

Coping with extremes, creating comfort: user experiences of 'low-energy' homes in Australia.

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Coping with extremes, creating comfort: user experiences of 'low-energy' homes in Australia.

Energy Research and Social Science

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Abstract

Low- and zero-energy homes are core elements in transitioning the housing stock towards a more environmentally sustainable model that responds to concerns about climate change and the need for energy demand reduction. Whilst there is a growing body of work on the technical performance of these homes, less attention has been paid to the experiences of users, particularly in cooling-dominated climates. Drawing on interviews that utilise an oral history approach with householders in Lochiel Park Green Village in South Australia, this research situates experiences and energy practices within individual housing histories in order to better understand the relationship between the occupant, the building and the resultant energy use. Within the context of debates around adaptive comfort practices this innovative method reveals that, despite the expectations of some residents, moving to a 'low-energy' home has reduced rather than eliminated their active involvement in maintaining a thermally comfortable environment

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1 Introduction

This paper explores heating and cooling practices in the context of 'low-energy' housing and technological and social change. It utilises a qualitative oral history approach with residents of the Lochiel Park Green Village, Adelaide, South Australia to reveal and explore changes in expectations and practices relating to thermal comfort over their lives and to situate this within their housing pathways, which include their present-day 'low-energy' home. Qualitative methodologies, of which oral history is an example, are suited to 'exploratory studies or accessing more in-depth information, such as how social actors construct meaning' [1].

In this research, such an approach provides a unique window into how the residents of Lochiel Park reconstruct the negotiation of extreme temperatures over place and time. The paper considers the evolving relationship between occupant and home in relation to thermal comfort, and provides new insights into the way purpose-built 'low-energy' homes may reshape that relationship. In doing so, it responds to calls by Ambrose, Goodchild and O'Flaherty [2] for more phenomenological investigations of user experiences and the rejection of the implication that the role of qualitative research is simply to supplement quantitative surveys.

Research on Lochiel Park has to date been concerned mainly with the energy and economic impacts of socio-technical change [3,4]. This reflects much of the literature on low and zero energy homes worldwide [5–7]. Our interest here is the user experience rather than building performance. Given that energy consumption can vary between seemingly identical buildings [8] and that householders can therefore have a substantial effect on the carbon performance of homes, understanding practices and experiences that shape them is an essential contribution to this literature.

Central to the user experience is the contested notion of comfort [9,10]. Whilst we argue that index measurement and engineering approaches have dominated building practice and regulation and result in a rapid growth of energy intensive comfort provision, we point to increasing interest in energy social science literature in adaptive approaches and low carbon practices [11,12]. Far from creating a technology-practice binary that absolves the building of its role in providing comfort, an adaptive approach calls for designers to look beyond a narrow temperature range and engage with the ways in which buildings can provide a space in which there is flexibility for comfort to be achieved in ways that are culturally, historically and socially sensitive.

This paper considers to what extent the lifetime experience of thermal comfort impacts the contemporary experience of thermal comfort in 'low-energy' homes. We start with an exploration of the literature on thermal comfort, after which we introduce our case study and methodology. An account of the interviews with householders is followed by discussion and interpretation that places the transition to 'low-energy' homes within the context of comfort provision, vulnerability and social justice.

2 Understanding Comfort

2.1 Comfort in Context

It has been recognised that energy use in buildings is the result of complex interactions and that human behaviour can result in substantial energy end-use differences in almost identical buildings in almost identical climates [13,14].

More recently there has been interest in the energy social science literature in user experiences of thermal comfort in homes, especially those designed to be 'low-energy' [15–

19]. A driver of this work is the need to reduce energy demand for heating and cooling as part of a transition to a low carbon future. This is in response to changes in comfort norms over recent decades, which have been heavily influenced, in warm climates at least, by energy-intensive air conditioning systems and an increasing consumer expectation of a narrow indoor comfort range [20].

An engineering approach has tended to dominate building practice and thermal comfort research, but there is increasing emphasis placed on alternative conceptualisations that foreground adaptive and practice-based approaches and seek to understand these within a context of historical comfort practices. In part this has been a rejection of a narrow interpretation of comfort but it also reflects concern for the environmental and social implications of energy-intensive ways of providing comfort. These concerns relate to increasing energy use in the context of climate mitigation efforts [21,22], the social gradient in access to energy and energy services [23,24], and technical challenges such as balancing network capacity and integrating renewable energy into the grid [25].

The contemporary debate on comfort transcends technical solutions and is increasingly focused not only on how homes provide thermal comfort, but also how householders are engaged with this process [15,26]. For example, Day and Gundersen describe how active occupant engagement in thermal comfort operations such as opening and closing windows can result in a willingness to tolerate wider temperature ranges. Low and zero energy housing is seen as important in addressing environmental concerns [27,28]. Less is known about the user experience of these developments, especially around how their thermal comfort practices are shaped by this new standard of housing.

2.2 The Science of Comfort

To explore further the relationship between thermal comfort and residential energy use, 'it is necessary to understand what a comfortable home means' [29]. A challenge here is that the concept has become contested in the literature [30]. An engineering approach relates to the 'science of comfort' developed during the 20th century and is demarcated by the physics of thermal comfort such as temperature, humidity, air speed and clothing insulation [9]. The dominance of this engineering approach is associated with a rapid uptake of mechanical heating and cooling systems, resulting in increases in energy use [12]. The use of air conditioning has shifted from 'luxury' to a perceived 'necessity' [31]. In the US more than 87% of homes now have some form of air conditioning [32] and in Australia it is in more than 75% of homes [33]. This uptake has shifted thermal comfort expectations for building occupants and created situations whereby occupants can set thermostats to deliver an arbitrary or idealised 'comfort' rather than an experiential and desired level of comfort, with research suggesting that many buildings are actually over-cooled and therefore not necessarily comfortable or healthy [34].

