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Household Energy End-use Project 2:

Report on winter comfort, heating and indoor temperatures (preliminary analysis)

HEEP2

Ben Anderson, Vicki White and Suzanne Jones

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Building Research Levy

MINISTRY OF BUSINESS,
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HĪKINA WHAKATUTUKI

1222 Moonshine Rd, RD1, Porirua 5381
Private Bag 50 908, Porirua 5240
New Zealand
branz.nz

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- Stats NZ for supporting participant recruitment
- over 750 households that took part in the national study in some capacity.

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Reference

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Abstract

The Household Energy End-use Project 2 (HEEP2) is a comprehensive national study of energy use and conditions in New Zealand homes designed to replicate the earlier HEEP1 study undertaken in 1999–2005. HEEP2 involves a national sample of over 750 households with data collected in various ways, including self-completion and on-site surveys, in-home monitoring and accessing metered energy data from retailers. This report presents the first insights from some survey and monitoring data, focusing on winter heating, comfort and internal temperatures. The survey data is derived from the in-home interview and building and appliance survey completed for 425 households throughout the country. The detailed temperature analysis is based on a subset of 125 of these households monitored over winter 2023. As this represents less than half the HEEP2 monitored sample, these results are preliminary only.

Key findings from the survey indicate that nearly half of respondents experienced colder-than-desired indoor conditions during winter and often experienced problems of dampness, condensation and mould. While most households reported heating their main living areas every or most days in winter, this did not apply to the respondent's bedroom, with over 2 in 5 never being heated. Bedrooms occupied by a child aged under 5 were more likely to be heated, but almost a third remained unheated. A high proportion of survey respondents reported behaviours to help keep warm such as closing curtains, using extra blankets, wearing extra clothes and closing off unused rooms. 1 in 20 (5%) said they had gone without heating at some time in the last year because they felt unable to pay for it.

Preliminary analysis of temperature data for the 125 households monitored over winter 2023 suggest improvements in indoor temperatures over the past two decades, yet average bedroom temperatures remain below recommended healthy levels. The average (mean) temperature in living areas in the evening was just under 20°C, while the average temperature overnight in occupied bedrooms was 16.5°C. The results draw attention to differences between socio-demographic groups, continued exposure to unhealthy night-time temperatures, particularly for those in lower household income groups, and the apparent prioritisation of young children's bedroom temperatures. They also give some indications of the potential role of improvements in insulation and heating appliances in contributing to higher room temperatures, although this requires further research and analysis.

Keywords

Energy use, indoor temperatures, heating, comfort.

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Executive summary

The Household Energy End-use Project 2 (HEEP2) is a national study of energy use and conditions in New Zealand homes. It was designed to closely replicate HEEP1, a similar study undertaken from 1999 to 2005.

Households were recruited to the national HEEP2 study through the Stats NZ Household Economic Survey (HES) 2021/22, with additional recruitment through the 2023/24 HES. All household types and typologies were eligible to take part.

HEEP2 is collecting data in various ways from a national sample of over 800 households. Data collection includes combinations of self-completion and on-site surveys, in-home monitoring and accessing metered energy data from retailers.

This report presents preliminary results, focusing on winter heating, comfort and internal temperatures in homes. It draws on data from an in-home interview and building and appliance survey completed for 425 households.

Analysis of internal temperatures uses a subset of this national sample comprising 128 households that were monitored over winter 2023.

All results reported here use unweighted data. As the monitoring data covers less than half of the HEEP2 monitored dataset, these results must be considered preliminary. Similar analyses will be undertaken and reported using the complete and final dataset.

Sample demographics

- Households in the HEEP2 sample are predominantly owner-occupied with respondents being slightly older and having slightly higher incomes compared to the national population.
- The regional spread reflects the national dwelling distribution with some exceptions due to fieldwork challenges (namely Tasman and Gisborne).

Dwelling characteristics

- The dwelling type and size of houses in the HEEP2 sample is consistent with previous national housing surveys with most homes being stand-alone single-storey dwellings.
- The age distribution roughly aligns with other data, though there are possibly slightly fewer houses built pre-1920 and post-2000 in the HEEP2 sample.

Occupant comfort and problems in the home over winter

- Almost half (48%) of respondents said their home felt colder than they would like at least some of the time in winter. Around 1 in 5 said they could see their breath and 1 in 5 reported that their home was cold enough that they shivered at least some time in winter. These results are consistent with those from a 2018 Stats NZ survey.
- Those who felt cold most commonly associated this with poor heat retention and efforts to reduce energy costs. They were more likely to have gaps around their windows (a potential source of draughts), while those whose homes were predominantly double glazed were much less likely to report feeling cold in winter.
- Damp (33%), condensation (75%) and mould (48%) were frequently reported.

Heating behaviours

- 85% said they heated their main living area every day or most days in winter, which corresponds to the original HEEP1 finding and results from a 2018 Stats NZ survey.
- 41% of HEEP2 respondents reported never heating their bedroom, which is lower than the original HEEP1 finding of 50%.
- Occupied bedrooms are more likely to be heated if the youngest occupant is aged under 5, with 41% reporting these are heated every day in winter compared to under 25% for other age groups. Nevertheless, just over 30% of young children's bedrooms were never heated.

Attitudes to energy use and perceptions of the home

- In line with results around feeling cold and cost being a reason for inadequately heating, 44% said they would like their homes to be warmer, 70% said they paid attention to energy bills and 79% reported making some form of change to their home to provide a more comfortable temperature.
- However, despite the prevalence of feeling cold, of experiencing damp, condensation and mould and of wanting their house to be warmer, 92% felt their home was a healthy place to live.
- Households adopted a range of different practices to help keep warm in their home in winter. A high proportion reported energy-efficient behaviours such as closing curtains, using extra blankets, wearing extra clothes and closing off unused rooms. However, having a hot shower/bath, which is a less effective way of using energy to keep warm, was also reported by around a quarter.
- Despite efforts reported by a high proportion of survey respondents to help keep energy bills down, 1 in 20 (5%) said they had gone without heating at some time in the last year because they felt unable to pay for it.

Indoor temperatures

- Preliminary analysis of a subset of the HEEP2 sample (125 households) monitored over winter (June to August) 2023 suggests indoor temperatures have increased over time, with significant improvements over the last 20 years (since HEEP1 was completed).
- The average (mean) temperature in living areas in the evening (17:00–23:00) for the HEEP2 winter 2023 subsample was just under 20°C compared to 17.8°C reported in HEEP1.
- The average (mean) temperature in bedrooms overnight (23:00–07:00) for the HEEP2 winter 2023 subsample was 16.1°C compared to 13.6°C reported in HEEP1.
- The average temperature overnight in HEEP2 occupied bedrooms was 16.4°C.
- While average living room temperatures exceeded the recommended healthy minimum of 18°C, average bedroom temperatures are still below this threshold – and substantially so for some.
- Frequency of heating appears a key factor in indoor temperatures achieved for both living areas and bedrooms.
- Early indications from the HEEP2 data suggest households in the lowest income group may experience bedroom temperatures significantly lower than other income groups, while houses built post-2007 may have higher temperatures in bedrooms.
- Preliminary results also suggest households with someone usually at home during the day are warmer than those usually unoccupied in the daytime, which aligns with self-reported heating habits.

- Age of bedroom occupant also appears a factor, with bedrooms occupied by young children being warmer than all other bedrooms, which again aligns with reported heating behaviours.

Conclusions

This report provides initial and, in the case of the internal temperature data, preliminary insights from the HEEP2 study. The results generally confirm findings from previous comparable studies while also indicating potential change (improvement) over time in internal temperatures but highlighting ongoing issues with cold, damp and mould.

The results draw attention to the differences between socio-demographic groups, the continued exposure to unhealthy night-time temperatures and the apparent prioritisation of young children's bedroom temperatures. They also give some indications of the potential role of improvements in insulation/thermal performance and heating appliances in contributing to higher room temperatures, although this requires further research and analysis.

The preliminary analysis of indoor temperatures will be updated and reported on for the complete HEEP2 dataset when available (2025).

1. Introduction

The Household Energy End-use Project 2 (HEEP2) is a national study of energy use and conditions in New Zealand homes. It was designed to closely replicate HEEP1 – a similar study undertaken from 1999 to 2005 with the final report in 2010. HEEP1 provided critical evidence and insights into indoor temperatures and the proportion of energy that households use for different services (heating, hot water, lighting, cooking and plug loads). The HEEP1 data, results and insights are still in use despite significant changes since HEEP1. This includes changes to our housing stock through changing building practices/Code and retrofits and changes to appliances in the home such as a shift towards more efficient modes of heating and lighting using heat pumps and LEDs. HEEP2 aims to provide an up-to-date picture of conditions and energy use in homes in the early 2020s by collecting data through self-completion and on-site surveys, in-home monitoring and by accessing metered energy data from retailers.

1.1 Sample recruitment

Households were recruited to the national HEEP2 study through the Stats NZ Household Economic Survey (HES) 2021/22, with additional recruitment through the 2023/24 HES.[1] Households were asked as part of the HES interview if they consented for their contact details to be passed to BRANZ to potentially take part in a household energy study. BRANZ attempted to contact all 2,710 HES respondents who consented via telephone and text. Households were taken through a consenting process involving verbal and written explanations about what the study involved. All household types and typologies were eligible to take part. Landlord consent was required for tenanted properties that were to undergo detailed monitoring as electrical and potentially gas work was required to install the monitoring equipment.

The HEEP2 national study comprises a nested sample approach with tiers of data collection from remote (self-completion) surveys through on-site interviews and building surveys to intensive in-home monitoring. These HEEP2 study groups are referred to as Light, Medium and Full, which reflects the amount of data collected as described below. This study design was intended to recruit as wide a range and as large a number of households as possible, acknowledging that in-home monitoring can be invasive and/or has some technical or consent requirements that may prevent some households from taking part. Koha was offered for taking part in all aspects of the study, with the amount adjusted to reflect the three levels of participation.

In addition to the national sample, a parallel Canterbury-based study group focuses on two distinct housing typologies: houses built to minimum Building Code requirements and houses built significantly above Code with respect to thermal performance. These households were recruited separately and are not included in the results in this report due to their distinct housing characteristics.

1.2 HEEP2 data collection

Households were recruited to the national sample from the Stats NZ HES contact list and then to one of three HEEP2 sample groups, with the level of data collection varying by sample group (Figure 1):

[1] Periods of fieldwork for both the HES and HEEP2 coincided with lockdowns due to the COVID-19 pandemic. This included a nationwide lockdown in August 2021, with restrictions preventing, limiting or impacting the movement of people until September 2022.

- **Light**: Short self-completion household survey including consent for access to energy use data from their retailer(s) (n=333).
- **Medium**: As for Light plus an in-home interview and building and appliance surveys (n=138).
- **Full**: As for Medium plus at least 12 months of detailed in-home monitoring and a final exit survey (n=287).

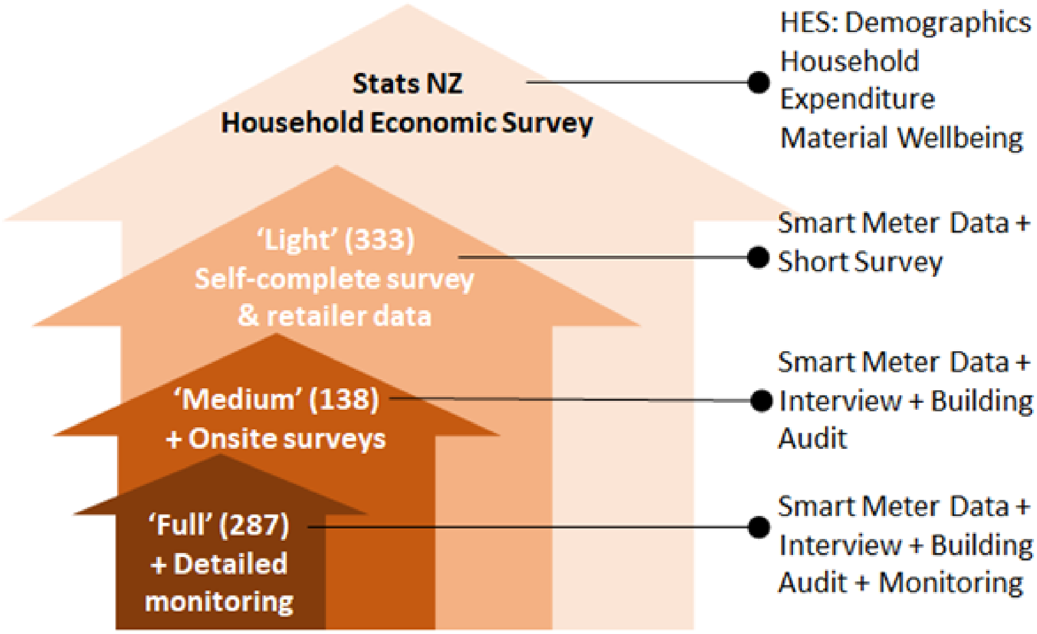

Figure 1. HEEP2 sample groups.

Figure 2 illustrates the data collected as part of the HEEP2 study in more detail. In addition, all households in the national sample have the potential to be linked to their full HES information through the Stats NZ Integrated Data Infrastructure (IDI) to provide additional information on household demographics, expenditure and material wellbeing. Integrating some of the HEEP2 dataset into the IDI is a long-term goal of the project.

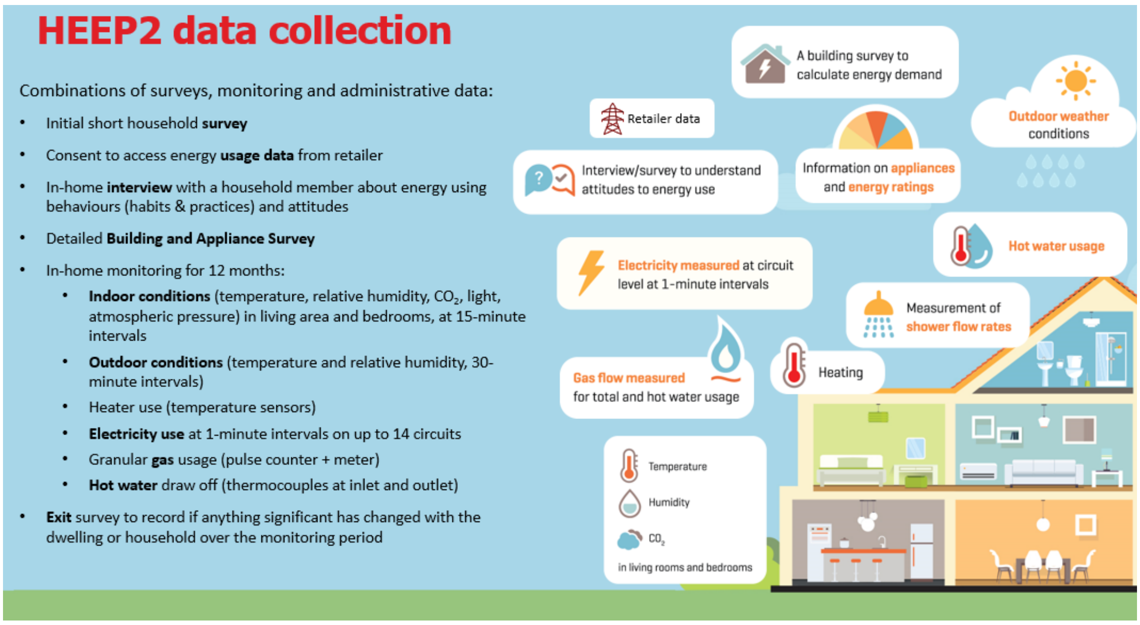

Figure 2. Overview of data collected in HEEP2.

