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Social housing temperature conditions and tenant priorities

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Abstract

The social housing sector provides housing to some of society's most vulnerable people, disproportionately housing people with disabilities and chronic health conditions, the aged and people unable to work. These groups are often more susceptible to health impacts from poor temperature conditions within their home. In this paper, we examine temperature conditions in Australian social housing, explore tenant experiences and reflect on possible remediation responses. Using a novel contact-free delivery protocol for data collection, temperature was measured in 36 social housing dwellings over a 3-month springtime period. Semistructured interviews were conducted with occupants to better understand their experience of (adverse) indoor temperature conditions. On average, participants spent 35 per cent of time across the study period in temperatures outside the WHO guidelines (18–24°C). Most participants perceived their homes to be cold or very cold during periods of cold weather, and many considered energy unaffordable. Building conditions, such as poor sealing around windows and doors, lack of insulation and inadequacy of space heating appliances, were of greatest concern to participants. Participants' preferences for remediation work suggest that considerable benefit could be gained from making homes more energy efficient through draft sealing and insulation.

KEYWORDS
cold housing, energy cost, energy efficiency, insulation, tenant

1 | INTRODUCTION

People spend approximately 70 per cent of their lives within their home (Baker et al., 2007); therefore, an understanding of the exposures and health risks attributed to unhealthy home environments is of high importance. Exposure to unhealthy home temperature conditions increases health risk; for example, cold indoor temperatures increase the risk of high blood pressure (Shiue & Shiue, 2014), respiratory issues (Spengler et al., 2004) and poor mental health (Critchley et al., 2007). In view of morbidity and mortality risks, the World Health Organization (WHO) Housing and Health Guidelines recommended indoor air temperatures between 18°C and 24°C (World Health Organization, 2018). A minimum of 18°C is widely regarded as a baseline, below which health is compromised (Jevons et al., 2016; World Health Organization, 2018).

Australian social housing is a government-subsidised "safety net" (Baker et al., 2021), providing affordable housing to those unable to access or afford suitable housing in the private rental market. Allocation policies mean that many people housed in the sector have experienced homeless or domestic violence, have a disability, long-term health condition or special needs. Currently, 40 per cent of social housing households include someone with a disability (Australian Institute of Health and Welfare, 2019). These vulnerable populations are at greater risk of cold-related morbidity and mortality (Alahmad et al., 2020; Bouchama et al., 2007; Hajat et al., 2007; World Health Organization, 2018) and generally require indoor temperatures higher than the 18°C minimum (World Health Organization, 2018). Elderly people, and those with a long-term disability or illness, are also more likely to spend more time within their homes, increasing their likelihood to be impacted by adverse indoor temperature conditions (World Health Organization, 2018). The 2018 National Social Housing Survey (NSHS) found that 38 per cent of houses did not meet the thermal comfort needs of the residents and 24 per cent did not meet the energy efficiency needs of the household (Australian Institute of Health and Welfare, 2019).

Although indoor environmental data, such as temperature, are a valuable research resource, research to date has been somewhat limited by a lack of large-scale data from homes (Daniel, 2018). Home temperature studies are limited by privacy concerns and difficulty accessing housing locations, with Australian studies to date being limited to 60 or less homes (Daniel, 2018). One study included over 500 aged care residents, in five facilities, but only measured temperature at the time of the participant interview (Tartarini et al., 2018). A combination of the prohibitive cost of equipment and personnel time for travel and installation, and the perceived or potential invasiveness of in-home monitoring almost certainly explain the scarcity of studies containing objective measurement of indoor environmental conditions within homes (Daniel, 2018).

This paper considers the tenants' point of view in terms of their experience of temperature in social housing and their priorities for improving thermal comfort, using qualitative and quantitative data. This is achieved through a field and interview study of indoor temperature and perceived housing conditions within social housing homes in Adelaide, South Australia. Social housing tenants often do not have the opportunity to voice their opinions and preferences for building improvements, and hence, their experiences and perceptions of their housing environment do not always contribute to housing providers' retrofit priorities (Baker, Moore, et al., In press). This study allows understanding of the contributing factors to temperature conditions in homes, understanding of the "real-life" experience of cold and suggestions to improve housing conditions.

This paper is guided by five research questions:

1. How do indoor temperature conditions of social housing homes compare with WHO Housing and Health Guidelines of 18–24°C?
2. What do tenants perceive to be the key contributing factors of unsuitable indoor conditions?

3. How do tenants currently respond to cold conditions in their homes and what implications does this have for energy affordability?
4. What remedial action could be taken to improve indoor temperatures in social housing?
5. What are the implications of using remote, contact-free data collection?