The engineering comfort approach has informed building energy performance regulations. It has typically been easier and cheaper to include mechanical heating and cooling systems rather than focusing on a more complex combination of passive design, material characteristics and user behaviour to provide thermal comfort. In Australia and elsewhere this has resulted in relatively thermally poor buildings, which have tended to reinforce need for mechanical heating and cooling [35]. Elsewhere the expectation to provide mechanical heating and cooling rather than address building design is similar. Winter [36] argues, for example, that in India 'in the space of a generation air-con has profoundly changed how buildings are built and conceived'.

2.3 Adaptive Comfort

In contrast to engineering-dominated approaches, an adaptive thermal comfort approach is based on the assumption that building occupants will take conscious actions in response to the physiological experience of the body alongside the involuntary physiological responses relating to the body's complex thermoregulatory system [9]. For example, adding or removing additional layers of clothing or opening and closing windows [37–39]. De Dear and Brager [40] argue that it is important to take account of the psychological dimension of adaptation 'which may be particularly important in contexts where people's interactions with the environment... or diverse thermal experiences, may alter their expectations, and thus, their thermal sensation and satisfaction'. This approach also responds to a school of thought representing comfort as a 'standardised set of conditions' such as applied in ASHRAE Standard 55-1992, which is in conflict with empirical social research that has evidenced 'cultural variation in meaning, experience and expectation'. Critics of a narrow approach point to 'thermal monotony' [41] or *the homogenisation of the built environment* [42] and highlight international variations of reported comfort in wide temperature ranges in studies in, for example, Japan and Pakistan [43].

Moore et al [15], find that there is a risk that relying on the building to provide comfort risks simplistic assumptions about householder comfort whereas 'an adaptive built environment allows householders to develop skills to better regulate their own culturally and socially appropriate levels of comfort.' To Shove [44] comfort is viewed as an 'achievement' through practice, rather than an 'attribute' of the building.

There are calls for a conceptual shift away from an isolated focus on technology or architectural design to deliver improved housing outcomes, towards the synergistic complementarity of building solutions and 'practices of comfort' [12], especially as we move towards 'low-energy' housing. This involves recognising and understanding the ways in which technology has co-evolved with building design and the associated 'changing meaning, technologies and routines of home living' [45]. Many argue that it also involves challenging user perceptions [11] as well as 'norms and expectations around indoor comfort that many now argue are unsustainable' [12].

2.4 Comfort Practices in an Historical Context

This means understanding user experiences and, as Trentmann [46] argues, 'lowering the analytical scale to the level where we can see how infrastructures have intersected with the home, domestic technologies and daily practices'. There is research that finds thermal comfort practices are passed down historically, acquired through practical knowledge and experience, and become co-dependent on householders' access to a range of housing materials and technologies, seasonal variations, and evolving social understandings, expectations and norms [47,48]. In viewing comfort practices in their historical and social setting we are reminded that 'norms of heat and comfort are products of history and debate' [49] and that 'the idea of what is comfortable has certainly changed from one time, place and season to another' [50], with modern conceptions of comfort arising in eighteenth century Europe [51]. Given this, arguably promoting simplistic and 'one dimensional definitions of comfort, which ignore history, are bound to be unsatisfactory' [51].

Winter, writing in an Asian context, suggests that such histories may reveal 'low carbon comfort pasts' [12] that may represent a resource for reducing future energy use impacts. Winter cautions against romanticising these past practices, however, and historical studies of energy and comfort practices do tend to reveal not only that expectations of comfort have changed over time, but also that the low-carbon pasts were also often low-comfort pasts.

At the household level researchers have conducted a localised history of domestic heating, seeking to capture the 'co-evolution of practices and material arrangements' [52] and explore the ways in which space heating spread from being limited to one living room to

reaching the whole home, and from restricted hours to other parts of the day, and the way this both responded to and influenced practices in the home. Goodchild, Ambrose and Maye-Banbury [53], in their exploration of home heating through oral histories in the UK explore practices for coping with cold weather including gathering in the one room with heating, and how even simple technologies such as hot water bottles enabled them to avoid cold beds. In a study of warm temperate Australia, Nicholls and Strengers [54], recalled that some residents had grown up with no air-conditioning and recalled low- or zero-energy mechanical cooling approaches to cope with heat related discomfort. Waitt et al. describe behavioural responses through the lens of 'tyrannies of thrift' brought about by circumstance and life experiences of older Australians [55]. Whilst these studies provide a valuable insight into the behavioural response of occupants to their experiences of thermal discomfort, there has been limited research placing housing energy practices in the context of energy histories in relation to purpose built 'low-energy' housing.

In arguing for a perspective that emphasises the role of comfort practices within their social and historical context, we do not seek to diminish the importance of the building itself. As Chang argues, the rise of air-conditioning has resulted in 'the loss of a more climatically and culturally sensitive way of design and comfort provision' [34]. Additionally, it is important to recognise that ability to adapt will vary across populations, with the very young, elderly or unwell typically being less able to do so. Far from creating a practice-technology dichotomy or an artificial distinction between building and occupant, it is essential to recognise the complexity of this relationship. An adaptive approach has opened the way for a 'more holistic and dynamic understanding of thermal comfort' [9] in which the role of designers and builders is to extend their thinking beyond a narrow temperature range towards how buildings can provide flexibility in ways that are culturally, historically and socially sensitive.

3 Lochiel Park Green Village

The Lochiel Park Green Village was developed by the State Government of South Australia as an image of the future, an example of sustainable housing that would provide a model for developers and the public. The estate applied new standards in urban form and house design and new practices in the local construction industry, while at the same time was designed to deliver a financial return for the government as land owner [4]. The homes were designed to provide comfort in the Adelaide climate, characterised as warm temperate, almost Mediterranean, with cool to mild winters, moderate rainfall, and warm to hot, generally dry summers.