Reasons for not taking part in the Full study included:

- householder declined (e.g. did not want monitoring equipment in their home)
- household wasn't eligible (e.g. planning to move within the next 12 months or insufficient network coverage for monitoring equipment)
- rented house where tenant unwilling or unable to obtain landlord's consent
- multiple dwellings/households on the same meter board.

Households unable or unwilling to take part in the Full study were offered the Medium or Light options. The Medium sample group had a target sample size of 130, which was easily achieved. The Light group had no specific target sample size. The final number reflects the relatively high level of response – of the 481 households that were sent the Light info pack, 69% completed and returned the survey and consent forms.

Table 1 shows the final outcome for all households in the HEEP2 national sample base (every household contact received from Stats NZ). These figures cannot be interpreted directly as response rates to the different samples because not all households were offered every option. If the Full sample quota had been filled for a particular region, a contacted household may only ever have been offered the Light option. Of those unable to take part, the primary reason (for almost half) was due to households possibly moving within the next 12 months – due to data collection timeframes for both monitoring data and retailer data, this was a requirement of participation. A number of households (around 8%) were no longer at the same address since completing the HES – for potential data linking, this was a limitation on taking part.

Table 1. Outcome of participation for all households in the national HEEP2 sample base (all contacts received from Stats NZ).

	Number of households
Full	287
Medium	138
Light	333
Light not returned (agreed but didn't return forms)	148
Declined	891
Unreachable	489
Unable to take part	424
Total HES contacts	**2,710**

1.2.1 Data collection timeframe and fieldwork

Recruitment to HEEP2 started in August 2021 and continued through to July 2024.[2] The first Wellington-based installations were completed in December 2021, but fieldwork (on-site interviews, building surveys and equipment installations) did not commence at the national scale until August 2022 due to COVID restrictions and other related delays.

HEEP2 fieldwork was a major logistical operation. BRANZ-trained field teams of surveyors, interviewers, electricians and (where required) gasfitters were established in Auckland, Hamilton, Wellington and Christchurch. Additional electricians were based in Dunedin, Taupō and Bay of Plenty. Surveys and installations outside of the main centres were organised on a regional trip basis.

[2] These dates reflect when the first and last household was contacted. As all fieldwork was complete in April 2024, recruitment beyond this date relates to the Light sample only.

Fieldwork spanned an 18-month period from August 2022 to April 2024 (Figure 3). This means the in-home monitoring data, which covers 12 months, will not be complete until April 2025 (12 months after the last installation) and the data will relate to varying points in time for different households.

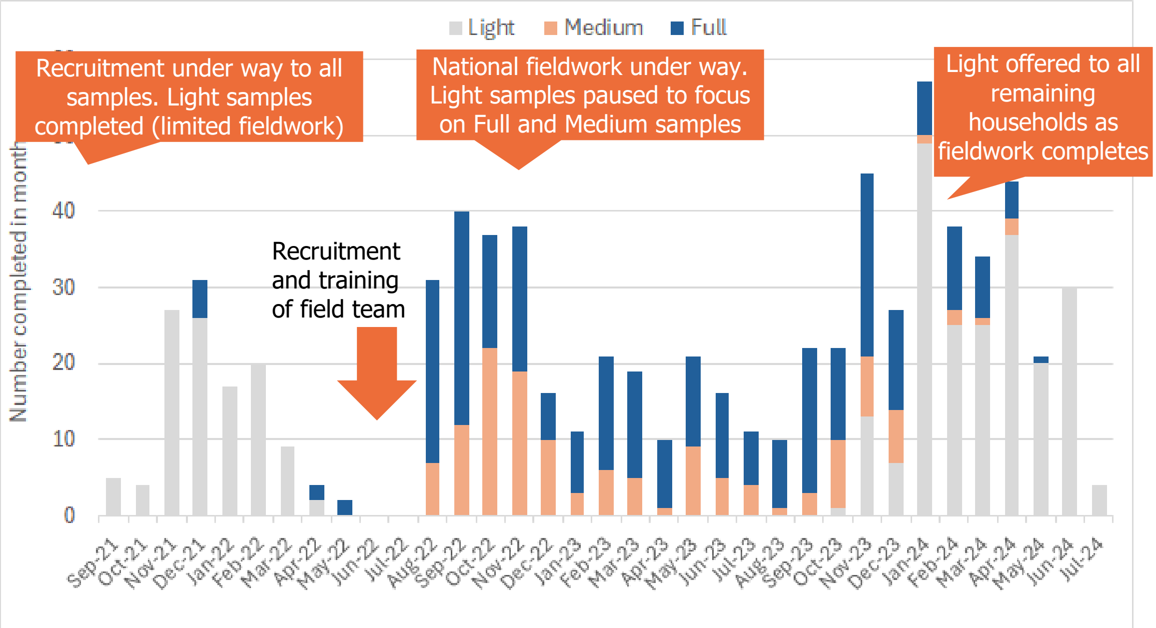

Figure 3. Data collection timeframe for the three HEEP2 national sample groups.

2. About the data in this report

This report draws on data from the building and appliance survey and in-home interviews completed for all households in the Full and Medium samples. These surveys were part of the fieldwork undertaken from December 2021 to April 2024 (as shown in Figure 3).

Indoor temperature monitoring data from a subset of households in the Full sample that were monitored during winter 2023 is then used to present some preliminary insights into indoor temperatures in living rooms and bedrooms.

For context and background, descriptive statistics about the sample are first presented. Results from the householder in-home interview focusing on those related to winter heating habits and attitudes towards using energy in the home are then reported for the Full and Medium samples combined, followed by some results from the building survey.

Finally, initial insights into indoor winter temperatures from the subset of houses monitored over winter 2023 are presented.

The building surveys and householder interviews are snapshots in time collected at the beginning of each household's involvement in the project. This data is considered complete although is subject to further cleaning and (re)coding as analysis progresses and/or missing data is infilled.[3] This may result in small changes to counts and percentages in future reports. All results reported here also use unweighted data. The final HEEP2 dataset may be subject to weighting to align the results with the national population.

The monitoring data, which is limited to the subset of Full houses that were monitored over winter 2023 (n=145) and for which clean data coverage was at least 95% (n=128), is neither final nor complete.

As the monitoring data presented here covers less than half of the HEEP2 Full monitored dataset and all data is unweighted, these results must be considered preliminary. Similar analyses will be undertaken and reported using the complete and final dataset.

[3] Missing data from the surveys, though limited, is being collected at the time of removal of monitoring equipment, hence some further updates to these datasets are likely.

3. HEEP2 sample characteristics

3.1 Region

The regional distribution of the HEEP2 survey sample (Full + Medium) is shown in Figure 4 (with a more detailed breakdown in Annex Table 1). Fieldwork was undertaken in all regions except Gisborne, which was impacted by Cyclone Gabrielle that hit the region in February 2023, and Tasman, due to poor connectivity for equipment and its relatively remote location. The HEEP2 sample aimed to recruit households in line with the national population distribution shown by the black markers in Figure 4 (population and dwellings shown). This was largely achieved, with the exception of slight under sampling in Auckland (due to slightly lower response rates) and oversampling in Canterbury and to some extent in Wellington (due to higher response rates).

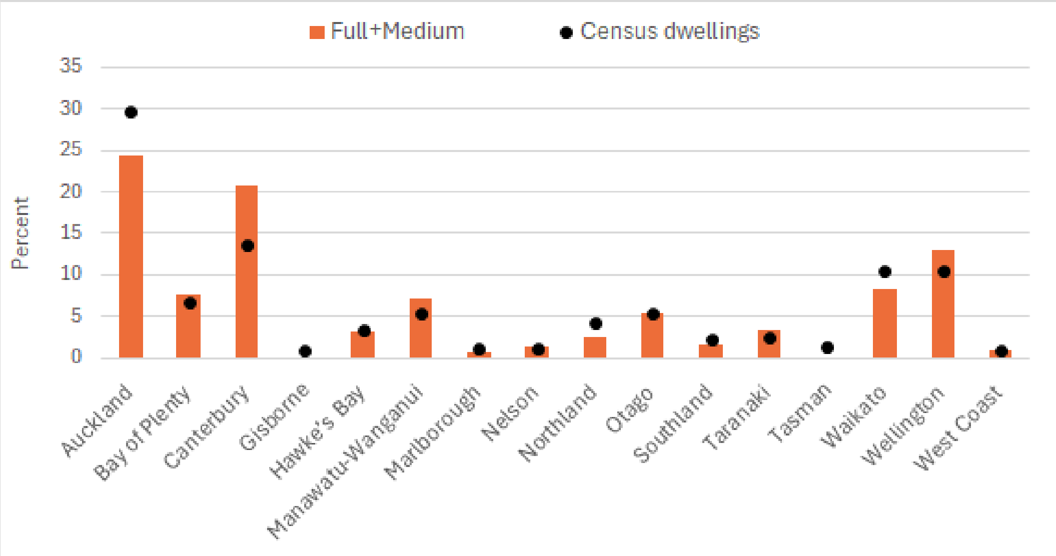

Figure 4. Regional distribution of the Full + Medium combined compared to 2023 Census dwellings.

3.2 Tenure and time at address

The HEEP2 national sample comprises mostly owner-occupied households.

While participation in HEEP2 was open to all household types, recruiting tenants proved a challenge. This outcome is consistent with previous BRANZ experience of running national housing surveys that require a lengthy site visit as was the case for both the Medium and Full samples. The additional requirement for landlord consent to take part in the Full study would likely have been an additional deterrent.

As a result, only around 10% of the Medium sample are rented homes while nearly all of the Full sample are owner-occupied homes. Across the Full and Medium sample combined, rented households make up just under 6% of the sample compared to approximately 35% of all New Zealand households (based on the 2018 Census). We know from previous research that the living conditions, behaviours and agency of tenants can differ substantially from owner-occupiers (White, 2020; Jones & White, 2023; Stats NZ, 2020). As a result, when considering the HEEP2 results reported here, it is important to bear in mind they largely reflect owner-occupied households only.

More than two-fifths of households (43%) in the HEEP2 Full and Medium sample had lived at their current address for more than 10 years, while a quarter (26%) had lived there for 5–10 years. These relatively long lengths of tenure reflect the mostly owner-occupied sample and older age distribution. According to the 2018 General Social Survey (GSS), which collected additional information on tenure security, "owner-occupiers were almost four times more likely than non-owner-occupiers to have lived at their house or flat for 10 or more years, and much less likely to have been there for less than three years" (Stats NZ, 2020, p. 41).

3.3 Age of respondent

More than one-third of HEEP2 household respondents are aged 65 or over.

The respondent is the person who first consented to be contacted by BRANZ through the HES and subsequently took part in the HEEP2 householder interview. HEEP2 participants had to be over the age of 18 to take part. This means some of the information collected and presented here does not necessarily reflect the characteristics and behaviours of all occupants in the household.

Figure 5 shows the age of the survey respondent for the Full and Medium samples combined. The distribution suggests a bias towards older age groups, with 16% of household respondents being aged 75 or over and more than a third (36%) aged 65 or over. While not directly comparable with the Census data, which represents people (total population) not households, these figures are notably higher, even when those aged under 15 are excluded from population percentages (shown by the dot markers in Figure 5). This tendency towards older age groups is again consistent with previous BRANZ experience of national housing surveys, perhaps reflecting availability of this age group to be home during the day for surveys to be completed and, in the case of younger age groups, the low number of rental homes in the HEEP2 sample.

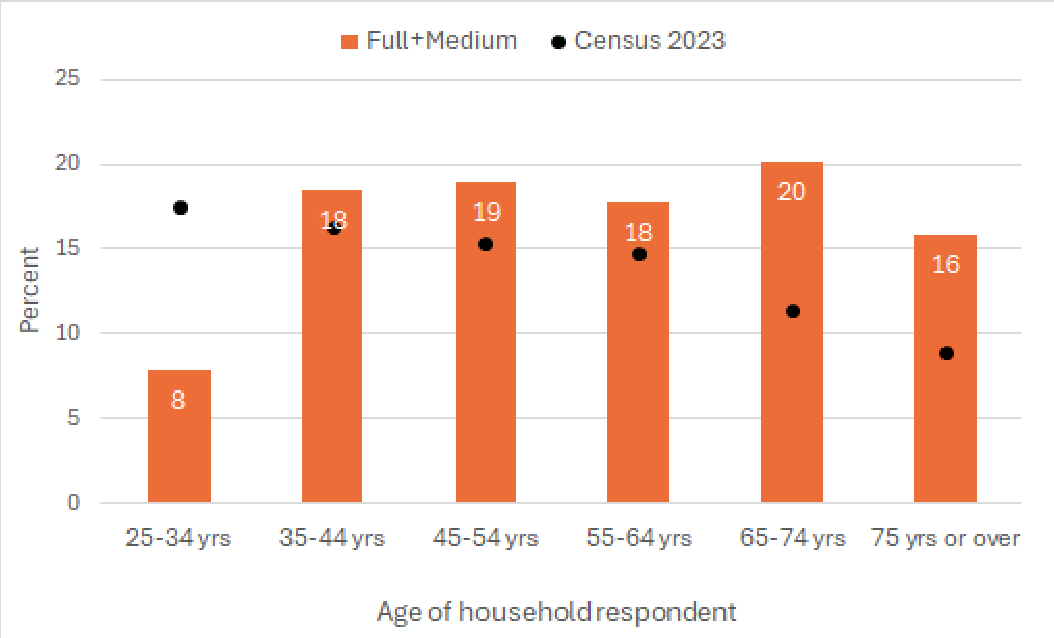

Figure 5. Age of respondents in the Full + Medium sample combined compared to 2023 Census total population distributions.