The remote data collection method trialled during this study constitutes a “participatory citizen science” engagement approach (Haklay, 2013). Citizen science methods have received criticism in the past, as the data collection conditions cannot be rigorously checked; however, there are many examples of successful citizen science programmes (e.g. Isley, Fry, Liu, et al., 2022; Taylor et al., 2021) where data quality is comparable with that compiled by professional scientists (Isley, Fry, Sharp, et al., 2022; Lowry & Stepenuck, 2021).

2 | MATERIALS AND METHODS

We collected indoor temperature and survey data from 36 social housing households across metropolitan Adelaide, South Australia. Monitoring was purposefully scheduled for a shoulder season (spring) so that we were able to trial the data collection procedure and observe indoor conditions over periods of cold and more moderate weather, within a relatively short time frame.

The recruitment process drew on participant lists from two previous projects (Baker et al., 2019; Baker, Daniel, et al., 2022). Participants who had given their consent to be contacted about future research were approached via telephone or e-mail. Participants were then sent a formal invitation e-mail, including participant information and consent forms. Chain referral was used to extend the sample.

Participants were posted a HOBO MX100 temperature data logger (OneTemp, n.d.), prepaid return postage envelope and logger placement instructions. Participants were guided to place the device in an open and secure location within their main living area, avoiding placing the device in any enclosed space, near heat sources and within reach of children or pets. Participants were contacted by either telephone or e-mail to confirm arrival and to provide assistance with set-up. Loggers were prelaunched to record air temperature at 30-min intervals, and card-mounted to allow the device to stand independently while allowing adequate airflow. Loggers remained in the same location for the entire monitoring period, over 13 weeks between September and November 2021. Monitoring periods varied slightly between households due to recruitment and postage timing.

Each participant was contacted via telephone for a semistructured interview upon completion of the monitoring period. Telephone interviews focussed on insights into temperature conditions within participant homes, the cause of these conditions, coping mechanisms and impacts on health, well-being and finances. Interviews were focussed on how well participant's homes protect them from any periods of cold weather, as well as home temperature experiences during the monitoring period. Responses were recorded in a Google Form. Interview questions are included as Appendix A. Following the telephone interview, participants were asked to return their device using the supplied prepaid envelope. Participant contributions were acknowledged with AUD 25 shopping vouchers upon logger return.

Public Health recommendations for temperature vary based on waking versus sleeping hours (Wookey et al., 2014). Australian typical sleeping hours are 11:30 PM to 6:00 AM (Manousakis, 2015). Data are therefore presented as “all hours” (all data) and “waking hours.” Based on postal tracking information, temperature data were discarded for 48 h after initial postage of loggers and prior to final logger receipt by researchers. Any further anomalies at the beginning and end of the monitoring period were also removed, assuming that transit times had been extended in these instances.

Using World Health Organization's (2018) minimum temperature standards of 18°C, the percentage of days where the average temperature (waking hours) was below 18°C was calculated for each participant. Mean, minimum and maximum daily temperatures were calculated for each participant and for the entire cohort. Local weather data were sourced from the Australian Bureau of Meteorology.

3 | RESULTS

Of the total 36 participants, indoor temperature data were successfully attained for 86 per cent ($n = 31$; $n = 3$ did not return their device, $n = 2$ of the devices failed).

3.1 | Weather conditions

Average external temperatures in Adelaide, South Australia, in 2021 during the monitoring period (September to November) were similar to those recorded since 1887 (Appendix B), with less than 1 per cent difference over the entire period. Still, individual months varied slightly, with September 2021 being warmer (+7 per cent) and October and November slightly cooler (−1 and −5 per cent). Rainfall over the entire period was varied from historical records by 3 per cent over the entire period, again higher or lower than average for individual months.

3.2 | Indoor temperature conditions

The average indoor temperature (Figure 1) across all homes for the entire study period (all hours, September to November) was 19.3°C, with a mean daily minimum and maximum of 17.3°C and 21.8°C, respectively.

Median temperatures over the entire period remained within the "healthy" range of 18–24°C. However, 15 per cent of days ($n = 14$) within the monitoring period returned a mean temperature of less than 18°C across all households during waking hours. Mean minimum daily temperatures (waking hours only), recorded across all households, over September to November, were typically less than the recommended 18°C (mean = 17.3°C). The coldest home had a mean daily minimum of 13.5°C during waking hours. There was no statistical difference between data for all hours and waking hours only (Figure 1, boxplot notches overlap); however, each month in Figure 1 is statistically different (progressively warmer) as spring progresses toward summer.