When the development of Lochiel Park began in 2008 the vision of near net zero energy homes in a net zero-carbon precinct was innovative in the context of South Australia, and Australia more broadly. It should be seen in the context of an emerging trend towards net zero energy and energy-plus buildings worldwide [56]. Numerous engineering studies of very 'low-energy' homes attest to the reduction of net delivered energy use through the application of passive solar design, appliance efficiency and local renewable energy supply [57].

Whilst the energy characteristics of purpose built 'low-energy' homes are well understood, less is known about the user experience [2], and much of that knowledge has concerned heating dominated climates [10,58,59]. In Lochiel Park, monitored energy use for heating and cooling [60] showed that household thermal comfort behaviour can vary significantly in near identical homes. This highlights the importance of understanding the different ways in which residents cope with and create comfort, and attests to the importance of understanding comfort practices and adaptive comfort. Moore et al [15] note for example that houses designed to deliver higher thermal performance 'typically require some interaction from and with their occupants'.

Lochiel Park contains 103 dwellings, with an average size of 203m², about the same as the South Australian average for new homes developed in 2008/9 [8], but large in comparison with those in the UK and to a lesser extent Europe [61]. The standard building envelope thermal performance required for Lochiel Park was a minimum of 7.5 Stars (<58MJ/m²/yr) on a 10 Star scale. Although this was significantly above the building regulatory standard at the time of construction (mostly 4 or 5 Stars), it was well below the 10 Star level that is understood to represent year-round 'perfect comfort' delivered by a combination of occupant actions and the building rather than via mechanical heating and cooling. The moderate application of passive design principles means that for periods of relatively cold or hot conditions, it is expected that mechanical heating and cooling is also required. Detailed monitoring - the number of days heating and cooling is applied, and energy used for mechanical heating and cooling - indicates that these homes are performing largely as designed, and that the level of thermal comfort provided is substantially better than nearby homes of a similar age whilst built to the lower performance standard [8].

The homes mostly take the form of two-story detached homes and are typically built to the lot boundary to increase urban density. All homes (see Figure 1) feature a combination of active solar, in the form of photovoltaic and solar water heating roof panels, and various elements of passive solar design, intended to promote solar heating in the winter and to protect against the summer sun [8]. The scheme was initially marketed as a 'nation leading green village' with the residential component set in natural parkland [62]. Consistent with this, the scheme has nature reserves located on three sides (see Figure 2), including the creation of an 'urban forest'. There is evidence of communal maintenance of external spaces, community managed meeting facilities and community gardening (Figure 3).



Figure 1 – An example Lochiel Park house.

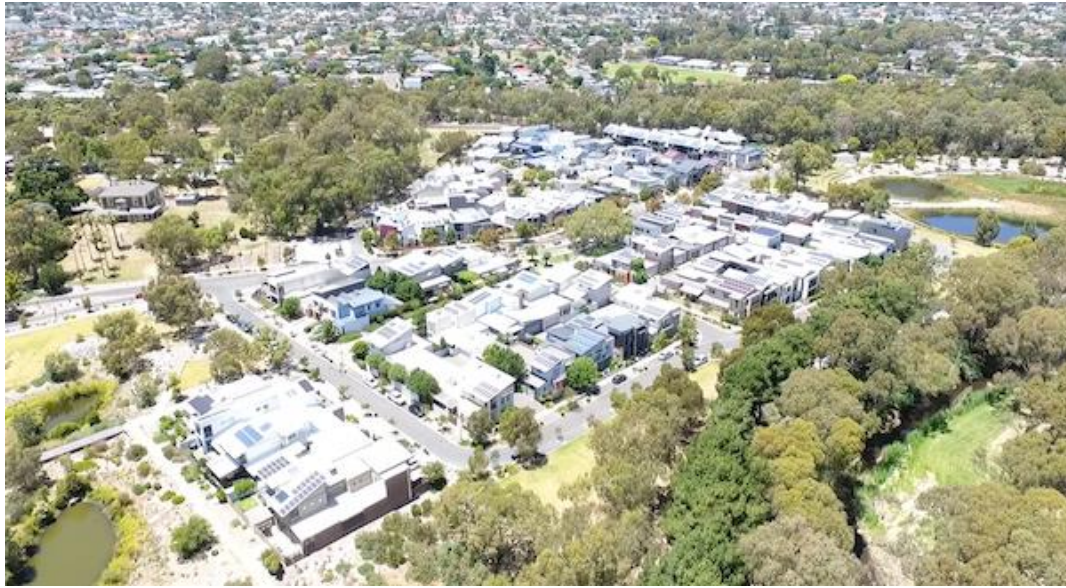


Figure 2 - An aerial photo of the Lochiel Park site.



Figure 3 – An example feature designed by community groups.

4 Methodology

This research should be seen in the context of an ongoing, long-term research programme that began in 2008 and includes interviews and surveys with householders as well as remote monitoring of energy and water systems, appliance and equipment audits. Lochiel Park is one of three urban development sites in the Adelaide Living Laboratory venture [63]. This research complements ongoing enquiry and utilises an oral history approach to reveal the sensory experience of the home, capture how experiences and expectations of comfort have changed over time, and identify emergent practices. The viewpoints of pioneer adopters of low-carbon technologies can provide an ‘important, often missing contribution’ to the literature[1].

The method foregrounds the ontology of personal experience and is therefore well suited to the collation and analysis of individuals’ unique and private accounts of everyday life in both the past and present day. Oral history is a flexible approach centred on enabling participants to recount their experiences in their own words, often with little prompting. Like Maye-Banbury and Casey’s [64] study of emigrants from Ireland to England, we guided the participants through their housing histories; in a variation to that study, however, we prompted specific reflections on comfort practices and energy use, reflecting the specific focus of the research. Although it is common to make available oral history transcripts with named interviewees available in public repositories, this would in this case be counter to the ethical approach of ongoing research at Lochiel Park and we have therefore anonymised respondents’ accounts.

The interviews form a biography of heating and cooling practices that includes both the individual’s experience and wider social factors [65]. Householders were asked to speak about each of their homes in succession, starting with childhood and progressing to their current Lochiel Park home. This approach was designed to situate the experiences of the householders within energy transitions [66] and, at a more individual level, housing transitions [67].

