", and that the local context had a greater bearing than cost or health, as largely assumed.

Intermediaries such as plumbers, electricians, and energy-efficiency advisers have been additionally found to play key roles in residents' approaches to technology engagement [32]. In a comparative case study involving five schemes across England, Owen et al. [32] suggested that greater attention in policy-making needs to be paid to the role microgeneration advisors have on the ways that residents decide to adopt energy-efficient technologies. Wade et al. [33] similarly discussed the role plumbing merchants have in heating installers' decision-making regarding choices relating to systems and associated energy-efficient heating technologies.

A deeper understanding of how cultural factors mediate practices is believed by some to be crucial for the development of sustainability-driven policies, especially in light of common discourses on climate change and energy security [34–36]. However, the scarcity of approaches regarding experiences and attitudes towards energy-efficient technologies within and outside a "low-energy home", as well as beyond the systems and technologies that enable it, is striking. Whilst the studies discussed in this section of the paper examine housing and heating broadly, they also enable an important understanding of how energy-efficient technologies, energy and heating are positioned within a wider set of relations between status, stigma [27], national identity, and notions of masculinities [26], as well as concepts of cosiness and glow [11].

2.2. The Role of Landscape, Building, and External Informal Spaces

Where external spaces and energy-efficient technologies have been studied, the focus has been mainly on methods of measuring thermal comfort, sensations, and/or energy use reduction in different climates and across diverse demographics [37]. These external spaces that act as thermal mediators have been variously described as semi-outdoors buffer zones, buffer spaces, in-between spaces, physical links, bridges between the interior and exterior environments and semi-enclosed or half-open spaces [38].

The domestic garden has been viewed as a component of green infrastructure as well as a thermal physical buffer benefitting human well-being, energy efficiency, and health in a multitude of ways [39]. Collective or community gardens, on the other hand, are recognised as physical as well as social buffers. In her study of three community gardens in Minnesota, Kurtz [39] highlighted the role enclosures and the different ways that gardens are bounded have influenced the ways that notions of community are played out. She suggested that gardens that had an open unenclosed aspect tended to be accessible to a wider group of people, and also had an openness to diverse opinions regarding how the gardens could be used and who could use them, whereas gardens that were fenced in some way appeared to be limited and less inclusive. Okvat and Zautra [40] discussed the potential contribution that community gardens can have to mitigating global climate change crisis, highlighting the need for community psychologists in urban and planning policy.

Community communication channels, rather than spaces, have also been suggested as critical to how energy-efficient technologies and measures are approached and adopted [41]. Through studying three UK communities, McMichael and Shipworth [41] examined how individuals sought information within their communities, emphasising the need for tailored community communication campaigns and channels for energy-efficiency programmes. Though it is widely recognised that community spaces can have an effect on how communities interact, socialise, and communicate, their role in learning and adopting energy-efficient technology has largely been under-examined. Stern [42] noted that more cross-disciplinary studies are needed that explain the complexities of the individual and community decision-making processes related to energy.

3. Research Methods

The research design is based on a narrative research approach, drawing on multiple data sources including documentary and photographic evidence, observations, semi-structured interviews and focus groups. Narrative research is a term encompassing a group of approaches that draw on the written or spoken words or visual representation of individuals. These approaches typically focus on the lives of individuals as told through their own stories. The emphasis in such approaches is on the story, typically in relation to both what and how it is narrated [43].

The research setting is based on a recently built low-energy development in southwest England consisting of over 185 homes ranging from one-bed flats to five-bed houses. The homes were originally designed to be zero carbon in accordance with Level 6 of the Code for Sustainable Homes (CSH), and were promoted as exemplary. In 2006, the UK government launched a policy called the Code for Sustainable Homes (which is no longer active) as a building standard designed to tackle environmental sustainability issues such as energy security, resource scarcity and the environmental impacts of activities that contribute to increased levels of carbon dioxide from the domestic sector. The Code's target was to make all new built homes "zero carbon" by 2016, with a 25% improvement in energy use before 2010 and a 44% improvement by 2013, against the 2006 Building Regulations (Part L).

The heavily insulated homes have a mechanical ventilation system with heat recovery (MVHR) installed, as well as a number of other sustainable features such as rainwater harvesting, solar collectors, and solar shading. The layout in most of the homes allows for the kitchen on the ground floor and the living room on the first floor.

3.1. Research Methods—Data Collection and Analysis

The methods for the study draw on a body of work in energy behaviour studies that seek to examine phenomena through stories [43]. An exploration of peoples' stories allows sense-making of events, as well as "understandings and feelings about them". They also play a critical part in notions of community building. In line with work by Smith et al. [43], the approach was to enable residents to tell their "stories", as the technique potentially "offers more expansive ways of allowing demands to be heard and actions to be considered".