The number of days households spent in "unhealthy" average temperature conditions during waking hours was calculated (Appendix C). The mean percentage of days households experienced average indoor temperatures (during waking hours) outside of 18–24°C was 35 per cent. One household experienced average indoor temperatures below 18°C for 98.7 per cent of days within the monitoring period. The majority of households experienced a greater percentage of days with an average temperature below 18°C (mean of 29.2 per cent of days) than temperatures above 24°C (mean of 5.7 per cent of days).

Diurnal patterns of indoor temperature over September to November are shown in Figure 2. In September, the beginning of spring, median indoor temperatures remained within the WHO-recommended range for around half of the day, from 1 PM to 2 AM, with 7 AM being the coldest hour. October continued this trend; however, it was slightly warmer overall, with median temperatures only below 18°C from 6 AM to 10 AM. We note here that September 2021, when these data were collected, was 7 per cent warmer, on average, than the historical monthly average since 1887. Throughout November, median temperatures remained within the WHO-recommended range for all hours.

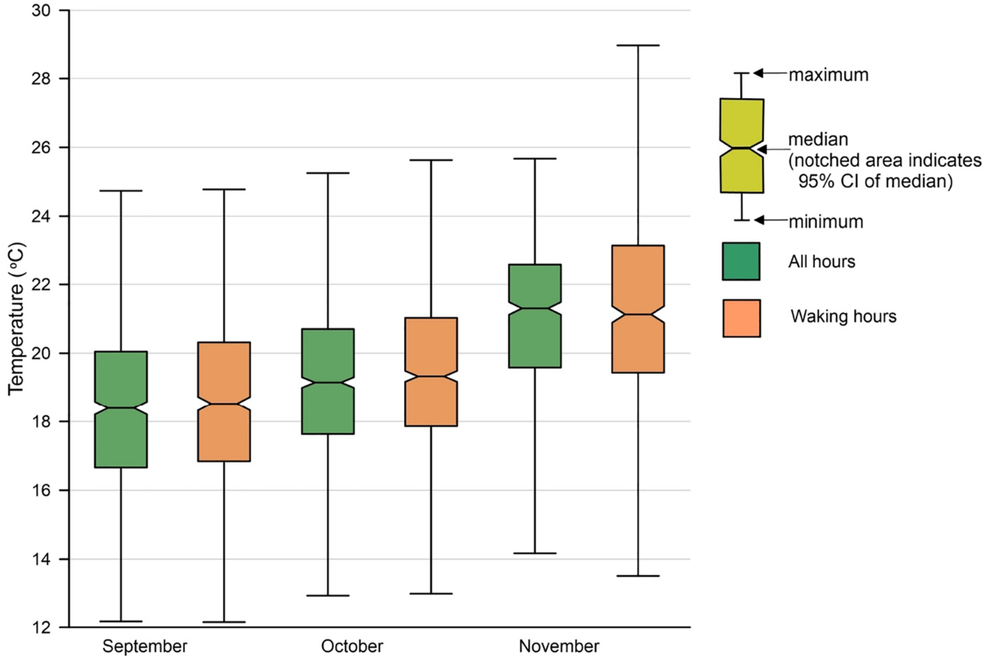

FIGURE 1 Daily average temperature in social housing homes over the study period.