Information about the ages of all occupants living in the household was recorded by age groupings (number of people in the household aged under 5, 5–17, 18–64 and 65 or over). Figure 6 shows that the age distribution of occupants in the HEEP2 households more closely reflects the overall age distribution of the population,[4] particularly for children and young people aged under 18. There is still a slight bias towards the older age groups however – 23% in the 65 and over group in the HEEP2 sample compared to 17% for the total population.

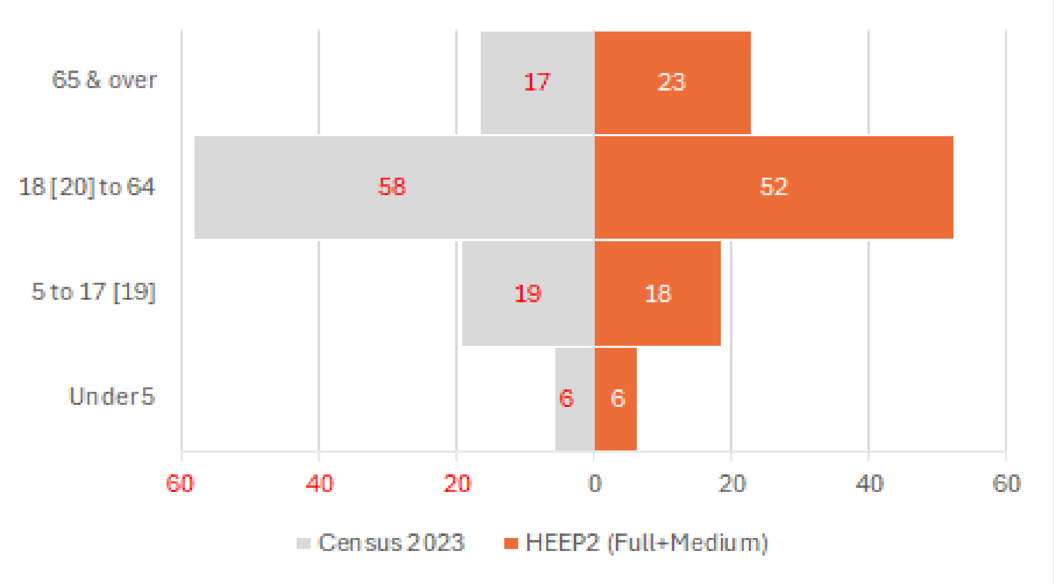

Figure 6. Age distribution of all HEEP2 occupants compared to 2023 Census.

3.4 Employment status

In line with the age profile of HEEP2 survey respondents, a high proportion were not in the labour force (34% overall for the Full and Medium sample), around half were in full-time employment and 14% were in part-time employment (Figure 7).

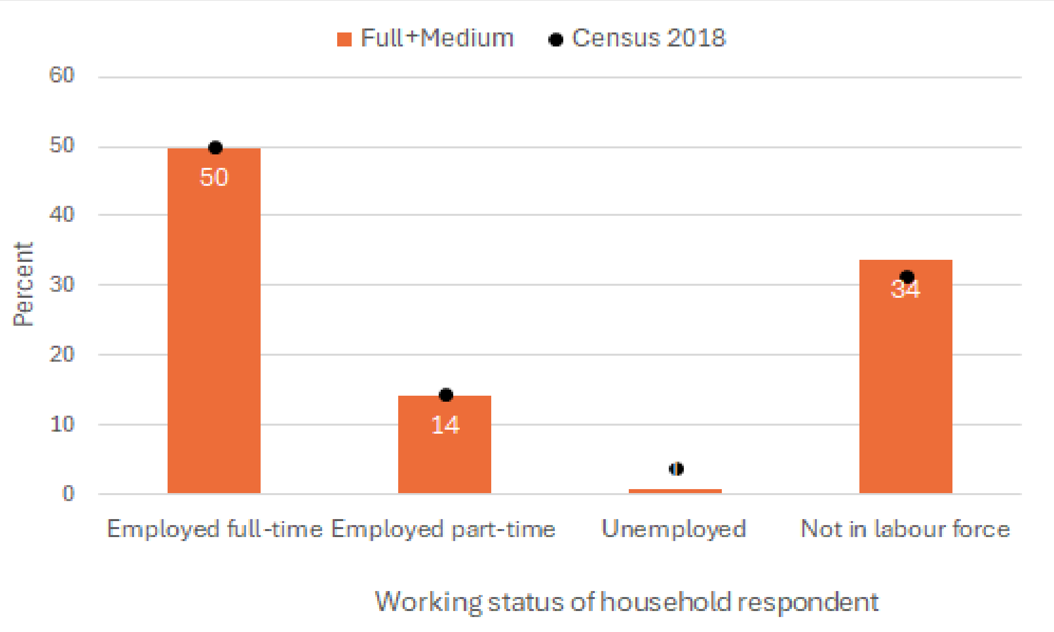

Figure 7. Employment status of respondents in the Full + Medium sample combined compared to 2018 Census.

[4] Data from Census 2023 is grouped slightly differently. Where the age band differs, this is shown by the figure in square brackets on the y-axis.

These proportions are similar to those from the 2018 Census,[5] again noting the latter records people while the HEEP2 results shown are just for the household respondent. The composition of the HEEP2 sample not in labour force group will largely comprise retirees, based on what we know about the age groups, and be lacking students.

3.5 House occupancy

Our survey asked participants what time(s) of day they are usually at home during the week and at weekends. This will help us to understand and give context to other information we have collected about their energy use. More than half of our sample are always home during the day and evenings on weekdays (54%). This reflects our older age distribution and our sample being slightly less likely to be in the labour force than the general population. A further 31% are usually home on weekday evenings. Most of our sample are always home on the weekends (77%). A further 16% said the times they are home at weekends is highly variable.

3.6 Income

A quarter of HEEP2 householders stated a household income of $150,000 or more.

The HEEP2 householder interview asked respondents about personal and combined household income. This part of the interview was designed to be self-completed, acknowledging the sensitive nature of this information. Even with that provision in place, the question still yielded a relatively high rate of non-response (1 in 10 selecting 'prefer not to say' or 'don't know'). Based on the data available, around one-fifth (19%) of the HEEP2 national sample had a household income of $50,000 or less, while around a quarter had an income of $150,000 or more (Figure 8). Compared to 2018 Census data for owner-occupied households, the HEEP2 sample has proportionally fewer households in the lowest income bracket and a higher proportion in the top income bracket.

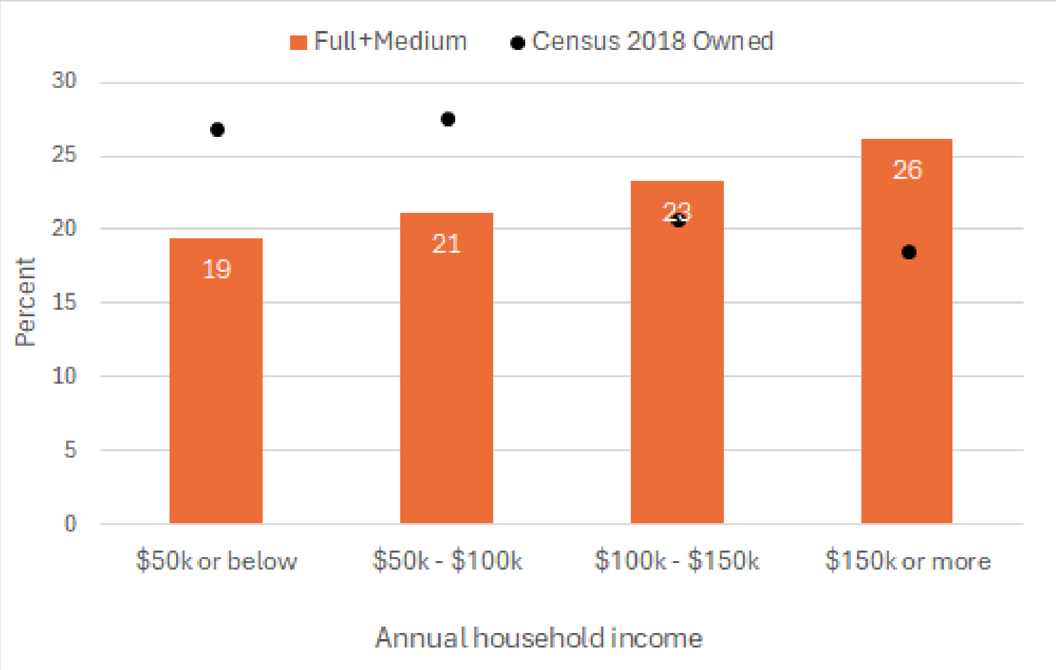

Figure 8. Annual household income (Full + Medium) compared to Census 2018 owner-occupiers.

[5] Employment status data from the 2023 Census was not yet available at the time of writing.

3.7 Health

Household survey respondents were asked how they rate their general health status on a qualitative scale from excellent through to poor. Overall, around a quarter (23%) of respondents considered their health excellent and a further 41% rated it very good (Figure 9). These figures are slightly higher than those reported from the Stats NZ wellbeing measures in 2021, with 15% and 38% of owner-occupiers rating their health as excellent or very good respectively (Stats NZ, 2022). Around 13% of HEEP2 respondents rated their health as fair or poor, slightly lower than the Stats NZ 2021 figure of 15% for owner-occupiers.

Around a quarter of HEEP2 householders rated their general health as excellent.

Figure 9. Self-reported health status of HEEP2 respondents compared to the 2021 GSS owner-occupied (OO) responses.

4. Dwelling characteristics

All households in the Medium and Full subsamples participated in a comprehensive building and appliance survey completed by a BRANZ-trained surveyor. This section describes some key features of the houses surveyed. These building features are then analysed alongside our respondents' levels of comfort during winter in section 5.

4.1 Dwelling type and size

The types of buildings in the HEEP2 samples are fairly consistent with previous housing surveys. In total, 62% are stand-alone single-storey dwellings, consistent with the national picture presented in the BRANZ 2018/19 Pilot Housing Survey (White, 2020). Dwelling type is shown in Figure 10 and dwelling floor area in Figure 11.

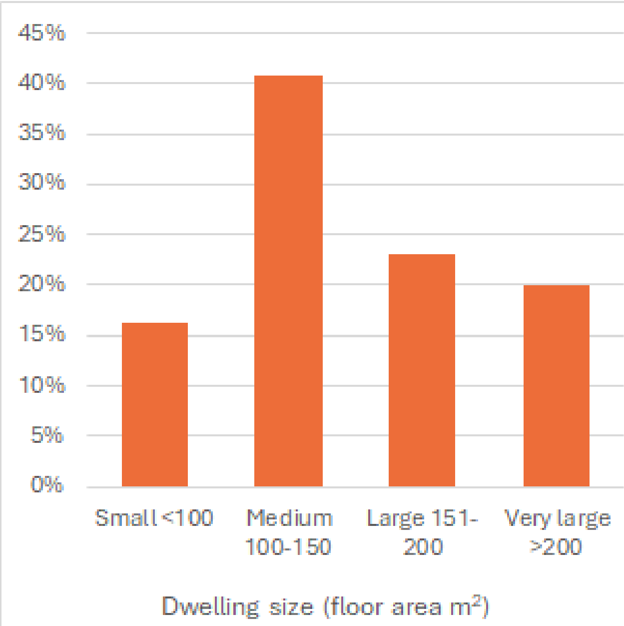

Figure 10. Dwelling type (HEEP2 Full + Medium).

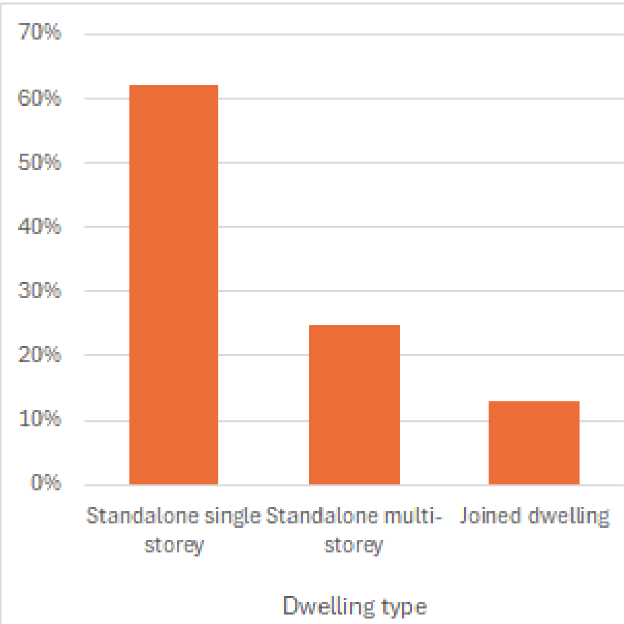

Figure 11. Dwelling floor area – grouped m² (HEEP2 Full + Medium).

4.2 Year of construction

Figure 12 shows the year of the HEEP2 houses' construction grouped into 20-year bands compared to the national housing supply. The median year of construction for HEEP2 houses was 1977, and the overall distribution by 20-year bands suggests that HEEP2 has slightly more older homes (built pre-1979) and slightly fewer newer homes (built since 1980) than the national picture.

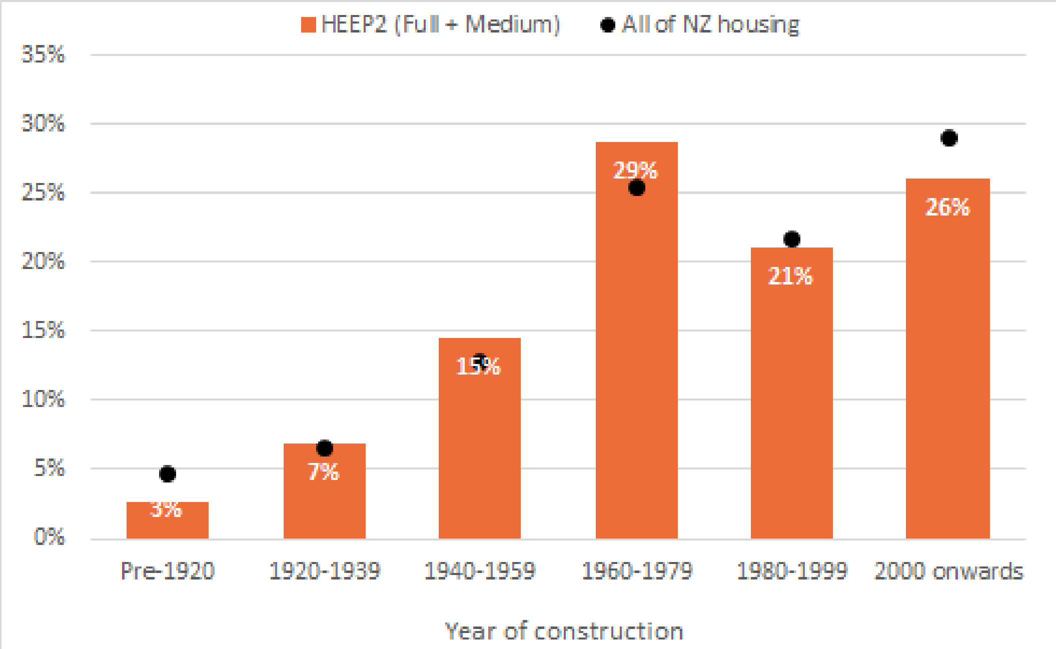

Figure 12. Year of construction (grouped) HEEP2 (Full + Medium) and all of New Zealand. (Source: CoreLogic housing data, 2022, supplied by Stats NZ)

4.3 Level of insulation

Year of construction has implications for thermal performance as insulation requirements have been introduced or increased in Building Code at various times. The first legislation making it compulsory for new homes to be insulated was introduced in 1977, with the requirements subsequently coming into force in April 1978 (Isaacs, 2007). Significant updates and/or additions took place in 2000, 2004, 2007 and most recently in 2021–2023.