3.1.1. Data Collection and Sampling Strategy

Data collection and analysis commenced in June 2016 and was completed in September 2017, with analysis and literature reviews overlapping. The study employed purposive sampling, where the size of the sample in terms of how representative it is becomes less of a consideration [44]; rather, the interest was on gathering "stories" across the housing development emphasising the issues of heating technology adaptation (that had been observed as "problematic" by a separate unpublished study conducted via energy monitoring methods). Interview and focus group 'story' sessions involved a total of 48 participants. Initially, five focus group 'story' sessions were held with groups ranging from 6–12 participants. During the focus group 'story' sessions, questions probed issues surrounding residents' expectations of the development when moving in, reasons for choosing to live in the development, as well as the circumstances that led to the decision to purchase a home in

the development. In addition, questions were concerned with approaches to energy-efficient heating technologies in their indoor environment, daily routines, meanings as well as changes to expectations and experiences in their home and the wider development.

Following the focus group sessions, in-depth semi-structured interview 'story' sessions in 10 homes with 12 participants of diverse ages and backgrounds were held to explore particular aspects that emerged in the focus group discussions. Houses varied, from flats and coach houses to two-bed, three-bed, and five-bed houses located throughout the development. In addition, the owners of two homes shared ownership with the housing association, whereas others were fully privately owned. These were complemented by interviews with housing association managers, site managers and designers where relevant. The research was mindful of ethical issues, and was conducted on an entirely confidential, anonymous and consensual basis.

The focus of this paper is on residents' views, acknowledging wider data scope and interests in the research project overall. The questions in all of the sessions (interviews and focus groups) focussed on three key aspects: *background and understanding of expectations and motivations*, *approaches to the indoor environment in terms of comfort and heat* and *views on control of comfort of indoor environment*. All of the discussions started with understanding a resident's previous home, their overall views on the housing development, their reasons for moving to the development and the importance they placed on the eco ethos of the development. Documentary evidence included design reports, drawings and models of the development as well as any promotional material on the development. Throughout the discussions with residents, photos of the key features of a home or development that were being discussed were taken during conversations. The photos were then studied with the rest of the data, paying close attention to their spatial characteristics [45].

3.1.2. Data Analysis

The study analysis drew on narrative analysis principles whereby stories are treated as knowledge "per se" through conveying a sense of a person's experience [43]. The 'stories' were collected as described in section above and analysed thematically in two stages, drawing out initially descriptive themes and then later analytic themes [46]. Descriptive theme codes are valuable in getting the analysis started, as well as summarising segments of the data. An analytic theme code pulls together material into smaller higher-level units. Descriptive themes included; 'not knowing what a home needs', 'finding out from others how to work things', and 'valuing the community events, gardens'. Over 30 descriptive code themes were grouped under three main analytic categories: (1) arrival, (2) learning and (3) managing (discussed in further detail in Section 4), and then related to the appropriate 'community spaces', as discussed in the data and literature as appropriate. See also Figure 1.

3.1.3. Validity, Reliability, and Generalisability

To ensure that the findings were credible, a number of points were taken into consideration while designing, conducting and writing the research. The points considered when addressing credibility issues included choosing appropriate methods and maintaining a rigorous and critical approach to handling the data [47]. The interview protocol was also refined and tested during the focus group sessions, and after during the individual interviews. Generalisability was considered in this study in terms of how theories developed in one setting may be applicable in another setting [46], drawing on a purposive sampling strategy. The sampling strategy for this study was clearly identified and sample criteria described for each stage of the research (for further information on sampling, see the section above).