In semi-structured face-to-face interviews, householders were asked a consistent set of open-ended questions reflecting upon their housing histories, for example, ‘Tell me about your first memory of home’; ‘Can you recall any times when you really felt too cold or too hot?’; ‘How comfortable is your home compared to those you’ve lived in before?’.

Seventeen interviews were conducted and transcribed in February and March 2017. Interviewees self-selected through an open invitation from a sample of approximately 50 candidate households who had lived there for a continuous period not less than 12 months, ensuring experience of the homes across all seasons. Interview timeslots were offered during and after work hours, and on the weekend for ten consecutive days. The interviewed households were owner occupiers, who represent the most common resident type. Where possible, and in the majority of cases, all adult owners of the home were interviewed together. Whilst a small number of the households included children, only the adults, who were expected to have a longer housing history, were interviewed. 11 of these were with two adult householders living as couples and the remainder with one adult.

This self-selection, combined with the short window for interviews, has resulted in a bias towards older households with greater availability and, it can be assumed, longer and more varied housing journeys. This study, like other qualitative research exercises, is limited by the availability of the research subjects – our interviewees. In this case, the ten-day data collection window, determined by the available project resources, limited the number and variety of interviewees. A larger data collection window, or set of opportunities timed throughout the year, may have resulted in a larger and more representative sample of the Lochiel Park community, and provided an opportunity to explore a wider range of issues such as differences in experiences across age groups and seasons.

Whilst the approach allows interviewees to recount their memories and focus on what is important to them, it is worth noting that in this study the interviewer structured the conversation around the interviewee's housing history and focused the discussion, from the beginning, on energy and thermal comfort. The interviewees see their stories through their own lenses and a limitation of this approach is that it is possible that childhood memories were romanticised, selective or limited – as children, for example, they would be unlikely to know about all the financial decisions being made in the household. Conversely, as adults, they may recall the enjoyment and sociability of sleeping outside but not be aware of efforts their parents were making to improve insulation or heating.

5 Comfort practices in Lochiel Park

The following accounts start with the ways in which interviewees and their families negotiated comfort on a day-to-day basis in their childhood homes; move on to how they created comfort in subsequent homes; and finally consider moving to Lochiel Park, the reasons for this and the ways in which comfort continues to be created and negotiated. Verbatim quotes are used, with households coded 01 to 17.

5.1 Childhood memories: Negotiating Comfort

Recollections from childhood reveal a range of practices employed to adapt to extremes of temperature. In the summer, sleeping outside was a common response to overheating in rooms:

'I do remember sleeping outside in summertime. When it was too hot to sleep in the house we'd sleep on the lawn and we'd get damp in the morning when the dew came and had to go back inside.' (01)

Some cooling practices were relatively spontaneous and occasional: 'so [...] you'd wake up and you'd go down on the beach and wrap yourself up in a sheet or something so the sand flies didn't eat you... but that was only occasionally' (12). However, for others it was planned in advance and semi-permanent. 'We'd actually move from the main house to sleep in the sleepout, and we'd stay there all summer' (11). In a minority of cases, as in this example, modifications were made to homes to facilitate these coping practices. 'We had a really long back veranda that was enclosed with louvres. Well that was very trendy then to have louver windows that you could open. That was after the renovations' (03).

The oral histories highlight the different ways in which these practices would be experienced by family members. The accounts suggest that such coping strategies were associated with family activities that tended to be an adventure for the children - 'The kids thought it was fantastic' (03) - whilst potentially putting a strain on other family members, with responsibilities falling on adults for tasks such as moving bedding: 'I think it wore my mother out having to get things in and out' (01). One interviewee, however, recalled community-wide gatherings in which adults and older people in the community gathered to 'party and drink and carry on at various people's houses until midnight... and the kids would have all their mattresses out on the front lawns... the houses just got too hot' (08).

Going to the swimming pool was another common practice and also had a recreational dimension: 'We didn't have air conditioning, per se, but we'd go in the pool all the time and sleep with the fan at night' (06). When asked to what extent this was 'intentionally about cooling down' one interviewee responded 'no, it [*cooling down*] was just bonus' (17). Still, from the oral histories we can see a range of coping mechanisms including the use of fans, swimming pools and sleeping outside the home.

Householders also recalled practices related to keeping warm, including gathering in an enclosed room with a wood fire or stove, sleeping with thicker bedding, and using portable heaters:

‘Yeah, we always huddled in one room because your bedroom was too cold and you’d put lots of pyjamas and everything on before you went to bed and put the hot water bottle in the bed before you’d go to bed.’ (06)

It is fair to say that practices relating to keeping warm were less associated with fun and socialising and more to do with maintaining thermal comfort through the winter, although it is clear that they played a part in shaping family and community life.

For many interviewees childhood was also a time when funds were limited. Those who were more affluent had options to take advantage of heating and cooling technologies or the ready supply of fuel: ‘my Dad was a dentist so consequently he could buy a bit more’ (08). Fuels and materials for heating and cooling could however be sourced outside the monetary economy. There were references to paying for regular deliveries of wood, coal and ice, but as another respondent noted: ‘there weren’t many costs involved with our heating and cooling. Wood was fairly plentiful so no I don’t remember people having to [...] think about the cost’ (03).