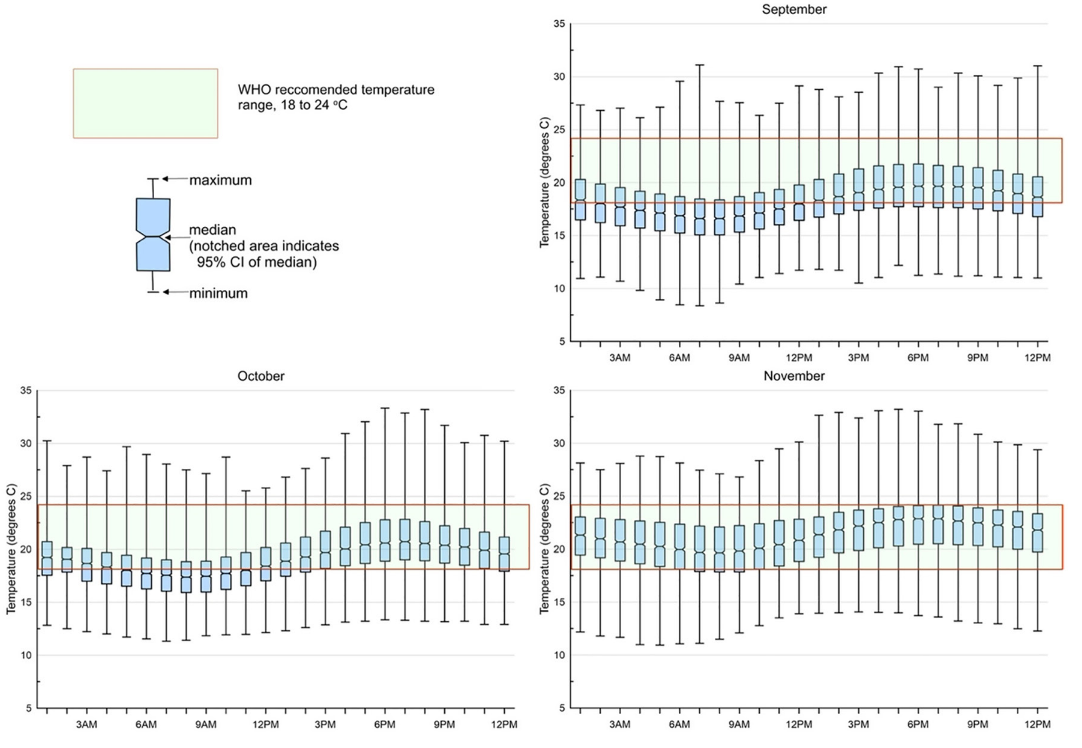

FIGURE 2 Diurnal temperature variation.

3.3 | Temperature experiences

When asked about the comfort level of their home during cold weather periods, the majority (70 per cent) of participants perceived their homes to be very cold or quite cold. Roughly a quarter perceived their home to be not "too bad" (23 per cent). One participant stated that they did not mind being cold, while another said they kept their home warm due to medical needs.

Participants who perceived their home to be cold during cold weather periods all attributed this to building conditions: gaps in windows, doors or floors ($n=12$), poor or no insulation ($n=10$), heat loss ($n=7$), age of home ($n=5$) and concrete floors ($n=3$). Four respondents did not have heating in their home and considered this to be the main factor for cold temperatures.

Most participants (55 per cent) viewed their health as "good" ($n=10$), "very good" ($n=4$) or "excellent" ($n=3$), while one-third self-assessed their health as "poor" ($n=8$), with others ($n=5$) perceiving their health as "fair." Nine noted an ongoing medical condition (e.g. asthma, arthritis, and emphysema), being exacerbated by cold conditions. Other participants perceived the cold conditions to cause or worsen colds or influenza ($n=5$), to limit mobility and restrict activities ($n=5$) and to impact their mental health and well-being ($n=3$). One participant with emphysema said that breathing was already difficult, but "breathing cold air feels like breathing glass." Another participant attributed their pneumonia to home conditions.

Respondents typically (68 per cent) only heated one room of the house, primarily being their main living area (kitchen, living and/or dining; $n=13$) or the room they were using ($n=7$). Participants displayed different heating behaviours, for instance, heating bedrooms just before bedtime, using different forms of heating in different rooms or only heating certain rooms depending on degree of cold. Only four participants heated their whole home, with the same number of people not heating their homes at all, due to lack of a heating appliance.

Time of day and duration of heater usage varied between participants. Most (55 per cent) used their heater as needed, for example when they felt cold. However, this very generalised response covers a broad range of behaviour: some did not impose limits on their heater usage; others chose to heat only when they felt particularly cold; or limited duration due to cost. Five participants reported that they used heating before and/or after showering to "take the chill off the air." One participant noted using the heater more during the day, when the running cost was offset by electricity from solar panels. Another stated that the reason they do not heat their home (at all) is because they live alone and feel that heating the home for themselves is "wasting power." Only two participants continued heating when they were not at home.

Prior to using heating, participants utilised different methods to keep warm. Most (58 per cent) donned extra clothing and footwear. Many (40 per cent) used blankets, or electric blankets. Half of participants utilised multiple methods to keep warm, before using their heater.

Windows and doors were perceived to be a significant source of heat loss, with participants keeping homes and curtains closed to retain heat, using "door snakes" or pillows to block draughts or even using blankets, towels and bubble wrap packaging as heat barriers on windows. Conversely, when outside temperatures became warmer, participants reported opening the home up and exposing windows to let the heat in. Other methods for keeping warm included cuddling pets, showering, drinking warm beverages, taking a nap and exercising.

Most participants considered electricity or gas costs to be affordable or somewhat affordable, with about one-third reporting their electricity/gas cost as unaffordable. One participant, on a pension, reported being unable to afford food because of unaffordable utility costs. Several participants ($n=11$) were utilising payment plans for electricity and/or gas. Three participants had solar panels; however, two of these participants said that the solar panels did not assist with the affordability of heating costs. Three participants stated they do not use their heater, or limited its use, due to cost.