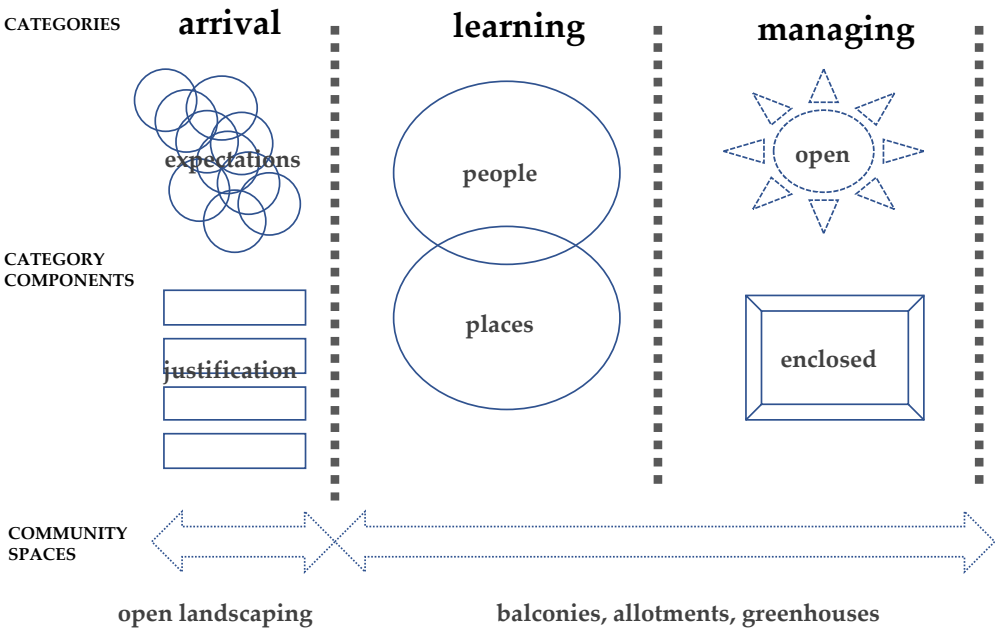

Figure 1. Overview of main category components and "community spaces".

4. Findings

The findings are discussed in relation to three key themes that emerged from the analysis of the stories that residents reflected upon in the focus group discussions and interview sessions. The stories relating to adapting and learning how to manage new energy-efficient heating technologies revolved around: The stories of (1) **arrival**, expectations and hopes; (2) **learning** what a home needs—people, collective spaces, and places; and (3) **managing** new technologies in home. See also Figure 1 above.

4.1. Stories of Arrival, Expectations, and Hope

In most cases, residents found the development by chance in magazines, portals, or local adverts, whether moving from elsewhere in the country or elsewhere within the city. In many cases, residents chose to live in the development in order to save money, seeing the promoted low running costs as the key attraction of the homes. In some cases, residents were drawn to the advertised "sense of community", and in some cases, the eco features promoted in the sales leaflets such as rainwater harvesting, solar panels, or recycling. An article published in *The Times* was often cited; specifically, residents viewed the 'sense of community' that was conveyed in the article image as attractive and desirable. See Figure 2.

Most residents were moving from conventional homes located within a street, and had never lived in an estate-type development or a new build home. In very few cases did the sustainable ethos of the development play a major part in residents deciding to purchase a home on the site.

> *"We moved to the development because we needed to downsize and needed to be frugal with money . . . obviously it's reduced bills here . . . "* (Linda and Richard, January 2017)

For most of the residents, the move was about a transition to a new stage of life such as retirement, being divorced, "children moving out" and the residents being left on their own, or "children staying at home" and needing more space.

> *"Basically, we were living across in Wales in a new development (that was like a) traditional build (being) detached with a garage and on two floors . . . We used to live nearby, and then moved around a lot; but we had friends here, so it made sense to move back here" . . .* (Simon, February 2017)

Figure 2. Image of "community spirit in times past" in *The Times*, 24 August 2012 (author Carol Lewis).

Whilst most residents did not choose to live in the development because of its low-carbon credentials, many were drawn to the idea of a "created community". After having described how they moved to the development, residents would often begin to discuss features of their home or development that were unexpected or disappointing. "Buying into" a community and finding that most residents were not "eco" or did not share the promoted ethos of the development was often reflected upon.

Dalia moved into the development having lived in the city most of her life and being familiar with the area. Though she wasn't planning to buy, she did note how she "stumbled across" the show home and was offered to buy on the condition "she sold hers by 5 p.m. that night". She chose her particular home because it had a kitchen window on the corner, allotments nearby, and a balcony "so the dog could watch people come and go". However, she found a type of community (her home was close to what she described as the "social housing" bit) that she did not expect, and a home that she felt "did not have what it needed" in terms of "knowing what to do and how to use it".

> *"I hadn't quite realised the impact of living here, as there is quite a lot of drama; sometimes it is like living in the middle of Eastenders with the bailiffs, police, paramedics, fire engines. You can get them all in one night, all outside my own house . . . "* (Dalia, January 2017)

Despite being disappointed, Dalia went on to justify the investment that she had already made into her home (emotionally as well as financially) by reflecting upon the wider "community as being lovely and a microcosm of the country" as well as observing how "a home is somewhere you have to love", reminding us of that her house has "lots of light and that extra kitchen window; a corner window".