The HEEP2 building survey captured the level of insulation in roof spaces, walls and subfloor areas where applicable and where accessible.

Year of construction will be an important proxy for estimating/assuming insulation levels areas not visible (such as walls) or not accessible at the time of the survey.

4.3.1 Roof space insulation

The survey recorded the presence of insulation in the roof space, detailing material type, depth and coverage, with the ability to record base layers and top-up insulation, where possible. Most houses had at least some insulation, with almost 3 in 5 (59%) having at least 120 mm – the minimum recommended by the Energy Efficiency and Conservation Authority (Figure 13). Nearly half (47%) had 150 mm or more of roof space insulation.

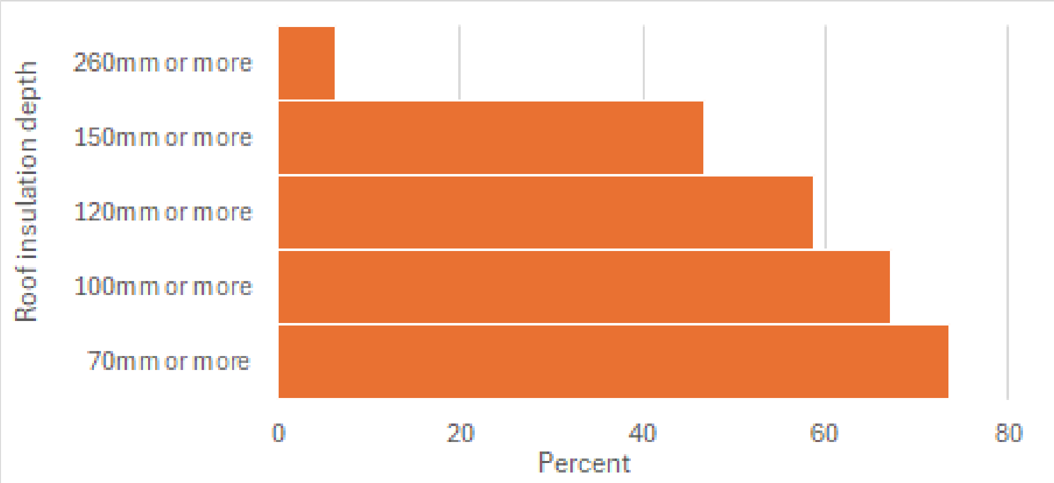

Figure 13. Roof space insulation depth.

4.3.2 Subfloor insulation

Houses built on concrete slabs made up almost half of the survey sample (48%).

To be effective, subfloor insulation should cover at least 80% of the accessible space. Almost half the houses in the HEEP2 sample had a concrete slab foundation (48%), and the vast majority are unlikely to have slab insulation due to house age (year of construction pre-dating any requirements for slab insulation). Of those with a suspended floor, almost three-quarters (71%) had at least 80% coverage of subfloor insulation.

4.4 Windows and glazing

4.4.1 Window framing

Aluminium was the most common framing material, being the predominant framing type for 71% of surveyed houses. This is consistent with the 2018/19 Pilot Housing Survey (White, 2020).

Surveyors looked for gaps in window frames, skirting and floorboards to detect potential sources of draughts. More than one-quarter of houses surveyed had gaps around windows with potential for heat loss and draughts. Gaps were much more common in timber-framed windows. Timber-framed windows are also more common in older houses, with more than 95% of predominantly timber window houses being built before 1980.

4.4.2 Glazing

Double glazing has been a requirement in new builds since 2008.

The increasing trend in double glazing observed in previous BRANZ house condition surveys (White, 2020) continues in the HEEP2 data. However, this appears mainly in the form of mixed glazing types throughout the house. That is, the proportion of houses with at least some double-glazed windows in HEEP2 was more than a third (36%). While an increasing proportion of houses now have some double glazing, around half were still entirely single glazed (51%). The presence of double glazing is much more common than in the HEEP1 study, reflecting changes to Building Code requirements and retrofit over that time.

5. Comfort and problems in the home in winter

Householder survey respondents were asked several questions about the comfort of their homes and other problems often experienced during winter.

5.1 Comfort

Almost half (48%) of the surveyed respondents stated that their house felt colder than they would like at least some of the time in winter. For 14% of respondents, this was always or often (Figure 14). These results are consistent with those from the 2018 GSS, which found 45% of owner-occupied households reported their home being colder than they would like at least some time in winter, and for 15%, this was always or often (Stats NZ, 2019).

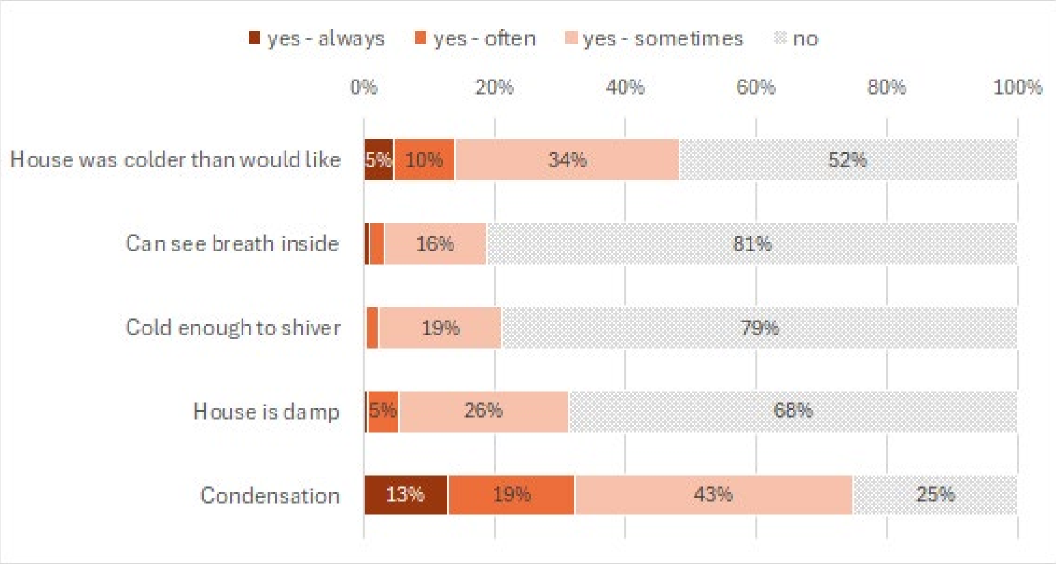

Figure 14. Comfort and problems in the home in winter – HEEP2 (Full + Medium).

Around 1 in 5 respondents (19%) said their home got cold enough that they could see their breath at least some time in winter. A similar proportion (21%) reported that their home was cold enough that they shivered. Overall, around half of those who stated that they could see their breath at least some time in winter also reported that their house was cold enough that they shivered.

5.2 Damp, condensation and mould

Households reported problems with damp (1 in 3), mould (1 in 2) and condensation (3 in 4).

Around one-third of HEEP2 households considered their house was damp, with 6% saying it was always or often damp (Figure 14). These results are comparable to the 2018 GSS for owner-occupiers (27% reporting damp) but are higher than those reported for the 2023 Census – 18% reported their home was always or sometimes damp. It is unclear why Census results are lower than both the GSS and HEEP2 but could be related to survey methods – both the GSS and HEEP2 were interviewer-collected data, while Census is self-completion.

Three-quarters (75%) of the HEEP2 sample reported experiencing condensation on windows or sills at some time in winter. For around a third (32%), this was always or often.

Almost half (48%) of the HEEP2 sample reported that their home gets mould. For around one-quarter of these (23%), the mould was larger than an A4 sheet of paper. These results vary somewhat from those reported in the 2018 GSS in which 30% of owner-occupiers reported experiencing mould. For 37% of these, the mould was larger than A4 size at least some of the time. For comparison, the most recent Census 2023 reports mould over A4 size in 14% of homes compared to 17% in Census 2018.

5.3 Reasons for feeling cold in winter

The house not retaining heat and trying to keep costs down were the most common reasons householders thought their home was colder than they'd like.

Respondents who stated that their house was colder than they would like in winter were asked what they thought was causing this. Respondents were given a list of options but were also able to give other reasons. Figure 15 shows the most common reasons were that they were trying to keep costs down by heating less and 'heat just disappears' – the house doesn't warm up adequately or stay warm when heated.

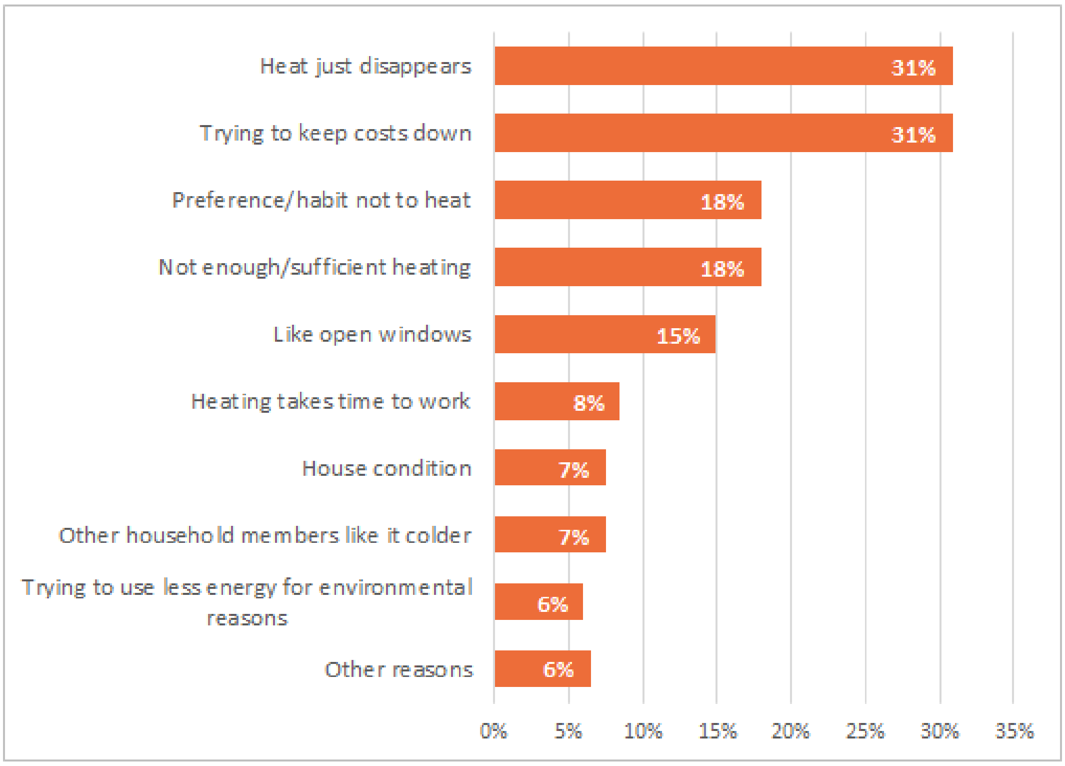

Figure 15. Reasons the house is cold in winter – Full and Medium samples who stated house was colder than they would like.

5.4 Building features associated with feeling cold in winter

Respondents in houses with predominantly timber-framed windows were more likely to feel cold in winter, and subsequently, respondents were more likely to feel cold in winter if gaps and draughts, particularly in windows, were prevalent in their house. As noted above, these tended to be older homes. For example, 39% of those who always or often felt colder than they would like in winter had at least some gaps around windows compared to 26% of those who did not report feeling cold in winter. Gaps in skirting boards and floorboards were less commonly observed and did not appear to have a strong relationship to feeling cold in winter.

Figure 16 shows the predominant types of glazing (single or double) in the surveyed houses by whether the occupants felt cold inside in winter. It shows that those with predominantly double-glazed windows were much less likely to feel colder than they would like in the house in winter – 65% compared to 45% of those with mostly single glazing.

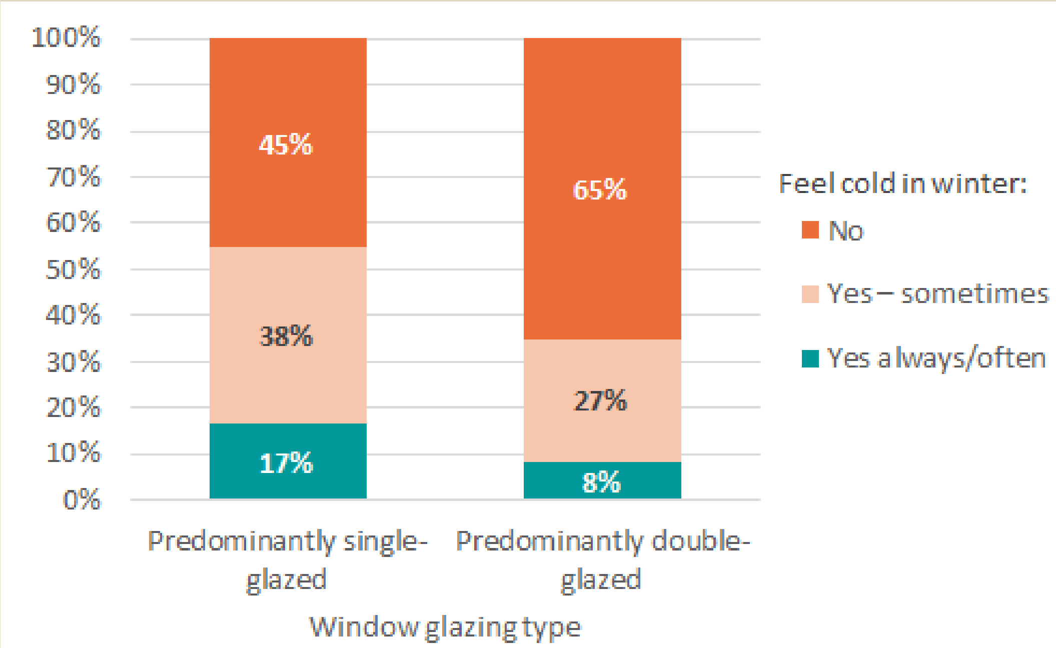

Figure 16. Predominant level of glazing by feel colder in winter – HEEP2 (Full + Medium).