Participants were asked what housing providers could do to make homes more comfortable and heating more affordable. Most participants suggested improvements to the home, such as better insulation, better flooring, improvements to windows, fixing gaps in windows and doors, and fixing dampness. One-third of participants proposed new heating, either because they did not currently have heating or because their current heating was not affordable to use due to poor efficiency. One participant noted that being provided tools to help cope with cold weather, such as door snakes and curtains, would be beneficial.

Participants were also asked whether they had any more to add regarding the thermal performance of their home during cold weather periods (Box 1). These responses demonstrate the diversity of cold housing issues. These range from lack of control of the housing environment, or of energy providers, as a tenant; housing conditions; affordability of heating; to health issues.

3.4 | Remote data collection

A contact-free approach to collecting indoor environmental data from participants' homes proved to be a reliable and promising method—no contact was required between participants and researchers, sample collection was less labour-intensive, and this facilitated increased sample size and diversity.

Due to the contact-free nature of this method, researchers were not required to travel to participants' homes at the commencement and conclusion of the monitoring period. With current practices transitioning to more "COVID-safe" routines, reducing individual contact provides a higher degree of safety to researchers and participants. In-home visits may also be potentially invasive and inconvenient for participants, thereby causing hesitancy in agreeing to participate. Removing the need for researchers to enter participants' homes provides comfort and convenience for participants. When asked how participants felt on the process of receiving and setting up the data logger, the majority ($n = 31$) found it to be easy. Two participants felt they were somewhat unsure about their choice of placement, and an additional two felt further instructions may have been beneficial.

BOX 1 Participant responses.

Is there anything else that you would like to tell us about the thermal performance of your house?

I had been waiting for maintenance but was turned down, I think it may be because they're going to demolish the homes and build new ones. Anything would be better than the one I am in now, I have been living here since 1962 and wouldn't mind an upgrade.

The Housing manager once came over at midday, and he even said the house was ridiculously cold – I am really happy we're doing something about this problem and researching it.

I have done things to my house myself in an effort to keep it cool or warm. I have insulated the ceiling. Last year, after having new windows installed, the installers took away the blinds that I had (because they were old, and wouldn't fit the new windows). The organisation that has taken over management of my property took forever to replace the blinds and curtain brackets. This added to the house being cold. Quilt covers really don't insulate from much at all.

My costs have gotten out of hand. On a fixed income, I struggle to afford food.

I have lots of health issues (stroke, malnutrition). When I had an inspection, I asked about getting the heater fixed and was told that as I pay the cheapest rent, I shouldn't complain.

The walls are very thin, with no insulation. Air comes in from doors, and the windows are small, so the sun doesn't come in. I would like a sun roof to let heat in. With the new solar panel scheme, tenants have to go with a particular electricity company where you don't get the good rate, so it doesn't really work out better for tenants.

4 | DISCUSSION

4.1 | Perception of temperature

The majority of participants considered their homes to be "cold" or "very cold" during cold weather periods. This is concerning because research shows that residents who indicated their homes were too cold in cold weather periods were more likely to have significantly lower well-being (Hiscock et al., 2017). It has also been demonstrated that socioeconomically deprived populations, comparable with those who inhabit Australian social housing, are more likely to be admitted to hospital in periods of extreme temperatures (Rizmie et al., 2022).

Whilst we measured temperature in homes during springtime, homes studied had a daily average of less than 18°C for 45 per cent of the time in September (beginning of spring, Figure 1). Indeed, over the whole spring period, homes were cold (below 18°C), on average, for 29 per cent of all days. Hence, it is anticipated that these homes also experience cold indoor conditions throughout the colder months of the year.

Australia is generally considered to be a warm country, and housing construction is generally focussed on heat resilience as opposed to heat retention (Daniel, Baker, et al., 2019). Indeed, previous studies have shown that wintertime temperatures in South Australian homes (Daniel, Baker, & Williamson, 2019) were on average below 18°C. This is also true of social housing homes in NSW, where four of 42 homes studied were below 18°C more than 90 per cent of the time during winter, and around half of the homes were below 18°C half of the time in winter (Daly et al., 2021). Internationally, homes within mild-climate countries, as opposed to those in more cold-dominated locations, are generally characterised by poor thermal efficiency (Howden-Chapman et al., 2017). For instance, a study of social housing in Spain, also considered a mild-climate country, determined that 25 per cent of homes had temperatures below 18°C, during occupied periods (San Miguel-Bellod et al., 2018).