Rose had similarly lived in the area and was familiar with the site, which had been historically populated by hospital buildings. She recalled the time that the hospital closed and "furniture [was] put up outside for sale", leaving many empty buildings in the area for some time. She described her previous flat as increasingly unaffordable and cut off. A leaflet about the development that had arrived in the post led her to go and have a look "out of curiosity" rather than with a plan. Although she could not buy, she found shared ownership a means of "having a space of your own". Though Rose also described being disappointed with the outside of her home not having trees, her ability to partially own it made up for any misgivings.

4.2. Learning What a Home Needs–People, Community Spaces, and Places

Whilst discussing adjusting to their new home environment, residents often described a long process of learning over periods of two to four years as an unexpected issue. In many instances, welcome packs and instructions were described as "being wrong", referring to a different type of environmental "control" and not giving enough of an insight into the "type of lifestyle this needed"

> *"I was a little bit of a guinea pig . . . so they showed me a building and asked me what questions I had, but they didn't hand over much, apart from a generalistic pack, so I had to find out myself. They also said some things that were utter rubbish; they said don't ever touch the ventilation system, which is utter rubbish, as you obviously have to change it to summer mode . . . "* (Dalia, January 2017)

For most residents, learning involved reliance on others, whether a next-door neighbour, an electrician "who visited and fixed the controls", a wider community social media network such as a Facebook page, or a manual produced by one of the residents on the use of the heating controls and maintenance of the systems. In many discussions, such a manual would be brought up, or the Facebook page where residents could post their issues with the development or their home was mentioned. However, most residents did not seek to question the difficulties encountered or complain to the developer or housing association in the first instance. Instead, residents noted how they had used heating controls before, and that "it should not be that difficult". In some instances, residents did not alter the programming since moving in, finding themselves often opening widows throughout the day and night, as their home was too hot.

Seeking advice from plumbers and electricians did not always resolve the issues, since they often "simply could not help" "or did not know". In two instances, residents bought an alternative thermostat "because another resident had done it".

> *" . . . we didn't know how to use it. Oh, well, we asked our plumber who services our boiler and he said he didn't know about thermostats and the such; we thought about the Hive, but really, we don't need all that, and it wasn't until Linda and Richard got one and we saw it and thought, "Well, it seems well installed." Actually, we did call Danfoss (as existing controls are provided by them), but they told us just to use any one? What, from the yellow pages? I wasn't going to call the yellow pages, was I?* (Yvonne, March 2017)

Places for ad-hoc outdoor chance meeting were of particular importance. Residents noted the value of balconies and shed spaces as places to meet and ask "how the systems worked" and find out how to "fix things". One of the residents spoke of being at times socially isolated, especially in a home that "needed a mathematical brain" and "preferably a partner". She described the value of a balcony off her main living space (see Figure 3) where chance encounters could take place and learning could be shared. Jasmin spoke of the people she met as "tend(ing) to be women over 60, (who) support each other . . . ". She discussed how in her "square" she was "the only one who is around in the daytime", and that the balcony provided an informal meeting place for social exchange. The balcony space provided direct access to Jasmin's home and main living space via a glazed entrance door, as can be seen from the photo.

Marcus similarly discussed how the development provided "a good community base", observing a sense of "togetherness in the street" and noting how in their balcony one is made to feel "part of the community base". Marcus discussed how his flat was his first home, and how although he was familiar with the area, he did not know the development. He did not participate in many of the community events, but described the balcony as a way of "staying in touch".

Many residents discussed the shed spaces and bin enclosures as areas where one "can see how green one is". One of the residents observed how the communal bin areas meant that one had to "get their bin bag out and clear up the mess", viewing that approach as being in line with the "point of a community". Some discussed maintaining community areas quite rigorously, and went as far as noting the need for residents to being "screened" so that the "message gets across as to what one is

meant to be doing here". The shed spaces are largely informally bounded with an openness to the landscape around and visibility to surrounding housing (see Figure 4).

Figure 3. Balconies as a way to share experience in an ad hoc way.

Figure 4. 'Shed' space as a way to share "what works and what doesn't".

4.3. Managing New Technologies in Home—Escape into the Green

When discussing how they found their indoor environment in terms of energy-efficient heating technologies, most residents noted long periods of adjustment, "not having what the home needed", and not knowing were things were or how they worked. One resident described the home as needing a particular set of skills and knowledge (which she perceived she lacked).