6. Heating behaviours and attitudes

The HEEP2 householder interview asked about a range of behaviours and attitudes towards energy use and keeping warm in winter. This section draws on a selection of these that relate to the dwelling characteristics and comfort issues described above.

6.1 Heating rooms in winter

85% of households reported heating their main living area every day or most days in winter.

Households were asked in which month they usually started and stopped heating their main living area. Most of the HEEP2 sample reported starting to heat in April (30%) or May (36%) and stopping heating in September (29%) or October (40%).

2 in 5 (41%) reported never heating their bedroom in winter.

The survey also asked how often they heated the main living area, their own bedroom, other occupants' bedrooms and any other rooms/areas of the house. The results for the main living area and respondent's bedroom are shown in Figure 17.

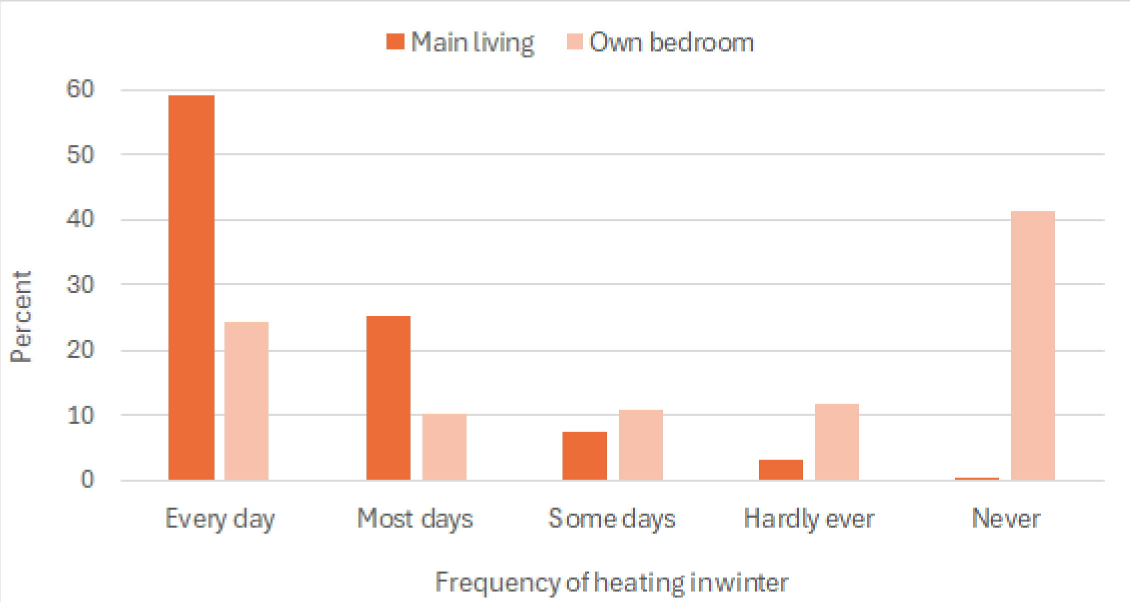

Figure 17. Frequency of heating main living areas and respondent's bedroom in winter – HEEP2 (Full + Medium).

This shows around 3 in 5 households reported heating their main living area every day in winter, with a further 25% saying they heated it most days. These results are consistent with those from the 2018 GSS, which found that 59% of owner-occupied households reported heating their main living area every night in winter and 24% heated most nights (Stats NZ, 2019). Heat pumps were the most common form of heating used in living areas, used by over 3 in 5 households (62%), followed by wood burners (25%).

In contrast to living room heating practices, only around one-third (34%) of HEEP2 households reported heating their own bedroom every day (24%) or most days (10%), while around 2 in 5 (41%) said they never heat their bedroom. Again, these results are reasonably consistent with the 2018 GSS in which 27% of households reported heating their bedroom every night (17%) or most nights (10%), while 48% reported never heating their bedroom (Stats NZ, 2019).

While portable electric heaters were the most commonly used form of heating in the respondent's bedroom, heat pumps appear a close second. However, further work is needed to differentiate those heating appliances heating the bedroom directly from those the occupant considered as heating flowing from other rooms.

More than half of households reported heating bedrooms occupied by young children every day or most days in winter.

Extending the analysis above to all bedrooms, Figure 18 shows that nearly half (47%) of occupied bedrooms are heated on at least some days in winter (every day, most days or some days), but this is more likely to be the case when the bedroom is used by young children with around 2 in 5 (41%) reporting heating bedrooms with children aged under 5 every day and an additional 14% heating most days. However, just over 30% of young children's bedrooms and 42% of older children's bedrooms were never heated.

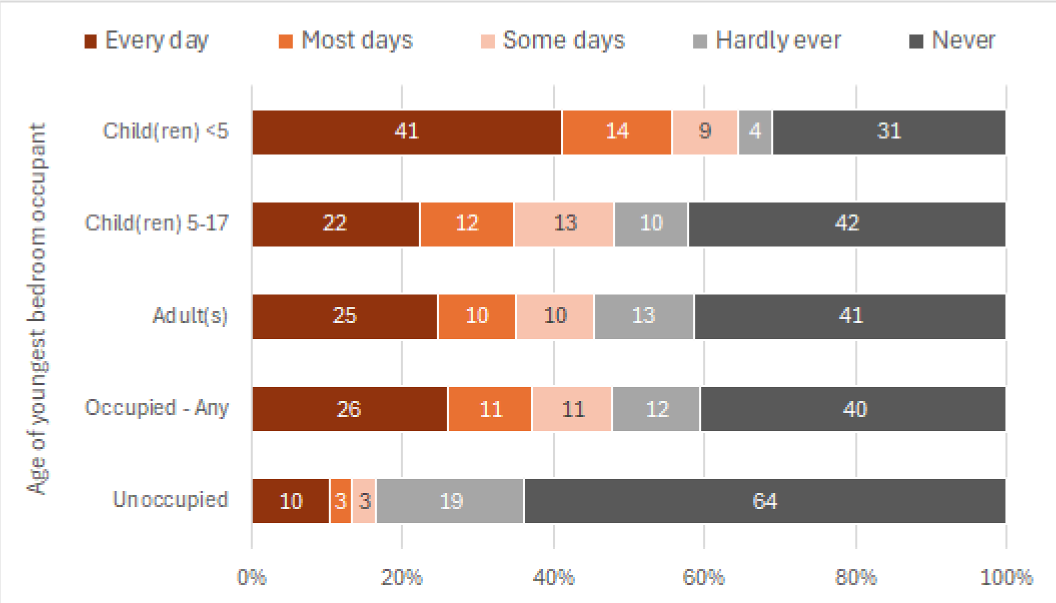

Figure 18. Frequency of heating by age of youngest occupant and overall for occupied/unoccupied bedrooms.

6.2 Attitudes to winter heating, comfort and energy use

6.2.1 Keeping warm

Householders were asked about other things they might do in the home to help keep warm in winter (from a predefined list, with the option of 'other').

The results show closing curtains and using extra blankets/winter duvet were behaviours adopted by over 4 in 5 respondents (Figure 19). Using electric or heated blankets was more common than hot water bottles. Around a quarter of respondents said they had a hot bath or shower to help keep warm.

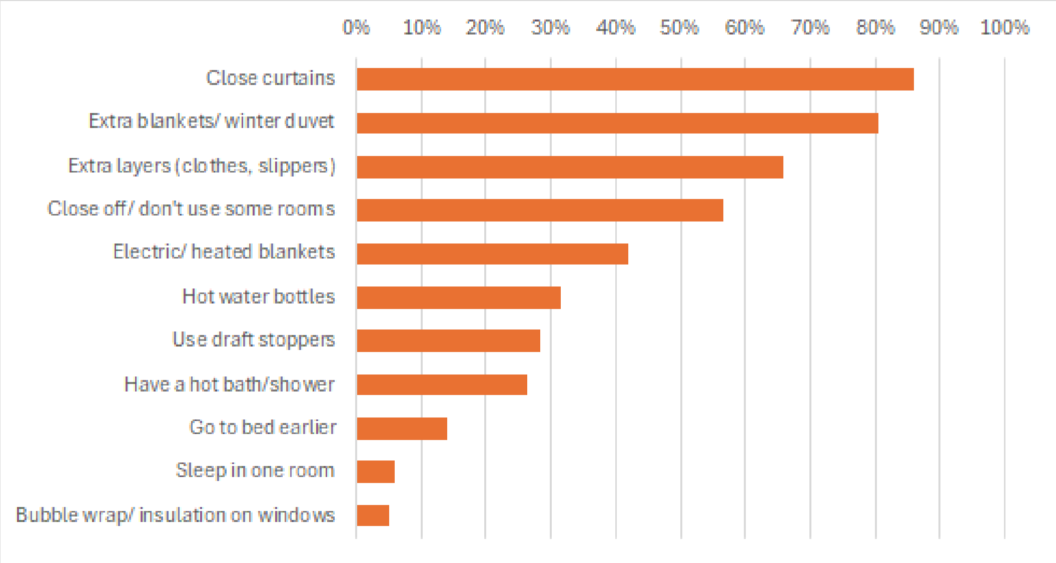

Figure 19. Things HEEP2 respondents do to help keep warm in their home in winter.

6.2.2 Attitudes towards using energy in the home

Householders were asked how important a range of things were to them when thinking about using energy in the home. Figure 20 shows being comfortable was very important (85%) or important (14%) to nearly everyone. Using energy efficiently appeared slightly more important than keeping energy costs low, with 57% and 48% of respondents respectively rating these as very important. Reducing carbon emissions was rated the lowest of the four statements though still very important to 37% of householders.

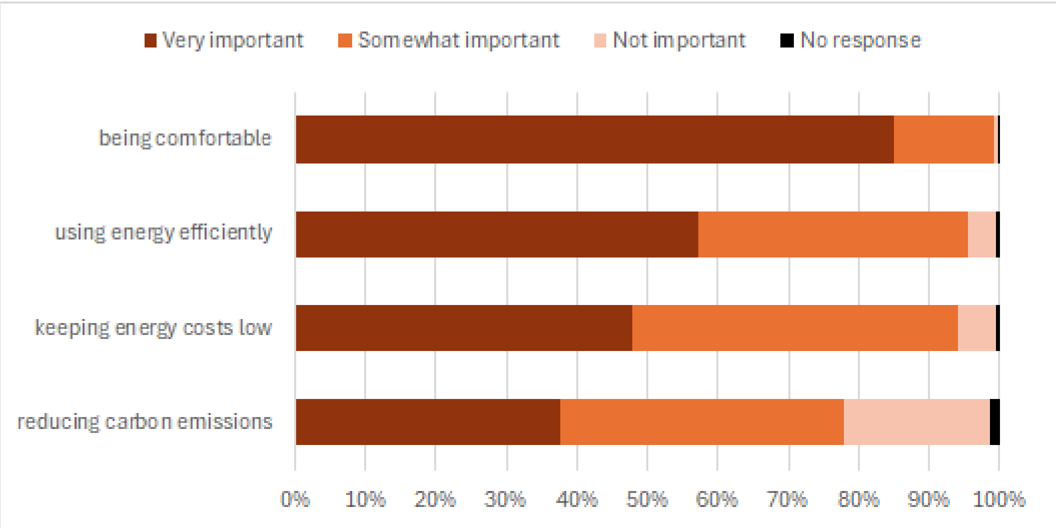

Figure 20. Importance of different factors when using energy in the home.

The HEEP2 survey also asked respondents how strongly they agreed or disagreed with a range of statements related to comfort and energy use in the home. The results show that nearly all householders agreed that their home was a healthy place to live (92% agreed or strongly agreed) (Figure 20). Around 4 in 5 (79%) agreed that they had made changes to help make their home a more comfortable temperature, and 2 in 5 (60%) agreed they had made changes to reduce the amount of energy they use. However, half considered making choices about energy efficiency in the home was complex, and over 2 in 5 (43%) agreed they would like their home warmer in winter.

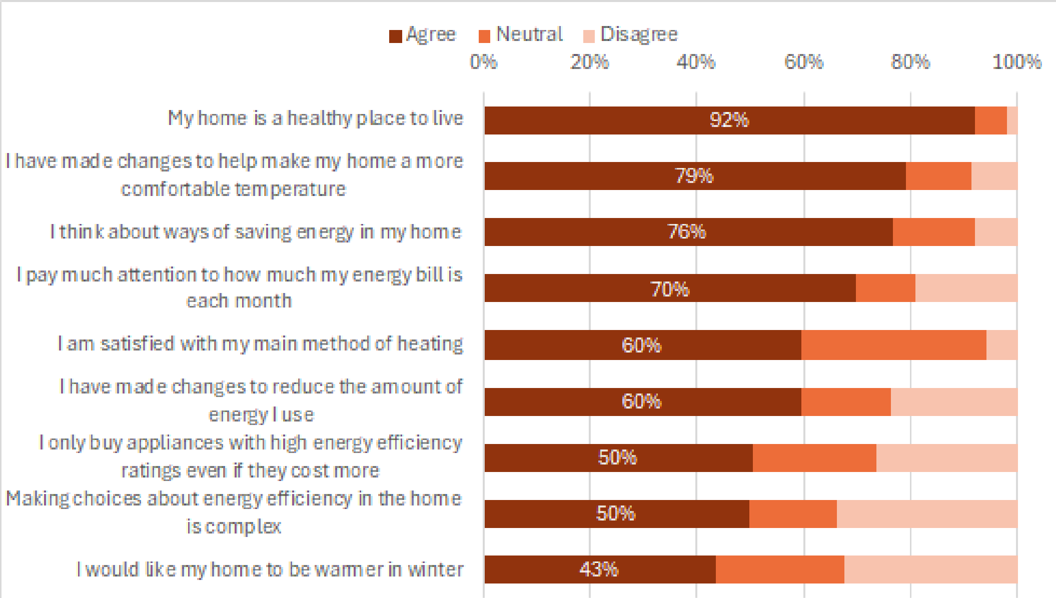

Figure 21. Householder attitudes towards and experience of heating, comfort and energy use.