Some interviewees reflected on ways in which limited budgets impacted household life:

‘I don’t recall my parents talking about that (*money*) but we did live on a very restricted budget. We would have been regarded as reasonably poor at that time. And my mother grew most of the food, vegetables in the garden, to supplement our budget.’ (01)

Sourcing wood in the winter, for example, was a means of saving money: ‘You’d scrounge for the wood. I don’t ever remember my stepfather buying wood’ (12); ‘I think we must have acquired the wood most of the time without paying much for it or it was not expensive’ (01). One interviewee contrasted lifestyles during their childhood, compared to contemporary affluence, with an implied criticism of the latter:

‘today people I think they live a profligate lifestyle in they have an expectation of having money to spend unnecessarily... Dining out was high days and holidays...we had money to pay our energy bill because we didn’t have that expectation of that kind of lifestyle.’ (04)

5.2 Adult Life: Creating Comfort within Technological Limits

The technologies recalled from childhood look basic by today’s standards:

‘We didn’t have gas heating, we just had a chip heater. You put chipped wood into it and burn it, and it heats the water, and then you can run it for your bath. We didn’t have hot water through the house, and we didn’t bath or shower like you do now, we used to have a bath once a week.’ (11)

Dealing with excessive summer heat likewise involved either simple technologies or non-technological measures such as managing the flow of air through opening windows and doors, particular references were made to utilising the ‘gully breezes’ in the Adelaide area. As interviewees progressed to early adult life and as air conditioning and heating became increasingly available and socially expected, informal coping practices appeared to be less common and in some cases were reproduced in modified form within the context of more modern housing and technology. In their first home after getting married, one couple reflected that ‘we’d all sleep outside if it were really, really hot. But then we got an air-conditioner’ (03). Whether sleeping outside stopped as abruptly as the quote implies or not,

the relationship between the advent of air conditioning and this practice is expressed clearly. Changes were also placed in the context of societal attitudes to public safety (whether misplaced or realistic): 'You'd sleep outside of a night. Do that now, you might not wake up in the morning' (06).

One householder suggested, however, that the earlier practice of gathering in one cooler space continued after air conditioning, reflecting the fact that the technology was not yet available in all rooms. Similarly, as another respondent explained:

'We were quite a bit hardier back in those days because in the early '60s we got an air conditioner, just a fit in the wall air conditioner, which not a lot of people had and it was designed to air condition one room where we all slept on very hot nights and got a bit of relief during the day.' (07)

As the interviews move into early and later adult life, changes in family structure brought about further changes in cooling practices. For example, one respondent noted that as children grew older and more mobile and independent, the pool, in this case, became less used: 'It really got very well used until the children were about – until they got their driving licences and then it wasn't so well used... And it became a burden then, rather than a useful form of exercise' (13). Air conditioning also brought about a reduction in the use of the pool: 'if you were in the house and it was air conditioned you then would think, I'm not going to go outside in the heat to get in the pool' (10).

Respondents discussed the idea, and their experience, of making the home comfortable per se, as opposed to heating and cooling being negotiated and enacted day to day and season by season. Increased comfort meant for some an increased intolerance of temperature extremes:

'... you did what you had to do... We tend to whine about everything now, "it's so hot", well it's always been hot in the summer at least a certain percentage of the days. I think we've technologically advanced but I'm not sure that it's for the better. Now we come to expect air conditioning, we come to expect a lot more than we did in those days. We lived a simpler existence and we just wore it, accepted it.' (15)

Controlling temperature had financial implications. One interviewee noted, for example, that after the adoption of air conditioning: 'Our power bill went through the roof' (08). Another couple explained how they had to 'watch' the money when they had children and this meant keeping down energy use 'as much as you could' (12). This behaviour continues for an increasing percentage of Australian households today with many modifying energy practices due to financial stress [68].

Some interviewees were relatively comfortable financially and bills were not perceived to be a problem. For example, when asked if they remember being concerned about the costs of heating and cooling at this stage of their housing journeys one household responded:

'No. We both worked. There were no children involved. We both worked in jobs that had close to the median sort of salary range or a little above so we had the financial ability to pay for the cost of the cooling or the heating or whatever we had. I've been lucky enough to be a situation where we've never been constrained financially from having a house that we could live in comfortably...' (07)

However, even if affluent, a combination of financial pressures and the discomfort of temperature extremes led some householders to alter their homes. The relative affluence of some respondents facilitated the task of home improvements. Home improvements were not easy, however and did not always have as much impact as desired. Bills remained higher

than they wished and indoor temperatures did not come under sufficient control, expressed here as an element of frustration:

'We had done everything in our old home to make it energy efficient, water efficient, but there's a limit to what you can do with an old home. It was built in '64. It was built to all the housing standards of the day then... You get to the point where you're throwing [good] money after bad, because apart from ... knocking the thing down and starting again, we couldn't improve the energy efficiency of our home.' (04)

So, that was pretty efficient but like I said, the recurrent costs were still high. (08)

Respondents were also aware that incomes might, in the future, diminish and that they needed security, especially on retirement.

'It never concerned me while I was at work ...you didn't have to worry about it [the money spent on energy, heating and cooling]. But as soon as you lose your job, you start thinking. Because of retirement my issue was recurrent costs, outgoing bills, paying for things, quality of life and all of those sorts of things and we thought I'm sick of maintaining this place, it's 100 years old.' (08)

5.3 Living in Lochiel Park

The motives for choosing to move to Lochiel Park were varied. Previous research identified location as the key driver above other factors such as environmental sustainability or downsizing [8]. During the oral histories some interviewees related the move to their struggles with maintaining affordable thermal comfort in their previous home(s) and the notion of reducing ongoing costs, especially for those preparing for retirement. In this respect the 'low-energy' promise of the homes was attractive and an element of the decision. The idea of an environmentally friendly home was also attractive to some: '[he] was interested in the environment, his plan always, for as long as I can remember, was to build his own home and have it environmentally friendly' (11). Others alluded to an impact the home had had on their awareness of environmental issues and their involvement in community activities: 'I don't think we were environmental vandals prior to the house, but I think our consciousness certainly is more alert' (10).