> *"Initially they (the developers) just wanted your deposit down . . . bear in mind I'm blonde and I'm artistic . . . and to live here you need to have mathematical brain . . . and preferably a partner" . . .* (Jasmine, February 2017)

For many, the energy-efficient heating technologies "could not be controlled", and efforts often relied on "taking chances" and trial and error. One resident noted how the "heating controls had a life of their own", and controlling them meant "tak(ing) a glass of sherry, cross(ing) my fingers and press(ing) the buttons". For some, the sense of helplessness in managing the indoor home environment was conflated with a sense of social isolation and being "on your own".

In most instances residents described their home as too hot, reflecting upon the vents "as being everywhere", and identified the balcony "as a social corner and chance to breathe". When prompted to describe how they "cool their home", in most instances "windows are left wide open" and "vents are not touched". For many, external gardens and allotments were viewed as spaces to "escape to" from a home that made one resident feel like an "oven-ready chicken in a wooden box". Allotments were viewed as places for chance encounters, where experiences of learning how to manage the home would be swapped and shared. Allotments had an "openness" as well as individuality about them where "boundaries were not strict" (see Figure 5).

Figure 5. Allotments as place to escape the "hot house".

In addition to allotments, for some residents, greenhouses played a key part in managing the technologies in their new home. One resident discussed how the greenhouse acted as a first encounter with growing vegetables, which was something she had not done before.

> *" . . . I have like most people struggled with the timer; the boiler; I didn't get any training . . . my neighbour has struggled as well; it was too hot; because we have such good glazing, it gets very dry hot . . . I have a greenhouse as well; I've never grown anything, and I thought id just try it . . . and I love it; it's pleasant there; its my thing; and you get to know everybody who has a greenhouse; you can wander down there and there are people there; they know what to do with the systems, so you learn . . . "* (Rose, February 2017)

The greenhouses were described as having a "sense of enclosure" as well as a "friendly" openness. In this environment, new skills could be learned, and common concerns could be shared in a sheltered space.

In some instances, residents (particularly those seeking an eco-community) viewed themselves "knowing something others don't". Yvonne and her husband, who lived in a two-bed house and had already lived in a similar "eco development up north", described their knowledge and interest in eco-living as being familiar and long established. They also described how they learned in community events and playgrounds of "others who don't seem to realise the Mechanical Ventilation with Heat Recovery (MVHR) system needs maintaining or the solar panels need cleaning". They also discussed how a lot of their time was spent "re-specifying the house", so light switches were zoned as built, and the house could be managed better.

> *"The outside light and inside light downstairs come on at the same time. Why? We wanted privacy...also it saves energy . . . and they did it . . . "* (Yvonne, March 2017)

Yvonne and her husband were concerned about the future of the community, more so than their house. They saw themselves as a part of something that had taken time and effort to learn, make, and maintain. Yvonne observed how heat, cold, and light were all parts of the house that they had to adjust to/buy into "when you move to an eco life?"

The discomfort of the indoor environment was often reflected upon through other disappointing features within the home, such as a "lack of wall space being occupied by doors and technology", or "light switches in strange places such as behind the door" as well as outside the home on bollards "that no one warned us about". Bollards were viewed as being installed without resident consultation (post-completion), and were viewed as obstructing the ways that residents could use the "front of the house" such as opening front doors for "cross-ventilation", as they might "encourage cars to get closer to the front door".

Overall, management and adjustment for residents revolved around engaging in community spaces (whether outdoor places or events) through which experiences on how to fine-tune, re-specify, or learn to control heating technologies would be exchanged. The spatial characteristics of the community spaces, such as the "openness of the allotments" or sense of friendly enclosure in the greenhouses, contributed to different ways of adjusting, learning, and sharing experiences.

5. Discussion and Conclusions

Extending Stern's [42] suggestion for a transdisciplinary examination of context in energy research, findings in this paper similarly suggest a need to analyse the dynamics of domestic energy use as intertwined with and through different spaces (indoor and outdoor) of everyday life. The study reported in this paper highlights the possibility of understanding how adaptation and learning to manage new energy-efficient heating technology occurs in and through collective community external spaces, and not just within a home. Though it is well established that community programmes can play a significant part in the social shaping of energy efficiency [48,49], the spaces and the effect of their particular spatial characteristics within which they take place have been largely overlooked.

How do the particular spatial characteristics of a collective space, such as an "openness" in the allotments or "sense of enclosure" in the greenhouses, shape energy-efficiency behavioural learning and adoption? It has been established for some time in anthropology that the built environment can hold repositories for social meaning, physical bodily orientations and identities [12]. In addition, research in the built environment has observed detailed relationships between comfort and clothing [25], as well as furnishings and openings [16]. This study extends this work by highlighting how the use of space (both physical and social) within and outside the home obstructs or enables particular approaches to the management of heat and heating in low-energy homes.