6.2.3 The Winter Energy Payment

Recognising the cost burden of staying warm during winter, the government introduced the Winter Energy Payment (WEP) as part of its Family Package in 2017 to provide financial assistance to eligible recipients over the winter months. The WEP is a weekly payment of between $20.46 and $31.82 (around $80–$130 a month)[6] paid automatically from 1 May to 1 October to people receiving New Zealand Superannuation, a main benefit or Veteran's Pension (Work and Income, 2024). While designed to help households with the extra cost of heating during the winter months, the payment is not tied to the energy account but is an income top-up.

HEEP2 households were asked if they received the WEP and, if they did, how this affected energy use in the home. A high proportion (44%) received the WEP, likely reflecting the tendency towards older age groups (retirees) in the sample. Of those who did receive it, around 1 in 6 (16%) said this payment did affect how they used energy in winter. Households described heating more, feeling less concerned about turning on the heater and worrying less about being able to pay their energy bill over winter as a result.

[6] Rates in winter 2024.

7. Winter 2023 subsample: preliminary indoor temperature analysis

7.1 The winter 2023 subsample

Of the 423 Full and Medium households that completed the detailed household and building surveys (reported on in the previous section), 145 of the Full sample had temperature monitoring sensors installed before June 2023 and removed after August 2023. The data for these households has been used to analyse indoor conditions over winter 2023 (referred to as the Full winter 2023 sample).

Understanding differences in the characteristics of the various samples (Full, Medium, Full winter 2023 and Full non-winter 2023) is important when considering the extent to which measurements from one may be applicable to and representative of the other and the extent to which monitoring data results may change when the non-winter 2023 sample is included. This section provides some insight into comparability of the difference samples with more detailed tables and analysis provided in Annex I: Full winter 2023 sample description and Annex II: Comparison of sample characteristics.

7.1.1 Characteristics of Full vs Medium samples

A comparison of Full and Medium suggests the samples may differ in these ways:

- Owner-occupiers were slightly more likely to be in the Full sample than the Medium sample (statistically significant at the 10% level: $p=0.051$).
- Homes that were stand-alone with multiple storeys were less likely to be in the Full sample, while attached single-storey houses were more likely ($p<0.05$ in both cases).
- Houses built since 1960 were more likely to be in the Full sample.

For further details, see Annex II: Comparison of sample characteristics.

7.1.2 Characteristics of the winter 2023 sample

Of the 145 households in the winter 2023 sample, 95% were owner-occupied and the household respondent was in full-time work in 50% (similar to the overall sample shown in Figure 7). Their health status was similar to that of the whole sample and there were similar proportions of respondents who reported their home being colder than they would like in winter at least some of the time (see Annex I: Full winter 2023 sample description for data tables).

Further statistical analysis comparing the winter 2023 Full subsample with the wider Full sample (reported in Annex I: Full winter 2023 sample description) indicates that household respondents in the winter 2023 sample were less likely to be aged 35–44 or 65+ and were likely to have been in their house longer compared to the remaining Full sample. They were also less likely to live in deprived areas but were also less likely to have annual household incomes over $150,000. When controlling for other factors, there were no statistically significant differences in terms of house types (such as stand-alone vs townhouse) or floor area.

> The differences between the winter 2023 subsample and the remainder of the Full sample suggest that future analysis using the complete Full monitored sample may produce different results to those reported here.

7.2 Temperature data collection

Internal temperatures were monitored using the Tether EnviroQ[7] in living areas and up to three bedrooms (if present) as well as other spaces where feasible. The sensors were attached to a wall, using 3M Command strips at a height of 1.5 metres above floor level, away from direct sunlight or heat sources.[8] The EnviroQ recorded the rooms' ambient temperature every 15 minutes. Accuracy is specified at ±0.2°C. However, further testing and calibration is being undertaken by BRANZ (see the data health warning below).

Households with continuous temperature monitoring data for the whole of the June–August 2023 period were selected from the pool of 145. For reporting, any temperature sensors with less than 95% of expected observations collected were excluded as were any obvious outliers. Several of these appeared to be due to sensors being placed in direct sunlight or too close to a heating appliance. This left a final pool of 128 houses and 382 monitored spaces of which 105 were living areas and 238 were bedrooms. While the 128 households were distributed across New Zealand, there were fewer than 11 in each region, with the exception of Auckland (37), Wellington (21) and Canterbury (24) – see Annex Table 14.

7.2.1 Data health warning and caveats

Other than the checks and exclusions outlined above, no further data checking has yet been undertaken. The data may therefore include periods when houses were empty and unheated due to holidays or other absences. In addition, the relatively small HEEP2 winter 2023 sample means that unusual heating or temperature patterns in a few households could potentially bias the results. This is especially true where the results are further broken down by region or socio-demographic categories. Finally, as noted above, further work is being undertaken by BRANZ to test the temperature sensor's response function and address data gaps. Hence, all results here are preliminary only.

7.3 Seasonal context

According to NIWA, winter 2023 temperatures in Aotearoa New Zealand were variable, with days in June and July 2023 some of the warmest on record. However, this did not continue into August, which recorded below-average temperatures.

> Temperatures were above average (+0.51°C to +1.20°C of average) for western parts of Southland, coastal Otago, eastern and inland parts of southern and central Canterbury, Nelson, Tasman, and coastal Hawke's Bay. Temperatures were generally near average (±0.50°C of average) for the remainder of the country. (NIWA, 2023)

Overall, the average temperature in winter 2023 was 9.2°C. This was 0.6°C above the 1991–2020 average and meant that winter 2023 was the fifth warmest on record.

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[7] The EnviroQ (https://www.tetherhq.com/enviroq) records temperature, relative humidity (RH), carbon dioxide (CO_2), atmospheric pressure and light intensity at 15-minute intervals. The sound measurement functionality was disabled in all HEEP2 devices. Temperature is measured in °C, with a range of -20°C to 54°C, and a specified accuracy of ±0.2°C.

[8] The practicalities of real-world fieldwork, house configurations and householder preferences meant this was not always perfectly achieved. Data quality checks in parallel with reviewing photos of installation placement are being implemented to assess potential impacts on readings.

7.4 Trends in internal temperatures over time

The HEEP1 study compared its results for 2001–2004 mean temperatures in living areas with those from a New Zealand Department of Statistics study from August and September 1971–1972 (Isaacs et al., 2010; Pollard, 2018; Department of Statistics, 1976). This study collected data from four regions defined as Northern and Southern North Island, Christchurch and Southern South Island.

Figure 22 allocates the winter 2023 HEEP2 households to the same regions and compares mean living room temperatures with both the HEEP1 and earlier study results.

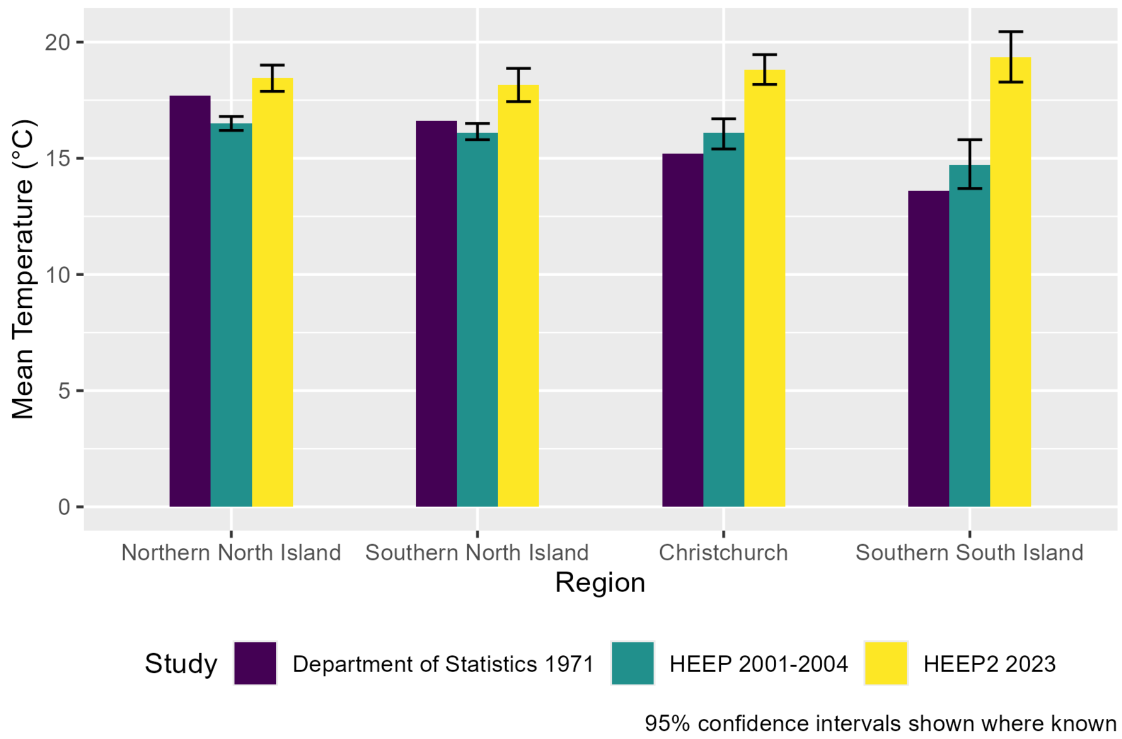

Figure 22. Mean temperature in living rooms/living areas (°C, August–September).

As Figure 22 shows, 50 years after the Department of Statistics study, mean temperatures in living areas for the HEEP2 winter 2023 sample were higher across all regions. This is especially notable for Christchurch and the Southern South Island, which reverses the regional trend found in the HEEP1 2002–2004 and earlier data.

However, **these results are based on very small sample sizes and should be viewed with extreme caution** (Christchurch = 18 houses with living areas monitored and Southern South Island = 10 houses in this period – see Annex Table 14). The behaviours and/or dwelling characteristics of a few houses in these samples could be driving the results seen here.

The HEEP1 study also reported winter (June–August) temperatures by time of day for living areas and bedrooms for 2001–2004. Table 2 compares these to the preliminary winter 2023 HEEP2 sample results for the same months. Overall, mean temperatures in the winter 2023 HEEP2 sample were 12–23% higher than their equivalents in HEEP1, with living areas now exceeding a mean of 18°C during the daytime and evening periods (at 18.4°C and 19.9°C respectively).

Table 2. Comparison of mean internal room and external[9] temperatures (°C) by time period – HEEP1 (winters 2001–2004) vs HEEP2 (preliminary winter 2023 sample).

	Room	HEEP1 (°C)	HEEP2 (°C)	°C (%) difference	HEEP1 internal - external (°C)	HEEP2 internal - external (°C)
Morning 07:00–9:00	Bedroom	12.6	15.2	2.6 (21%)	4.8	7.6
	Living area	13.5	16.6	3.1 (23%)	5.7	9.0
	External	*7.8*	*7.6*	*-0.2 (-2%)*		
Day 09:00–17:00	Bedroom	14.2	16.7	2.5 (18%)	6.4	9.1
	Living area	15.8	18.4	2.6 (16%)	8.0	10.8
	External	*12.0*	*12.2*	*0.2 (1%)*		
Evening 17:00–23:00	Bedroom	15.0	17.4	2.4 (16%)	7.2	9.8
	Living area	17.8	19.9	2.1 (12%)	10.0	12.3
	External	*9.4*	*9.7*	*0.3 (3%)*		
Night 23:00–07:00	Bedroom	13.6	16.1	2.5 (18%)	5.8	8.5
	Living area	14.8	17.1	2.3 (16%)	7.0	9.5
	External	*7.6*	*7.7*	*0.1 (2%)*	*5.7*	*9.0*

Although the mean bedroom temperature during the main sleeping period (23:00–07:00) in the winter 2023 HEEP2 sample (16.1°C) was 2.5°C higher than reported for HEEP1 (and 8.5°C above external), this was still around 2°C below the 18°C threshold recommended by the World Health Organization (WHO) (2018).

While night-time mean temperatures in bedrooms appear warmer in the preliminary HEEP2 winter 2023 sample than in HEEP1 (2001–04), they remain below the minimum recommended healthy threshold.

Table 2 also shows that mornings are still the coldest time of day for each room type but that the differences between the HEEP1 and HEEP2 mean temperatures are also higher for the morning, whether for bedroom (2.6°C) or living area (3.1°C). In addition, the differences were also larger in this period (0.5°C compared to 0.1–0.3°C for the other periods).

This suggests that, while bedrooms are still being allowed to cool overnight, living areas may now be heated to at least close to comfortable temperatures in the morning period.

As we would expect given the overall winter 2023 summary above, the 20-year difference in the mean external temperatures is relatively small. The differences between mean internal and external temperatures for the HEEP2 winter 2023 sample are therefore substantially larger than was the case in 2001–2004. This could indicate the effects of additional insulation, double glazing and improved heating methods. For example, the HEEP1 study reported that most households did not heat bedrooms overnight but the HEEP2 survey results suggest that nearly half of occupied bedrooms are now heated at least some of the time (Figure 18), with more than 50% of young children's bedrooms being heated every day. There has also been a significant shift to heating with heat pumps since HEEP1 was undertaken. Only four households (1%) had a heat pump in the HEEP1 sample compared to over 62% in the HEEP2 sample (overall and for the winter 2023 subset) potentially enabling relatively rapid heating in morning periods.

[9] HEEP1 and HEEP2 mean temperature by time period for the winter period(s) across the NIWA stations closest to the selected houses.

7.5 Living room and occupied bedroom temperatures by times of the day

Table 3 deepens the analysis above by reporting mean and median temperatures for living areas and occupied[10] bedrooms at different times of the day together with the 25th and 75th percentiles and the minimum and maximum values observed in the period.[11]

Given the exclusion of unoccupied bedrooms, the mean values for bedrooms are likely to be slightly higher than those reported in Table 2.

Table 3 shows median and mean living area temperatures during the day and evening were between 18°C and 20°C. A quarter of observations were below 16°C during the day, represented by the 25th percentile (p25) in the table.

Living areas averaged around 20°C in the evening.

In contrast, occupied bedrooms are still consistently colder, with median and mean temperatures in bedrooms at night for this sample being 16.4°C and 16.5°C respectively. The 25th percentile shows that a quarter of the observations in bedrooms at night were less than 14.5°C, and the minimum observed reading was only just above 4°C.

A quarter of observations in bedrooms at night were below 14.5°C.

Table 3. Temperatures in living areas and occupied bedrooms by period of the day (HEEP2 winter 2023 sample).