Although the interviews were centred around the concept of thermal comfort, the sense of community of the area was also mentioned and seen to be appealing, with organised activities such as a reading group and an arts club or informal activities such as the community garden, proving popular with residents: 'the community activities are improving all the time' (17). Conversely, the houses afforded residents a degree of privacy, with the closed backyards: 'There's bushes on the other side of my fence, which has got the screening' (05). The location was also considered attractive, with access to a bus route, employment, shopping and other amenities. The setting, in woodlands and wetlands, was also appealing: '... when we realised that a block along here was available looking over the wetlands that was just too good to be true' (09). To one interviewee at least, these location related factors were as important as the 'low-energy' features: 'If the energy costed more we'd still live here, okay, ... we just love it' (10).

In many ways, the 'low-energy' homes delivered what was expected. In the words of one respondent: 'we're very happy in the house. It's well insulated. Doesn't get hot, doesn't get cold. And we've got that (*air conditioning*) over there if we need it, which is rare' (02). Many were more critical, however, especially in the light of promises apparently made at the time of purchase.

'The little things annoy you when you think you're coming into an ecologically designed house that they would have thought about all those aspects of it.' (01)

'I've got the money so I might as well use it [the air conditioning]. That's my attitude. But there are people who may be quite upset about the fact that they bought something that they thought would save them money because it was ecologically friendly and secure and what have you, and then they were disappointed.' (05)

The tone of the comments varied between and within interviews, sometimes implying that finding ways to adapt to hot and cold was simply part of living in a (relatively) new house, and sometimes expressing frustration about deficiencies in house design. All were agreed, however, that heat and cold still had to be managed. Selective use of only part of the house, in both the summer and the winter was one method:

'I just don't use the spaces that tend to get hotter in the summer if I can avoid it. And I tend to keep those windows open in the hallway. I just don't use the spaces if I don't have to.' (16)

'I won't change even in the bedroom. It's cold and I hate it so I'll get changed in here or in the mornings I'll grab my clothes and run in here to get ready because the fire is on. I don't want to do it in the bedroom. That's probably only two months of the year but it's awful.' (06)

Other coping mechanisms included sleeping in different parts of the house during particularly warm or cold periods. One household had a set of mattresses ready to take downstairs for hotter periods. Another worked downstairs, instead of in their upstairs office during hotter periods. Householders also described techniques they had developed over time to manage the indoor temperature. These include making the most of the two levels: 'where it cools down overnight and you open the top and the bottom windows, it will draw the cool air in...' (14). This interviewee also noted, however, that opening the windows only worked when the outside air temperature was sufficiently cool to allow them to have the windows open overnight. Other techniques included using a retractable blind to provide shade over outside walls and entertainment areas (09). Cold weather also stimulated adaptations, but these were less common. One example was the purchase of an electric blanket for use in the living area.

Interviewees made connections with their childhoods, describing using particular rooms in the house during extremes of temperature: 'Yeah, we live in one room. We live in here again so we're back to our childhood. You're right. We are. Isn't that weird?' (06). Going back to the practices of childhood was not always practical, however. Another commented that they were 'not as resilient as I would have been as a kid or a young adult' (07).

6 Discussion and interpretation

The interviews provide insights into the householders' changing relationship with and expectations of comfort and home. The modified oral history approach provided an understanding of the user experiences of purpose built 'low-energy' homes within the context of their housing and energy journeys. This historical approach illustrates the extent to which comfort is something that has been actively negotiated throughout their life course and has changed over time; due to different buildings but also changes to social norms and the use of technologies.

6.1 Creating Thermal Comfort

The accounts of the householders reveal the ways in which expectations of comfort, and how comfort is achieved, have changed over time. The historical approach draws our attention to increasing expectations of the level of comfort provided by a home, as noted in previous studies [29,51,53] including Edwards and Pocock's [69] early work with the first residents of Lochiel Park. The research illustrates not only an expectation of increased comfort, but also changing perceptions in relation to how that comfort is provided.

In previous homes, particularly during childhood and early life, extremes of hot and cold were coped with through a range of adaptive practices including sleeping outside, using the pool, and gathering in a warm room. Whilst some spoke of comfort modifications made to homes, such as 'sleepouts' and verandas, these were designed to augment and facilitate these coping mechanisms. As time passed the trend for the interviewees was for the introduction of technologies, such as air conditioning, that created comfort. Extremes were still coped with and negotiated to some extent, but the dominant narrative shifted to the technological creation of a comfortable environment in which the need for coping practices was reduced 'almost overnight' as one respondent stated. In Shove's terminology [44], comfort was being shifted from something that was actively achieved, towards an attribute of the home, albeit provided by installed technology.

Moving to Lochiel Park was a step change, since interviewees communicated expectations that the house itself would passively provide comfort and that the need for active heating and cooling technologies would be minimised. We witness, then, a transition from the individual coping with extremes and negotiating comfort on a day-to-day basis, through installed technology creating indoor comfort, to the house passively providing comfort.

6.2 Expecting Comfort

Whilst interviewees expected their Lochiel Park home to be near net zero energy and talked of preparing for retirement by investing in capital to reduce or eliminate ongoing utility costs, their recollections reveal that maintaining high levels of comfort in extreme hot and cold periods continues to be a challenge and that there continues to be a dynamic between day-to-day coping and ongoing attempts to make improvements to the house to create comfort and in effect reduce the need to actively cope with extremes. The former includes techniques such as moving mattresses downstairs to sleep, adjusting blinds and curtains, and getting dressed in the warmer living room; the latter include building additional shade.

Whilst householders were nevertheless very positive about the thermal performance of their homes, and tended to use air conditioning when they perceived it to be necessary, rather than routinely [69], there was a level of frustration that stemmed from having to continue to actively pursue comfort, albeit less often than in previous homes. For some, their Lochiel Park experience followed attempts to improve the energy performance of one or more previous houses. Whilst energy use information is provided to households through an in-house energy feedback display, no house user guide was provided to advise households on strategies for maintaining or improving thermal comfort. Many were aware that they had learned to manage indoor temperatures through a range of approaches without relying on air conditioning, and these are likely to account at least part for the variations in household energy use across the neighbourhood. Interestingly, some interviewees implied that the idea of living in a 'low-energy' house made them more determined not to rely on air conditioning.