Within UK policy, the concept of a zero or low-energy house has been (re)defined several times, with an emphasis placed on fabric, energy sourcing and energy demand management [50]. Missing are broader implications of physical characteristics of the outdoor home context, and the spatial features of spaces such as allotments, balconies, greenhouses and domestic gardens. Instead, too often the focus is

on the technological components of heating systems such as valves, controls, thermostats or boilers' inaccessible technology, rather than users' lack of preparedness or understanding.

The context of heating and energy-efficiency learning is not just within a home, its associated social networks and its community channels; it is also within the diverse collective community spaces through and within which the networks and channels take place. Recent literature has suggested that more focus should be placed on the community level and that energy users should be engaged in their role as citizens, rather than only that of consumers [41]. Most of the discussion on low-carbon communities focusses on place-based communities such as cities, municipalities, or neighbourhoods [51], without necessarily taking into consideration their relationship and/or effects on a home.

This study focussed on one development in the UK, recognising that other developments within and outside the UK may bring about a diversity of experience, stories and meaning. There is a need for comparison studies that take into account several low-energy housing developments within one country or across climatic contexts in order to develop a greater understanding of community space and place, and its relationship with the learning and management of heating energy-efficient technologies. Further research is also needed in order to better understand the ways that the physical and social components of a home environment (both inside and outside) help shape how heat management is approached, controlled, or ignored.

The study findings make several contributions to policy and practice. In terms of policy (within the UK and similar European climatic, housing, and regulatory contexts) specifically related to space heating, a greater acknowledgment of the outdoor community context within which homes are designed is needed. Understanding how spatial characteristics of outdoor space (community and otherwise) enable or not community learning is critical to the development of current and future energy demand reduction strategies. There are also implications in this paper for designers (including architects, landscape architects, planners, urban designers, community empowerment agents and housing developers) of both homes, as well as the environment that surrounds them (the landscaping and balconies), regarding the spatial, environmental, and urban conceptualisation and management of community outdoor space, including its relationship with individual homes. This paper enables some initial observations of the potential importance the design and management of outdoor space and place play in the ways that decisions on comfort and heating in particular are made by residents.

Author Contributions: Sonja Oliveira is a Senior Lecturer and Co-Programme Leader in architecture and environmental engineering at the Department of Architecture and the Built Environment (UWE). Sonja Oliveira's research and practice have developed through working at the interface of industry and academia as well as across a range of cross disciplinary contexts (including architecture, environmental science, management, behaviour studies and sociology). She has worked as a senior design manager, sustainability advisor and strategist for over 15 years, harnessing diverse disciplinary skills to innovate, lead and develop new or extending current understandings of complex phenomena in the built environment. Her research expertise is built on developing new insights in energy use and design practice across scales of analysis from policy level global reviews, organizational dynamics in implementing new digital technologies in design firms to household heating practices in low carbon architecture. Elena Marco is Head of Department of Architecture and Built Environment (UWE). Elena Marco's main areas of expertise are in the symbiosis between architecture, health and sustainability. Externally, Elena Marco was selected by the Architects' Journal as one of the 20 most influential Women in Sustainable Architecture in the UK, and has been part of the Judging Panel for the Royal Institute of British Architects (RIBA) in the Silver Medal (Part 2 design projects) category as well as the RIBA South West Awards 2017.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Frerk, M.; MacLean, D. *Heat Decarbonisation, Potential Impacts on Social Equity and Fuel Poverty*; National Energy Action: London, UK, 2017.
2. Committee on Climate Change (CCC). *Report 'Next Steps for UK Heat Policy'*; CCC: London, UK, 2016.
3. Department of Energy and Climate Change (DECC). *How Heating Controls Affect Domestic Energy Demand: A Rapid Evidence Assessment*; HM Government: London, UK, 2014.
4. Department of Business, Energy and Industrial Strategy (DBEIS). *The Future of Heat: Domestic Buildings*; HM Government: London, UK, 2016.