Room	Period	No. of houses	No. of rooms	Min.	p25	Median	Mean	p75	Max.
Bedroom	Morning 07:00–09:00	107	177	4.9	13.7	15.5	15.58	17.4	30.0
Bedroom	Day 09:00–17:00	107	177	4.5	15.1	16.9	16.93	18.8	32.8
Bedroom	Evening 17:00– 23:00	107	177	4.0	16.0	17.8	17.72	19.5	31.6
Bedroom	Night 23:00– 07:00	107	177	4.1	14.5	16.4	16.48	18.3	29.7
Living area	Morning 07:00–09:00	100	105	6.2	14.2	16.4	16.62	18.9	28.5
Living area	Day 09:00–17:00	100	105	6.3	16.2	18.4	18.41	20.6	29.6
Living area	Evening 17:00– 23:00	100	105	8.0	17.9	20.1	19.91	22.1	29.0
Living area	Night 23:00–07:00	100	105	6.5	15.0	17.0	17.11	19.1	28.7

Note: Data is not available for a small number of houses. Incomplete survey data meant it was not possible to determine which bedrooms were occupied in some cases. A small number did not have the main living areas monitored and some rooms' devices were filtered out during data cleaning.

To give more insight into temperature fluctuations, half-hourly median temperatures by room type are shown in Figure 23. The 25th and 75th percentiles are also shown, along with three health-related thresholds based on the literature:

[10] As reported by the survey respondent.
[11] Noting that extremely low/high values have been excluded as described above.

- 18°C –World Health Organization (2018) recommended lower limit for a healthy home.
- 16°C – threshold at which resistance to respiratory infections may be diminished (Collins, 1986; Raw et al., 2001).
- 12°C – threshold below which cold extremities and slight lowering of core temperature can induce short-term increases in blood pressure (Collins, 1986; Raw et al., 2001).

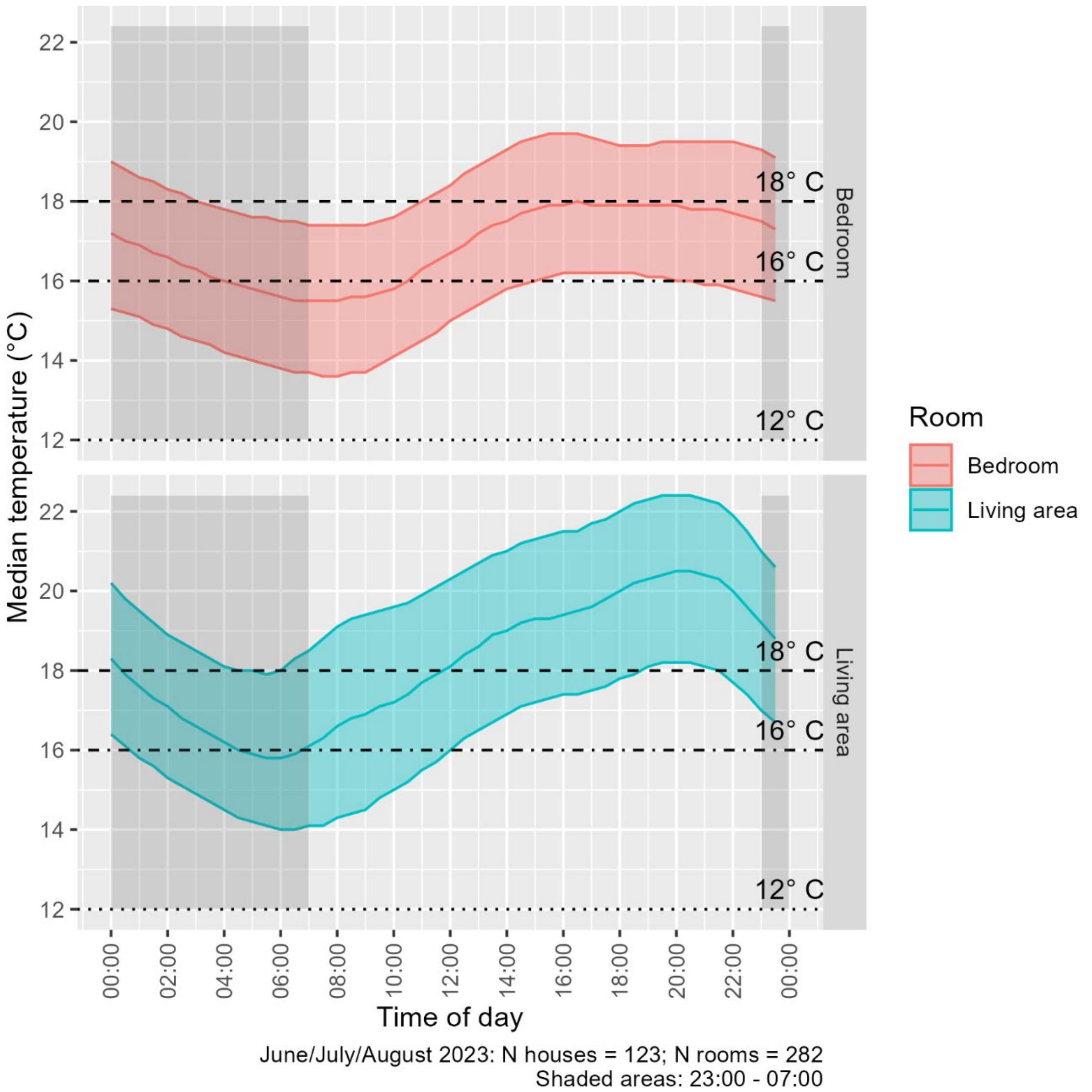

Figure 23. Median half-hourly temperatures in occupied bedrooms and living areas for the HEEP2 winter 2023 sample. Ribbons show the 25th and 75th percentiles. Healthy temperature of 18°C with 16°C and 12°C thresholds shown.

Figure 23 shows that the median temperature in living areas in this preliminary sample exceeded 18°C from 12:00 to past midnight. Occupied bedrooms were colder, with the median bedroom temperature in the sample occupied bedrooms falling from just below 18°C in the early evening to below 16°C by 07:00. The 25th percentile line indicates that 25% of occupied bedroom observations in this preliminary sample were below 14°C by this time (7am).

Two-thirds of the households in this preliminary sample experienced night-time temperatures in bedrooms of below 12°C.

More detailed analysis (Table 4) shows that 43% of the observations in occupied bedrooms were below 16°C during the night-time and 6% were below 12°C. This translates into 96% and 67% of households in this small preliminary sample experiencing occupied bedroom temperatures of below 16°C and 12°C respectively at least once during the night during winter 2023 (see Annex Table 19).

Table 4. Percentage of observations below 18°C, 16°C and 12°C for occupied bedrooms (HEEP2 winter 2023 sample).

	Morning 07:00–09:00	Day 09:00–17:00	Evening 17:00–23:00	Night 23:00–07:00
<18°C	80.6	64.3	51.5	70.9
<16°C	55.5	35.7	23.9	43.2
<12°C	10.4	4.2	2.2	6.0

7.6 Differences by household income

Figure 24 shows mean half-hourly temperatures by income group for living areas and occupied bedrooms together with estimated 90% confidence intervals that indicate the considerable uncertainty due to the small sample size (see Annex Table 20).

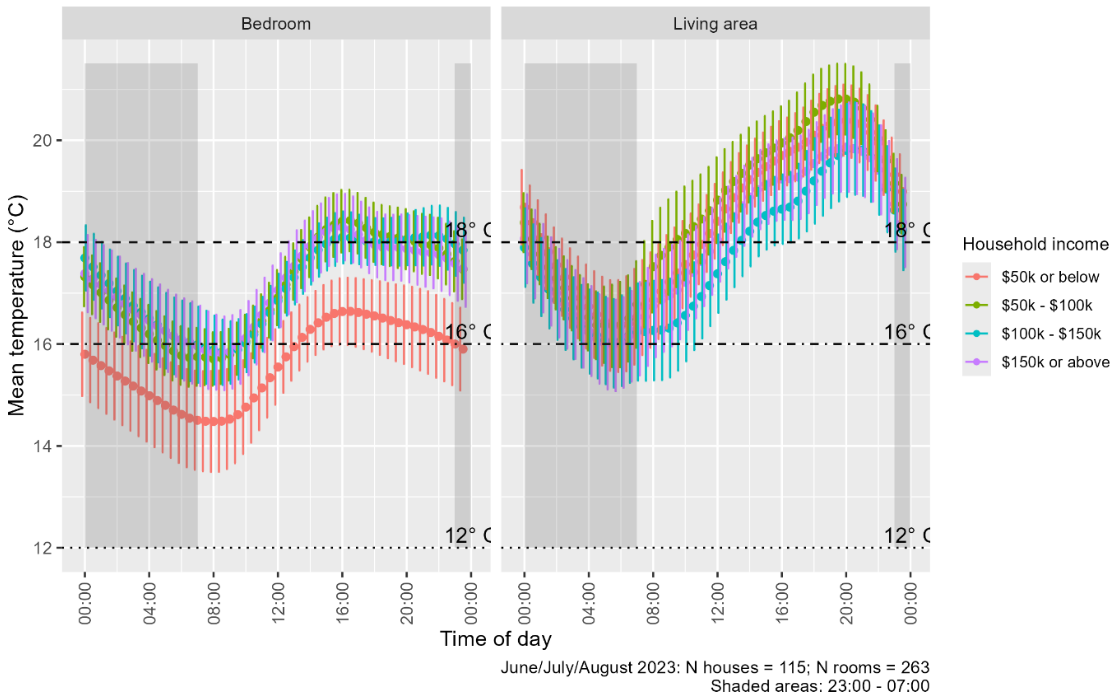

Figure 24. Mean half-hourly temperature in living areas and occupied bedrooms by household income group (N households: <$50k p/a = 23; $50k–$100k = 25; $100k–$150k = 27; >$150k = 29; error bars represent 90% confidence intervals).

The plot suggests a tendency for occupied bedrooms to be substantially colder at all times of day in the lowest income group in this sample. For those with annual household incomes below $50,000, the mean bedroom temperature remained below 16°C for the entirety of the sleeping period and never reached 18°C, even during the day. Of particular concern, 70% of the winter 2023 respondents in the under $50,000 income group are aged 65 years and over, and 82% are not in the labour force. This suggests older, retired

Early indications from HEEP2 data suggest households in the lowest income group may experience bedroom temperatures significantly lower than other income groups.

respondents in the HEEP2 winter 2023 sample were experiencing much lower bedroom temperatures. Older people are more at risk to adverse health impacts of low indoor temperatures such that the recommended healthy minimum is 20–22°C.

Mean temperatures in living areas do not show the same income-related pattern with little difference between the income groups although there was some indication that those in the $100,000–$150,000 income group had lower mean temperatures between 09:00 and 20:00. However, the extent to which the confidence intervals overlap suggests that this difference may not be robust.

7.7 Differences by age of dwelling

Figure 25 repeats the previous plot but shows the mean half-hourly temperatures by the grouped build year of the house. These groups were defined to correspond to the changes in the Building Code requirements for increased insulation levels in roofs and walls described in section 4.3.

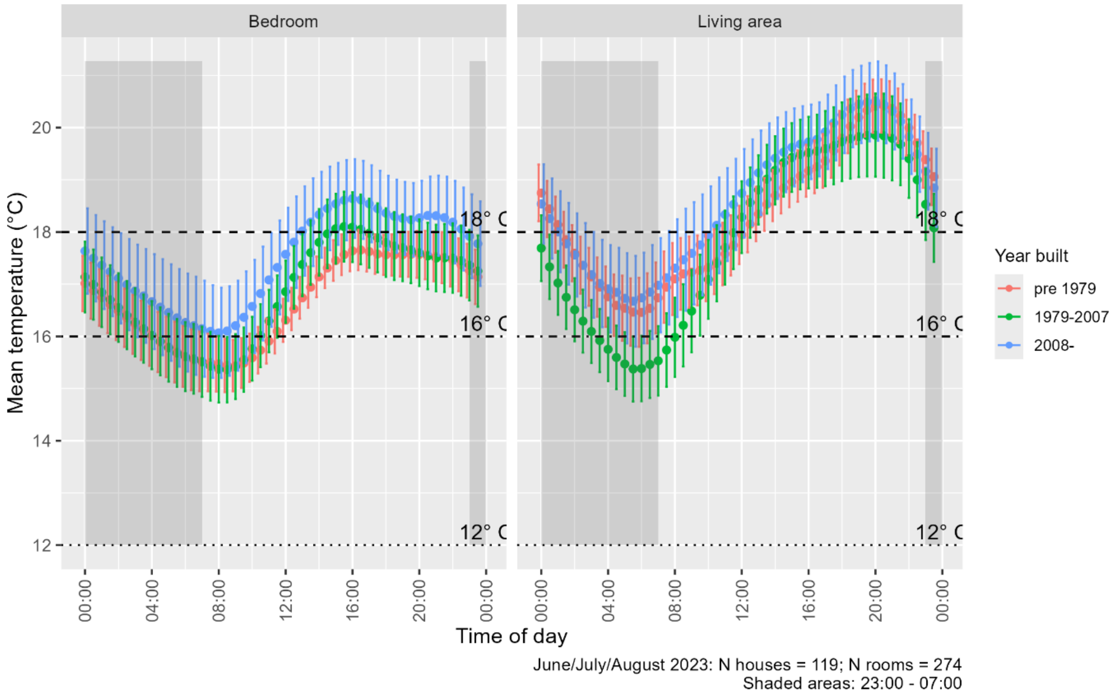

Figure 25. Mean half-hourly temperatures in living areas and occupied bedrooms by year of construction (N households: 57 (pre-1979); 39 (1979–2007); 22 (2008–); error bars represent 90% confidence intervals).

Early indications from the HEEP2 data suggest houses built post-2007 may have higher temperatures in bedrooms.

If we assume these build year groupings are a reasonable proxy for insulation levels,[12] the plot suggests that the changes to insulation requirements may be associated with higher mean temperatures, although the confidence intervals indicate considerable uncertainty (see Annex Table 21 for subgroup household and room counts). The difference between houses built since 2008 and the others is noticeable in bedrooms at night, which we know are less likely to be heated. This is not the case in living rooms during the day, which are more likely to be heated and where the means are difficult to distinguish. In both cases, however, there appears to be less

[12] This does not capture improvements to the home since this date such as additional wall and especially roof insulation. More detailed analysis of surveyed insulation levels will be included in future reports.

overnight heat loss so that bedrooms in more insulated homes do not cool as much as may have historically been the case, while living areas require less morning heat to be comfortable.

7.8 Differences by daytime occupancy

Preliminary results suggest households with someone usually at home during the day are warmer than those usually unoccupied in the daytime.

It is likely that daytime occupancy will lead to greater daytime heating demand in winter to maintain comfortable living area temperatures during the hours someone is at home. Figure 26 indicates this might be the case. The mean temperatures in living areas where at least one person is usually at home on weekdays are notably higher than in houses where this is not the case. Analysis of the survey data for the winter 2023 sample used in Figure 26 suggests that households where someone is usually at home all day on weekdays are more likely to be in lower household income groups (75% of the <$50,000/year group) and have older respondents (72% of homes where the respondent was 65–74 and 95% of those where the respondent was 75+). Correspondingly, 70% of these households heated their living areas in the morning (compared to 51% who did not report all-day occupancy) and 36% heated their living rooms in the afternoon (compared to 25%).