It is interesting that individuals who live on their own may perceive it was a "waste" to heat their homes for only themselves. This attitude aligns with the literature concerning physical measurement of temperature in homes, where single-occupant homes are more likely to be less than 16°C (Hutchinson et al., 2006). Across Australia, there is an attitude of stoicism, where Australian "cold weather" is considered to be pleasant compared with other parts of the world, with the need to stay warm and use adaptive measures being largely ignored (Hitchings et al., 2015). This stoicism is demonstrated in comparable cohorts internationally; for example, in the UK, older people admitted avoiding some adaptive measures, such as wearing head coverings to bed, because they did not want to appear "old" (Day & Hitchings, 2011).

Occupant heating behaviours described by our participants are similar to studies which show that living rooms and bedrooms are the most likely rooms to be heated (Magalhães et al., 2016), with living rooms being the rooms most frequently occupied (Khajehzadeh & Vale, 2015). Bedrooms are typically heated before sleeping hours and living rooms in the evening ($n = 12$). Turning off heating during the day is part of many older people's culture in the UK, as is keeping bedrooms colder, perhaps even opening bedroom windows (Wright, 2004). The practice of opening windows in cold conditions was not apparent among the sample of the present study.

Some of the measures taken by participants to stay warm, such as lining windows with bubble wrap, or cuddling pets, are innovative. In a study of UK residents aged over 65 years, Hughes and Natarajan (2019) found that older people in particular often resorted to "extreme" methods of remaining warm. This is likely to become more prominent in countries with ageing populations (Hughes & Natarajan, 2019).

Discussions with participants and review of relevant literature reveal several ways to improve thermal conditions in the social housing sector. This information from tenants is highly important, as it has previously been established that social housing tenants are seldom consulted in regard to their preferences and priorities for building condition improvements (Baker, Moore, et al., In press). Indeed, with social housing providers balancing their obligations as businesses with their social obligation to tenants, retrofit priorities of social housing providers tend to misalign with those of tenants (Baker, Moore, et al., In press).

Among available actions, there are low-cost interventions, which either do not cost money, tenants may be able to afford themselves, or could be provided at little cost. While those in social housing do not own their homes, there are simple ways to improve comfort and energy efficiency. Many study participants had focussed their efforts on windows. Indeed, up to 40 per cent of heat escaping from homes in cold weather occurs through windows (Sustainability Victoria, 2021). Mitigating measures include closing or opening blinds, or using blankets and bubble wrap, to keep in warmth; or uncovering windows to let in the sunshine, with the reverse applying in summertime (Climate Council, 2021). Using lined curtains, window films and installing a sheet of plywood, plastic or fabric behind curtain rails can further insulate windows (Victoria State Government, 2022).

Additional measures include being aware of outdoor conditions and opening the home to let in favourable temperatures; closing and sealing internal doors (Australian Government, 2022); or using dividers, such as blankets, to block doorways in order to more effectively heat or cool one area (Climate Council, 2021). Adding rugs to floors also provides insulation (Australian Government, 2022). Cracks and gaps that account for up to 25 per cent of heat loss from homes may be sealed using weather stripping, gap filler and "door snakes" (Victoria State Government, 2022). Improving air tightness in homes reduced heating energy needs by 9 per cent in UK homes (Gillott et al., 2016) and cost relatively little (AUD 300) compared to other measures, such as insulation and floor sealing. Taking hot showers to warm up, as one participant reported, is not energy efficient and may cost more than heating the home (Australian Government, 2022).

Similar to the concern of participants in this study, about the effectiveness and efficiency of their heaters, occupants of Spanish social housing also lacked adequate heating systems (San Miguel-Bellod et al., 2018). New gas and electric appliances sold in Australia come with energy efficiency ratings for both heating and cooling. These can help to choose a heater, or air conditioner, which will most efficiently keep the home at a comfortable temperature. Fan-type heaters are inexpensive to buy, yet are the most inefficient and hence the most expensive to run; purchasing a more energy-efficient heater would comparatively save money in future. In New Zealand homes, the costs involved in purchasing efficient heating tended to outweigh the financial benefit, except in households with higher asthma rates (Preval et al., 2010). For high health system users in New Zealand, installing a combination of insulation and or efficient heating resulted in health cost savings that equated to a one-year payoff period for the interventions (Hamilton & Johns, 2016). Considering that social housing tenants often have increased health needs (Section 1.0), they are therefore more likely to benefit from efficient heating. It is, however, difficult for those on the lowest incomes, who do not have the funds for the initial outlay. This may also be difficult in rental and social housing situations where installation is required, for example reverse-cycle air conditioning. The provision of energy-efficient heaters is likely to be beneficial to those in social housing situations.