5. Department of Energy and Climate Change (DECC). *What People Want from Their Heating Controls: A Qualitative Study*; HM Government: London, UK, 2013.
6. Department of Trade and Industry (DTI). *Meeting the Energy Challenge: A White Paper on Energy*; HM Government: London, UK, 2007.
7. Halvorsen, B.; Larsen, B.M.; Wilhite, H.; Winther, T. Revisiting household energy rebound: Perspectives from a multidisciplinary study. *Indoor Built Environ.* **2016**, *25*, 1114–1123. [CrossRef]
8. Gill, Z.M.; Tierney, M.J.; Pegg, I.M.; Allan, N. Low-energy dwellings: The contribution of behaviours to actual performance. *Build. Res. Inf.* **2010**, *38*, 491–508. [CrossRef]
9. Stevenson, F.; Carmona-Andreu, I.; Hancock, M. The usability of control interfaces in low-carbon housing. *Arch. Sci. Rev.* **2013**, *56*, 70–82. [CrossRef]
10. Pitts, A. Passive house and low energy buildings: Barriers and opportunities for future development within UK practice. *Sustainability* **2017**, *9*, 272. [CrossRef]
11. Devine-Wright, P.; Wrapson, W.; Henshaw, V.; Guy, S. Low carbon heating and older adults: Comfort, cosiness and glow. *Build. Res. Inf.* **2014**, *42*, 288–299. [CrossRef]
12. Fennell, C. 'Project heat' and sensory politics in redeveloping Chicago public housing. *Ethnography* **2011**, *12*, 40–64. [CrossRef]
13. Lomas, K.; Haines, V.; Beizaee, A. *Heating Controls Scoping Review Project*; Department of Business, Energy and Industrial Strategy (DBEIS), HM Government: London, UK, 2016.
14. Oliveira, S.; Prestwood, E.; Chatterton, T.; Poghosyan, A.; Gething, B. *Heating Controls: International Evidence Base and Policy Experiences*; Department of Business, Energy and Industrial Strategy (DBEIS), HM Government: London, UK, 2017.
15. Leaman, A. People, Environmental Control and Buildings in Use. Talk held in Reading, UK, 26 January 2006.
16. Raja, I.A.; Nicol, J.F.; McCartney, K.J.; Humphreys, M.A. Thermal comfort: Use of controls in naturally ventilated buildings. *Energy Build.* **2001**, *33*, 235–244. [CrossRef]
17. Peffer, T.; Pritoni, M.; Meier, A.; Aragon, C.; Perry, D. How people use thermostats in homes: A review. *Build. Environ.* **2011**, *46*, 2529–2541. [CrossRef]
18. Andersen, R.V.; Toftum, J.; Andersen, K.K.; Olesen, B.W. Survey of occupant behavior and control of indoor environment in Danish dwellings. *Energy Build.* **2009**, *1*, 11–16. [CrossRef]
19. Bell, M.; Wingfield, J.; Miles-Shenton, D.; Seavers, J. *Low Carbon Housing: Lessons from Elm Tree Mews*; Joseph Rowntree Foundation: York, UK, 2010.
20. Monahan, S.; Gemmell, A. *How Occupants Behave and Interact with Their Homes, The Impact on Energy Use, Comfort, Control and Satisfaction*; NF 35; NHBC: Amersham, UK, 2011.
21. Shipworth, M. *Motivating Home Energy Action: A Handbook of What Works*; Australian Greenhouse Office: Kingston, UK, 2000.
22. Pett, J.; Guertle, P. *User Behaviour in Energy Efficient Homes—Phase 2 Report*; Association for the Conservation of Energy: London, UK, 2004.
23. Stevenson, F.; Rial, H. Paper 595: The Sigma Home Towards an Authentic Evaluation of a Prototype Building. In Proceedings of the PLEA 2008—25th Conference on Passive and Low Energy Architecture, Dublin, Ireland, 22–24 October 2008.
24. Hellwig, R.T. Perceived control in indoor environments: A conceptual approach. *Build. Res. Inf.* **2015**, *43*, 302–315. [CrossRef]
25. Cupples, J.; Guyatt, V.; Pearce, J. "Put on a jacket, you wuss": Cultural identities, home heating, and air pollution in Christchurch, New Zealand. *Environ. Plan.* **2007**, *39*, 2883–2898. [CrossRef]
26. Wilhite, H.; Nakagami, H.; Masuda, T.; Yamaga, Y.; Haneda, H. A cross-cultural analysis of household energy use behaviour in Japan and Norway. *Energy Policy* **1996**, *24*, 795–803. [CrossRef]
27. Hards, S. Status, stigma and energy practices in the home. *Local Environ.* **2013**, *18*, 438–454. [CrossRef]
28. Barr, S.; Gilg, A.W.; Ford, N. The household energy gap: Examining the divide between habitual-and purchase-related conservation behaviours. *Energy Policy* **2005**, *33*, 1425–1444. [CrossRef]
29. Mills, B.; Schleich, J. Residential energy-efficient technology adoption, energy conservation, knowledge, and attitudes: An analysis of European countries. *Energy Policy* **2012**, *49*, 616–628. [CrossRef]
30. De Meester, T.; Marique, A.F.; De Herde, A.; Reiter, S. Impacts of occupant behaviours on residential heating consumption for detached houses in a temperate climate in the northern part of Europe. *Energy Build.* **2013**, *57*, 313–323. [CrossRef]