This frustration highlights the gap between expected and delivered comfort, much of which may be related to a lack of knowledge and experience associated with both 'low-energy' homes and household energy rating schemes. As noted above, although the 7.5 Star standard of the homes is significantly above the building regulatory standard at the time they were built (4 or 5 stars), it is still also well below the 10-star scale's maximum. This illustrates the ongoing challenge that policy makers and the real estate sector face in communicating

the likely householder experience of different energy performance standards, and illustrates the ongoing challenges of the ambiguities and multiple interpretations of 'low-energy'.

Whilst situated within a broad trend of the increasing use of technology to moderate the indoor environment [70] then, householders continue to demonstrate practices that echo their approaches in previous homes, sometimes mirroring childhood experiences. The dissonance between this and their expectation of their 'low-energy' house creates frustrations, but we would question whether this situation is as problematic as it first appears. Moore et al [10] for example, noted that not only do coping practices, which they have observed in other 'low-energy' homes, continue to be employed in purpose built 'low-energy' homes, but they can help householders be more comfortable. By discouraging the achievement of comfort through non-mechanical means, air conditioned buildings can bring about a 'weakening of adaptive capacity' [20] and in turn increase vulnerability to heat stress [15] and power outages [54].

What the historical approach suggests is that part of the reason householders become frustrated at 'resorting' to these coping mechanisms is that they are associated with childhood and the frustrations of previous houses, and therefore given the expectation of perfectly delivered thermal comfort these interventions appear to negate the technological progress implicit in the purchase of a relatively expensive 'low-energy' house. This has clear implications when considering the possibility of returning to comfort practices in our low carbon heritage [12].

6.3 Monetising Comfort

The interviews show that as technology has eased the struggle to maintain comfort, financial considerations have become increasingly dominant in relation to heating and cooling. Childhood memories included sourcing wood for free or taking deliveries of coal and ice through a relatively informal local economy. This reflects a dispersed energy economy with energy sources coming from a range of local networks and sources. As air conditioning became more dominant, comfort becomes an increasingly financial arrangement in the monetary economy and, for some, the struggle to maintain comfort is a financial one. Goodchild et al [71] place the aspirations of the householders in the context of modernity and growth of the money economy.

For many of our interviewees, Lochiel Park represents a particular stage in the relationship between money and comfort in that they have consciously attempted to reduce their ongoing energy use and costs through capital expenditure in a 'low-energy' home. Older residents were particularly clear on the attraction of reducing operational energy costs when going into retirement, particularly in-light of recent energy price increases in Australia, and related this to years of struggle with poor levels of thermal comfort in various houses over their adult life. The development of Lochiel Park as a 'niche' development has enabled these relatively affluent home purchasers to use personal capital or their borrowing capacity to invest in a home in the expectation of reduced long-term energy costs.

This has implications for affordability and social justice and resonates with debates on energy vulnerability, justice and resilience [72]. In the terminology of this discourse, the householders have in effect used their financial resources to minimise their vulnerability of experiencing fuel poverty, particularly for those consciously moving towards retirement from paid employment. In an Australian context, Moore et al [15] situate affordability of air conditioning, and the associated health impacts of living in overheating homes, in the fuel poverty literature. Although our research identifies a set of historical, and free, practices, such as sleeping outside and using public spaces, the interviewees also suggest that these may be less practicable in contemporary society, whether due to space availability, social acceptability, their physical health, or concerns of safety.

Nicholls and Strengers link this to the privatisation of space and find that access to publicly available, accessible and affordable cooling facilities outside the home can be an issue for vulnerable communities, 'potentially excluding households without an air conditioned car or public transport close to their home' [54]. In this light, comfort is something that has been increasingly monetised and privatised.

6.4 Socialising Comfort

To the extent that 'thermal monotony' [41] can be achieved, with its proliferation of air conditioning and controlled temperature, it implies a simplification of what is a set of more diverse and social practices: householders' relationships with comfort are increasingly financial and individual rather than enacted through social and family practices. The pool, beach and the sleepout provided sites for socialising, exercise and family life, again illustrating the reciprocal relation between cooling and heating practices and home life. The simpler, or at least low-tech, practices of the past offered a way of bringing families and communities together. Shove [44] and Cooper note the potential of outside cooling practices to foster social exchange.

There is little evidence in the interviews of nostalgia, however; if anything there is a recognition that the need to 'escape' extremes of temperature determined or shaped, perhaps even restricted, social activities. Cooling activities seemed to be experienced differentially across families: whilst sleepouts and swimming trips may have been fun adventures for children, there were suggestions that they may have been viewed less positively by adults. Additionally, activities for coping with cold, such as gathering together in one room, were less likely to be viewed positively.

In fact, the interviews reflect ways in which the ability to control and moderate temperatures may facilitate increased family and social life. Examples include home offices, recreation areas with computer consoles set up and various activity rooms for music and other hobbies. Householders used technology to shape or facilitate socialising practices, whether in the cooled home cinema, by turning on the air conditioning when expecting guests, or through the installation of an additional oven for occasions with the extended family. Interviewees referred to visiting swimming pools and using outdoor space but this was now primarily a social or leisure pursuit rather than something necessitated by uncomfortable indoor conditions.

Whilst uncomfortable indoor temperatures, and the need to cope with them, can be seen to shape socialising practices in their early life, the accounts suggest that as the comfort offer of the house improves so does the ability to actively shape the indoor environment to facilitate desired social activities – a reversal of the relationship. This has implications for the notion of traditional low-carbon comfort practices, which Winter [12] anticipates in arguing that the point is not to 'create a nostalgia for a "golden era" of sustainable comfort that has little viability within today's high-rise, high density cities'. Related to this, our interviewees evidence a narrowing spatial context of comfort, from outdoor spaces that included public parks, beaches and swimming pools, to the expectation that comfort is created in the boundary of the home. The narrowing spatial context of comfort, noted above, also implies that those practices that relied on outdoor, and even off-site, spaces that are less prevalent.