More costly interventions are less attainable for those who do not own their homes, or are short on funds. Well-insulated homes use up to 45 per cent less energy for heating and cooling (Environment Victoria, 2019), yet social housing tenants are generally unable to effect this. A retrofit study in the UK (Hong et al., 2006) found cavity wall and loft insulation reduced heating fuel consumption by 17 per cent in properties that were not centrally heated. An Israeli study showed that insulation of ceilings was cost-effective, but only in the longer term (15–30 years); wall insulation also resulted in energy cost savings, but these were less than the cost of the insulation (Friedman et al., 2014). In New Zealand, when both energy and health savings were considered, the savings from insulating homes were up to twice the cost of installing insulation (Chapman et al., 2009).

Improving the energy efficiency of homes at risk of fuel poverty has a profound impact on well-being and quality of life, financial stress, thermal comfort, social interaction and indoor space use (Grey et al., 2017). Boemi and Papadopoulos (2019) found improving the energy efficiency of homes was key to alleviating energy poverty. However, previous Australian experience shows that whilst increasing the energy efficiency of the home does improve thermal comfort (Willand, 2016), it must be combined with other measures to create a warm living environment (Burholt & Windle, 2006; Sherriff et al., 2019).

Participants in this study often perceived their homes to be poorly insulated. Again, this is similar to Spanish social housing (San Miguel-Bellod et al., 2018). Provision or improvement of insulation would significantly benefit social housing tenants, improving energy efficiency and affordability of keeping homes comfortable in hot and cold weather. Yet, the cost of insulation is relatively high. Marí-Dell'Olmo et al. (2017) concluded that policies on energy efficiency for social housing can reduce the health consequences of fuel poverty, but these need to be free to users, target the most vulnerable groups and be adaptable to their needs.

With 30 per cent of participants stating that they did not find energy affordable and one-quarter of participants on energy payment plans, affordability of energy is an ongoing issue for social housing tenants. Daly et al. (2021) also observed this tension between Australian social housing tenants desiring to stay warm but being worried about the cost of using heating appliances. Similarly, in Greece, another warm-climate country, lower socioeconomic groups were unable to afford to heat their homes (Santamouris et al., 2014). Australian energy retailers may not impose penalties for late payment; however, they do offer "discounts" of 10 to 40 per cent for on-time payment, effectively penalising those in financial hardship who are unable to pay on time, or those on payment plans (Australian Energy Regulator, 2021b). Combined with rapidly increasing energy prices, this makes those in financial hardship more likely to be disconnected, with disconnection allowed following a debt of $300, compared to an average 90-day debt of $1000 in 2020–2021 (Australian Energy Regulator, 2021a). One-quarter of participants stated that they were on an energy payment plan; this is around 10 times the rate of the overall Australian population (Australian Energy Regulator, 2021b) and demonstrates the vulnerability of social housing tenants to energy poverty. Subsidising energy for the most vulnerable is only part of the solution, however, as their homes need to be more energy efficient and have adequate heating systems in order to effectively keep warm.

A review of Australian policy for social housing retrofit and energy efficiency measures over the past 20 years (Baker, Moore, et al., In press) noted that policy specifically targeting social housing (or vulnerable households in general), on a national scale, was limited to smaller programmes, affecting up to 220 existing dwellings and 500 new dwellings. The majority of policy was initiated on a state-wide basis, including grants to community housing providers to improve home conditions, provision of solar panels and energy efficiency improvements such as supply of LED lighting or energy-efficient appliances. Gauging from the participant responses in this study, despite these efforts, there is still significant room for improvement in mitigating indoor cold for social housing tenants.

The remote sampling protocol enabled data collection to be expanded to regions, which may not have been easily accessible by researchers. Location limitations may reduce the relevance and generalisability of data, resulting in smaller sample sizes and narrow variation. By contrast, posting loggers enables sample sites to be expanded nationally or even globally (Isley, Fry, Liu, et al., 2022). The success of posting the data loggers presents opportunities for future research to cost-effectively access remote participants. This will potentially increase sample sizes and diversity of households and experiences, providing a more robust dataset.

This method has potential, beyond temperature studies, to a broad range of indoor environmental analyses. We suggest that the replied paid envelopes be sent toward the end of the monitoring period, to minimise loss, as well as acting as a useful prompt for participants to return the logger. The loss of some devices (in this case, 8 per cent), should be factored into the research plan and budget.

5 | CONCLUSION

Across the monitoring period, social housing homes studied had, on average, indoor temperatures below WHO's recommendations (18°C) approximately one-third of the time. Participants considered material building conditions to be the major factor in being unable to keep warm in cold weather periods, with issues such as gaps in windows, floors and walls or inadequate insulation most frequently mentioned. Further to this, about one-third of participants considered energy for heating to be unaffordable. Several of the interventions suggested in the literature had already been employed by the participants in this study, in response to cold conditions in their home, such as covering windows, blocking draughts and using clothing and blankets. These measures may be improved with additional input from housing providers, for example professional sealing of gaps, doors and windows or provision of more thermally effective window coverings. Additional suggestions, made by participants, for the provision of more energy-efficient heating appliances, would also be of benefit. The greatest benefit is likely to come from the improvement of energy efficiency of the housing via insulation, a solution that is out of reach of the tenants themselves.