31. Hitchings, R.; Waitt, G.; Roggeveen, K.; Chisholm, C. Winter cold in a summer place: Perceived norms of seasonal adaptation and cultures of home heating in Australia. *Energy Res. Soc. Sci.* **2015**, *8*, 162–172. [CrossRef]
32. Owen, A.; Mitchell, G.; Gouldson, A. Unseen influence—The role of low carbon retrofit advisers and installers in the adoption and use of domestic energy technology. *Energy Policy* **2014**, *73*, 169–179. [CrossRef]
33. Wade, F.; Shipworth, M.; Hitchings, R. Influencing the central heating technologies installed in homes: The role of social capital in supply chain networks. *Energy Policy* **2016**, *95*, 52–60. [CrossRef]
34. Harrison, C.; Popke, J. "Because you got to have heat": The networked assemblage of energy poverty in eastern North Carolina. *Ann. Assoc. Am. Geogr.* **2011**, *101*, 949–961. [CrossRef]
35. Hitchings, R.; Day, R. How older people relate to the private winter warmth practices of their peers and why we should be interested. *Environ. Plan. A* **2011**, *43*, 2452–2467. [CrossRef]
36. Rupp, R.F.; Vásquez, N.G.; Lamberts, R. A review of human thermal comfort in the built environment. *Energy Build.* **2015**, *105*, 178–205. [CrossRef]
37. Pitts, A.; Saleh, J.B. Potential for energy saving in building transition spaces. *Energy Build.* **2007**, *39*, 815–822. [CrossRef]
38. Cameron, R.W.; Blanuša, T.; Taylor, J.E.; Salisbury, A.; Halstead, A.J.; Henricot, B.; Thompson, K. The domestic garden—Its contribution to urban green infrastructure. *Urban For. Urban Green.* **2012**, *11*, 129–137. [CrossRef]
39. Kurtz, H. Differentiating multiple meanings of garden and community. *Urban Geogr.* **2001**, *22*, 656–670. [CrossRef]
40. Okvat, H.A.; Zautra, A.J. Community gardening: A parsimonious path to individual, community, and environmental resilience. *Am. J. Commun. Psychol.* **2011**, *47*, 374–387. [CrossRef] [PubMed]
41. McMichael, M.; Shipworth, D. The value of social networks in the diffusion of energy-efficiency innovations in UK households. *Energy Policy* **2013**, *53*, 159–168. [CrossRef]
42. Stern, P.C. How can social science research become more influential in energy transitions? *Energy Res. Soc. Sci.* **2017**, *26*, 91–95. [CrossRef]
43. Smith, J.; Butler, R.; Day, R.J.; Goodbody, A.H.; Llewellyn, D.H.; Rohse, M.H.; Whyte, N.M. Gathering around stories: Interdisciplinary experiments in support of energy system transitions. *Energy Res. Soc. Sci.* **2017**, *31*, 284–294. [CrossRef]
44. Blaikie, N. *Approaches to Social Enquiry*; Polity Press: Cambridge, UK, 2007.
45. Hodson, M.; Marvin, S. Cities mediating technological transitions: Understanding visions, intermediation and consequences. *Technol. Anal. Strateg. Manag.* **2009**, *21*, 515–534. [CrossRef]
46. Miles, M.B.; Huberman, A.M. *Qualitative Data Analysis: An Expanded Sourcebook of New Methods*; Sage: Thousand Oaks, CA, USA, 1994.
47. Silverman, D. *Qualitative Research: Theory, Method and Practice*; Sage: London, UK, 1997.
48. Saintier, S. Community energy companies in the UK: A potential model for sustainable development in "local" energy? *Sustainability* **2017**, *9*, 1325. [CrossRef]
49. Mengolini, A.M. Prosumer Behaviour in Emerging Electricity Systems. Ph.D. Thesis, Politecnico di Torino, Torino, Italy, 2017.
50. Zero Carbon Hub (ZCH). *Design as Built Performance End of Term Report*; ZCH: London, UK, 2014.
51. Jalas, M.; Hyysalo, S.; Heiskanen, E.; Lovio, R.; Nissinen, A.; Mattinen, M.; Nissilä, H. Everyday experimentation in energy transition: A practice-theoretical view. *J. Clean. Prod.* **2017**, *169*, 77–84. [CrossRef]