7 Conclusions

An oral history approach has made possible an exploration of experience and perceptions of energy, in the broadest sense, over the lifetime. It provides insight into experiential and phenomenological aspects of the interviewees' relationship with home comfort within the context of societal changes and in some cases indicates relationships between those experiences and expectations of contemporary housing. It is this ability to provide a window on how residents reconstruct the negotiation of extreme temperatures over place and time that makes it stand out amongst other qualitative approaches.

In tracing the housing histories of residents of purpose built 'low-energy' housing in South Australia, this research has revealed an ongoing dynamic of coping with extremes and attempting to create a thermally comfortable indoor environment. The accounts reveal a change over the lifetimes of the householders from a situation in which extremes of hot or cold were coped with through a range of adaptive practices, through the introduction of mechanical heating and cooling technologies promising to reduce the need for adaptation, towards, in the case of Lochiel Park, an expectation that comfort is mostly provided by the house. Comfort has been transformed from an achievement of the householder to an attribute of the building.

Central to this is the relationship between occupant, the building and its technologies and their respective roles in the provision of comfort. A common thread is that householders continue to be actively engaged in the comfort of their home. Australia is not alone in seeing substantial growth in the use of heating and cooling technologies, expectations of increasing levels of comfort, transitions to a warmer climate and an electricity grid increasingly dominated by renewables. Our findings are therefore pertinent to other countries, particularly those whose energy consumption includes a large component of mechanical cooling, and contributes to the growing literature on comfort and 'low-energy' habitation. Whilst some practices may be specific to Australia, the principle of adaptive comfort is one that is pertinent in many countries.

The accounts also reflect a growing expectation of the levels of comfort and, whilst most interviews noted that the 'low-energy' homes of Lochiel Park perform significantly better than their previous dwellings and provide a high level of comfort, frustrations were expressed that their investment had not afforded them a home in which year-round 'perfect comfort' is guaranteed without the need for adaptation or active heating or cooling. This is in part attributable to the ambiguity in the way the homes were described and sold – they are after all low, rather than net zero, energy homes, and at Star levels below that of what could be considered 'perfect comfort'. There is a role therefore for policy makers to help consumers better understand what the rating system means and better align this to expectations of energy efficiency overall, and thermal comfort in particular.

There is a broader question relating to the extent to which living in purpose built 'low-energy' homes should imply an expectation that no comfort practices will be needed. Even if the dwellings are designed to perform to an exceptional standard of thermal comfort, it is possible that some occupants will still want to use supplementary cooling or heating, or develop their own ways of coping on hotter days. This may stem from individual preferences and cultural and social norms. The research suggests that buildings designed to allow occupant engagement may result in greater comfort and satisfaction. Rather than assume that an engineering approach can remove the need for additional comfort practices, such practices can be seen as a way of getting the most from our homes [41]. An acceptance of adaptive thermal comfort practices may help to legitimise and enable 'low-energy' designs [11].

What, then, does the set of practices for a 'low-energy' house look like and where do these practices come from? One source is the historical adaptive practices, our low carbon

heritage [12]. This research suggests that although some of those practices do appear to 'travel' with householders through their housing journey, householders may feel reluctant to deploy them. This may be related as much to the marketing of 'low-energy' houses and the idea of technological progress as to the practices themselves, although broader changes in society and urban form make some of them, such as sleeping outside, feel impractical, unsafe or simply dated. A related concern is the risk that 'unlearning' comfort practices increases vulnerability and reduces adaptive capacity to climate extremes such as heat waves.

'Niche' 'low-energy' and low-carbon developments such as Lochiel Park must be understood within the context of the broader housing stock. Raising standards in new build for the long-term has many advantages, but it also redefines and calls into question the standards used in the existing stock, the affordability of 'low-energy' housing to those with limited capital or borrowing capacity, and the difficulties renters face in accessing thermal improvements and on-site renewables.

This study raises important issues relating to low-energy habitation and these point to future research. One thread will be to continue to study Lochiel Park and its residents and observe the ways in which comfort practices and perceptions change over time. These practices can be viewed in the context of changes that householders may make to the fabric and technological configurations of their homes. Given the wealth of energy data collected as part of the ongoing relationship of the research team with Lochiel Park, there are opportunities to investigate how monitored data corresponds with resident behaviours and perceptions. This would help further develop the socio-technical relationship between quantitative and qualitative methods in energy research, as discussed by Ambrose, Goodchild and O'Flaherty [2] and mentioned in our introduction. In bringing together mixed methods research that triangulates qualitative accounts with empirical records of energy consumption, there is a potential for micro-scale energy epidemiology [1] that in turn contributes to macro understandings of the relationships between buildings, behaviour and energy use. The study also highlights the importance of understanding perceptions and the ways in which these are influenced by the communication strategies of those selling and advocating low-energy living. Investigation into the ways in which promotional materials have and continue to influence expectations and behaviour can help to ensure that building users can approach energy transitions on a well-informed basis. Finally, there is a need to continue to identify and conceptualise low energy practices and to understand their role in an energy transition. In particular, there is the question of how practices are learned and unlearned and whether and how they are passed on to future generations.

Given the strong international policy direction towards nearly net zero energy buildings, we need to rethink the relationship between occupants and 'low-energy' homes. To create the impression that comfort in purpose built 'low-energy' homes will require neither mechanical heating and cooling nor active involvement of the householders is to risk householders being not only disappointed but also unprepared, and for nations to fail in pursuing their energy and carbon reduction goals. Whilst countries can learn from good practice globally, there is a need to ensure consideration of local climate conditions as well as of cultural expectations relating to comfort. Whether, and by when, net zero energy homes will replace the current housing stock is yet to be seen, but what is clear is that even in high performance housing there continues to be a role for residents in creating thermal comfort and coping with extremes of climate. This is not only a challenge for housing and households in Australia, but applies around the world as we seek to transition towards more sustainable habitation.

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