AUTHOR CONTRIBUTIONS

Gemma Sansom: Investigation; methodology; writing – original draft. **Cynthia Faye Barlow:** Investigation; writing – original draft; writing – review and editing. **Emma Baker:** Conceptualization; supervision; writing – review and editing. **Lyrian Daniel:** Conceptualization; methodology; supervision; writing – review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors report there are no competing interests to declare.

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APPENDIX A

Participant survey questions

Q1. Can you please tell me a little bit about the warmth conditions within your home during cold weather periods? Is your home generally quite comfortable or does it often get very cold?

Q2. [if they say their home is overly cold] What do you think are the primary causes of these cool/cold conditions?

Q3. How do you think that these cold conditions impact you and your household's health and well-being?

Q4. Would you say your health is excellent, very good, good, fair or poor?

Q5. What is the main way you heat your home?

Q6. What rooms of your home do you normally heat?

Q7. When and for how long do you normally use the heater?

Q8. Do you have any techniques that you use to warm up before turning the heater on?

Q9. Do you turn the heater off when you leave the house?

Q10. Would you consider your electricity cost affordable for you?

Q11. Would you consider your gas cost affordable to you?

Q12. What would the number one thing that your housing provider could do to make your house more comfortable and affordable during wintertime?

Q13. Is there anything else that you would like to tell us about the thermal performance of your house during winter?

Q14. Finally, can you please tell me how you felt about the process of this research in regard to receiving and setting up the data logger?

APPENDIX B

Temperature and rainfall conditions during the study period in comparison with historical data

	Year	September	October	November
Mean maximum outdoor temperature (°C)	1887–2021	18.4	21.4	24.5
	2021	19.6	21.1	23.4
Mean minimum outdoor temperature (°C)	1887–2021	9.3	11.2	13.2
	2021	9.9	10.4	13.0
Rainfall (mm)	1887–2021 mean	50.7	44.2	30.5
	2021 total	26.0	61.8	33.6

APPENDIX C

Participant temperature data summaries during waking hours

	Mean daily temperature	Mean daily minimum	Mean daily maximum	% days mean < 18	% days mean > 24	Total % outside 18–24°C
1	19.3	17.2	21.2	32.4	4.1	36.5
2	14.4	13.5	15.1	98.7	0.0	98.7
3	18.4	17.0	19.6	45.7	0.0	45.7
4	19.8	17.4	22.4	27.8	8.9	36.7
5	17.2	14.8	18.7	77.5	0.0	77.5
6	21.1	18.6	23.7	2.9	11.6	14.5
7	20.4	17.9	22.6	18.2	8.0	26.1
8	19.0	16.2	21.6	40.7	3.5	44.2
9	18.0	17.3	18.9	56.4	0.0	56.4
10	21.9	20.2	23.5	3.3	17.6	20.9
11	21.1	17.8	24.0	1.2	2.0	3.2
12	18.1	16.3	19.7	56.1	0.0	56.1
13	18.1	16.8	19.2	53.4	0.0	53.4
14	19.7	18.9	20.9	6.6	0.0	6.6
15	19.5	16.5	22.1	17.6	0.0	17.6
16	19.5	17.9	21.2	30.0	2.2	32.2
17	20.3	18.7	21.3	11.2	2.3	13.5
18	17.7	16.3	18.9	63.2	0.0	63.2
19	19.8	16.1	23.0	29.3	8.6	37.9
20	20.1	17.6	22.6	17.9	6.0	23.9
21	18.4	15.5	20.6	52.9	4.3	57.2
22	18.0	16.9	18.9	56.3	0.0	56.3
23	20.6	17.9	22.6	1.3	1.3	2.6
24	18.6	16.1	20.9	36.7	1.0	37.7
25	22.4	18.5	27.1	0.0	6.3	6.3
26	18.5	16.5	20.6	51.6	1.6	53.2
27	20.0	17.0	22.5	12.9	3.2	16.1
28	22.3	18.7	25.1	1.4	18.3	19.7
29	21.7	19.8	23.4	1.4	18.1	19.5
30	20.3	17.7	23.4	4.3	4.3	8.6
31	22.0	19.2	25.4	0.0	21.3	21.3
Mean	19.6	17.3	21.6	29.3	5.0	34.3