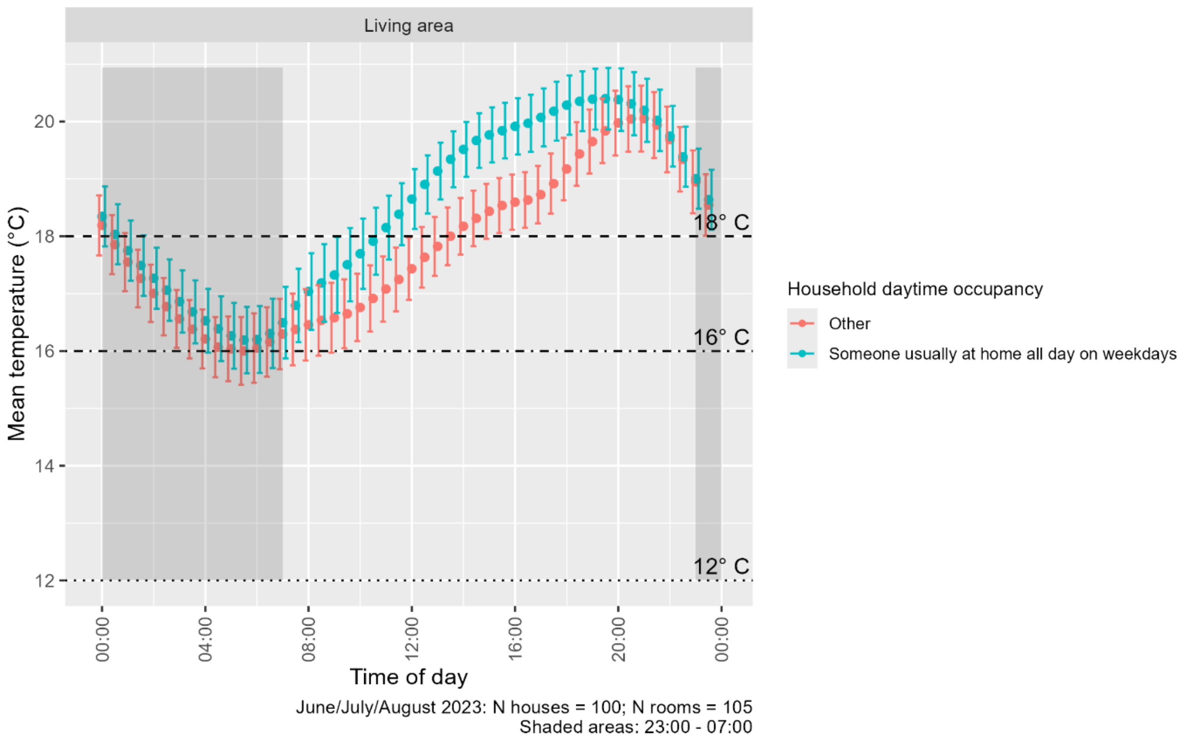

Figure *26*. Mean half-hourly temperatures in living areas on weekdays by reported daytime occupancy (N households: 42 (other); 58 (someone usually at home); error bars represent 90% confidence intervals).

7.9 Differences by frequency of heating

Following on from the discussion of daytime occupancy, unsurprisingly, the frequency of heating particular rooms makes a difference to internal temperatures observed in occupied bedrooms and especially in living areas (Figure 27). Households that report heating living rooms everyday experience notably higher temperatures in the daytime and evening periods. This is also true for those who heat bedrooms every day. The survey results reported above suggest that this could be related to the age of occupants (see Figure 17 and Figure 18).

Due to the small number of households in the winter 2023 sample that reported heating living areas only on some days (9) and even fewer reported hardly ever (5), the width of the confidence intervals for these groups is large (see Annex Table 22).

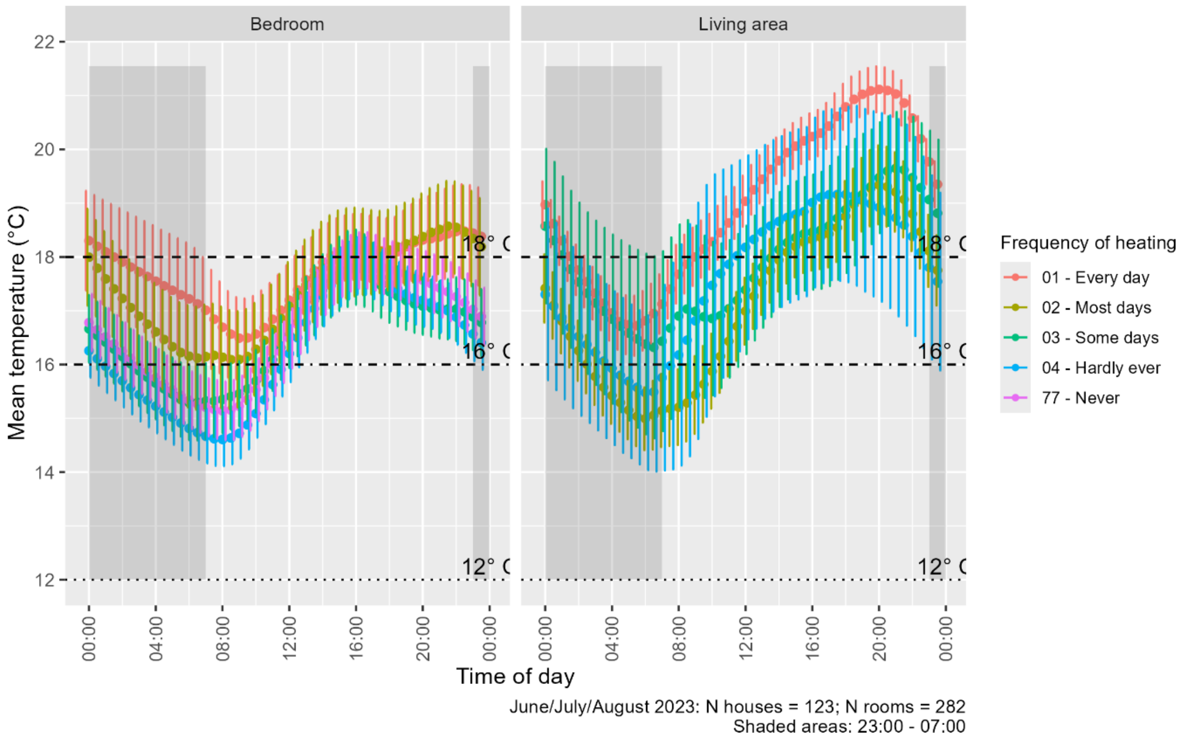

Figure 27. Mean half-hourly temperatures in living areas and occupied bedrooms by frequency of heating the specific room (error bars represent 90% confidence intervals).

7.10 Occupied bedrooms – the influence of occupant/sleeper age group

Figure 28 shows the mean half-hourly temperature in the bedroom by the age of the youngest occupant of that bedroom.[13] Despite the small sample size (see Annex Table 20), the graph shows evidence that bedrooms occupied by younger children in this sample are warmer. Mean temperatures in these rooms never fell below 16°C and there was a noticeable increase in mean temperature from 19:00 to 23:00 indicative of heating (see also Figure 27).

Preliminary results suggest bedrooms occupied by young children are warmer than bedrooms occupied by adults or older children.

This result is not surprising given that the bedrooms of young children in this sample were much more likely to be heated every or most days in winter (55%) compared to those used by children aged 5–17 (34%) and adults (Figure 18). Just over 42% of the bedrooms occupied by the 5–17 age group were never heated compared to 31% of those occupied by children aged under 5 and 41% for adults.

[13] Five cases where younger children shared with adults or older children are included in the aged <5 category.

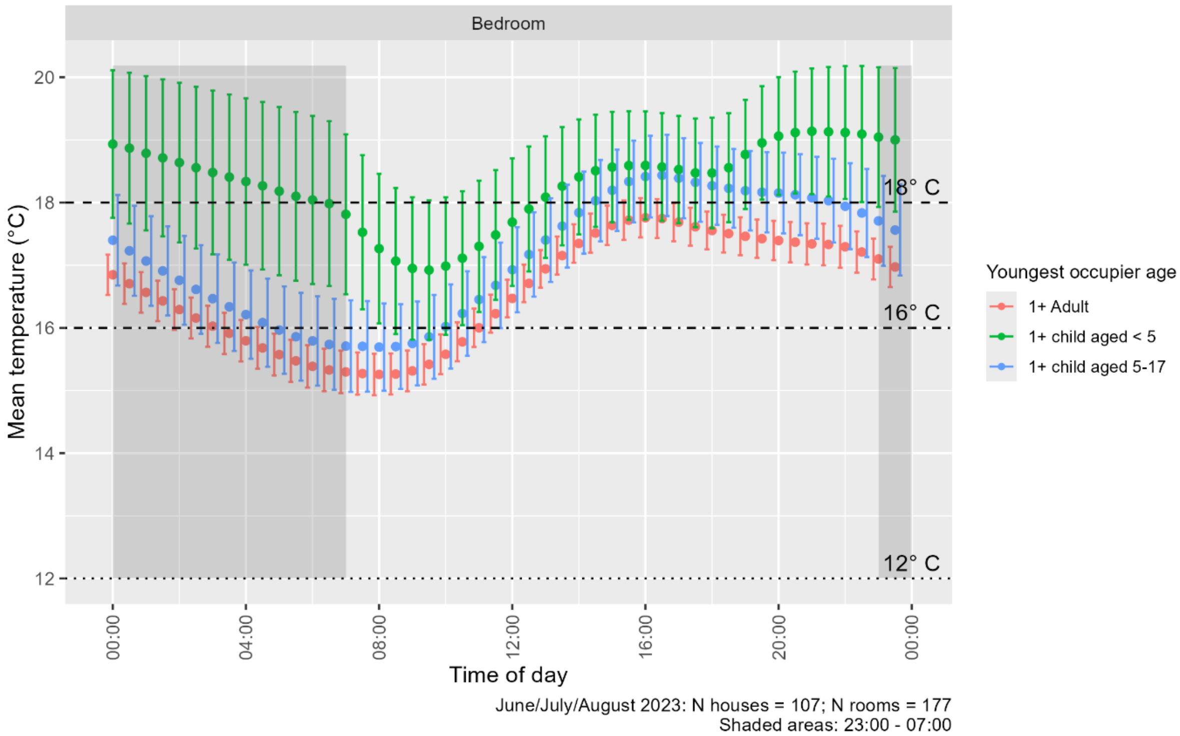

Figure 28. Mean half-hourly temperatures in occupied bedrooms by age of youngest occupier (number of rooms/households: 123/102 (1+ adult), 18/16 (1+ child aged <5), 35/25 (1+ child aged 5–17); error bars represent 90% confidence intervals).

7.11 Which factors are more strongly associated with room temperatures?

This section reports the results of two simple linear regression models that combine the factors explored in the preceding sections and assess their association with daily mean temperatures in living areas and occupied bedrooms (see Annex IV: Temperature multivariate regression models for further details). The core analysis factors (covariates) are:

- household income group
- frequency of heating the room in winter
- age of dwelling defined by insulation requirement changes (see above)
- region – as an imperfect proxy for climate zone to control for different external conditions.[14]

These models are intended to inform the interpretation of the descriptive analysis provided above by estimating the size of the statistical effect of each factor while controlling for the others.

It should be noted that the effects reported are statistical correlations and should not be treated as causal. In addition, the sample size is small, which is likely to result in large confidence intervals and thus considerable uncertainty. The results should therefore be viewed with caution.

[14] Future work will use the external temperature data from the nearest NIWA weather station to more robustly control for locally experienced external temperatures.

7.11.1 Living areas – weekday evenings 17:00–23:00

This model was estimated for the 17:00–23:00 period on weekdays, a time period when most occupants are expected to be at home and active (not sleeping/in bed). Table 5 shows the average marginal effects for each factor of interest while the full results are reported in Annex Table 24. Average marginal effects can be interpreted as the average net effect of each factor on the mean temperature – controlling for the effect of all other factors in the model. The 95% confidence intervals (CI) indicate the uncertainty of the estimated effect and can be used to provide more information than the p value alone. The marginal effects results show the following:

- Unsurprisingly, not heating every day tended to be associated with substantially lower evening living room temperatures (~2°C lower). The result was statistically significant at the 95% level ($p<0.05$) for those who heated most days and at the 90% level for those who heated some days. The 95% confidence intervals suggest the result would most likely hold true for hardly ever with a larger sample size.
- Houses built after 2007 had higher mean evening living room temperatures (~0.8°C higher) than those built before 1979 but the difference was not statistically significant at the 90% level ($p=0.18$, 95% CI: -0.377–2.019)
- No statistically significant effects for income or region (not shown in Table 5).

Table 5. Average marginal effects for full multivariate regression model – factors associated with mean weekday evening living area temperatures in winter (n rooms = 104).

	Factor	Average marginal effect	p	95% CI (lower)	95% CI (upper)
Living room heating frequency (every day)[15]	Most days	-1.854	0.002	-3.019	-0.689
	Some days	-1.700	0.066	-3.513	0.114
	Hardly ever	-2.170	0.072	-4.530	0.190
Annual household income (<$50,000)	$50k–$100k	0.478	0.557	-1.118	2.074
	$100k–$150k	-0.522	0.487	-1.993	0.949
	$150k or above	-0.520	0.515	-2.084	1.044
	Refused, not stated or prefer not to say	-0.363	0.696	-2.179	1.454
Year built (pre-1979)	1979–2007	-0.056	0.911	-1.046	0.934
	2008 onwards	0.821	0.179	-0.377	2.019

The goodness of fit for this model is relatively poor with 17% of variance explained (see Annex Table 24). Future work with the complete sample will look to extend the model to account for a wider range of explanatory factors and would be expected to reduce the uncertainty of the effect sizes.

7.11.2 Occupied bedrooms – all days 23:00–07:00

This model was estimated for the 23:00–07:00 period and for all days of the week. Given the results shown in Figure 28, it includes an indicator of the age of the youngest bedroom occupant. Since the frequency of heating a bedroom appears to be related to the presence of young children, an interaction between these two factors was included in the model. This is likely to suppress the size of the net effect of each of the factors.

[15] No respondents said they never heated their living area in winter so this does not appear in the model.

Table 6 shows the marginal effects for the model while full model results are reported in Annex Table 25.

Table 6. Average marginal effects for full multivariate regression model assessing factors associated with mean overnight occupied bedroom temperatures in winter (n rooms = 176).

Factor (contrast)		Average marginal effect	p	95% CI (lower)	95% CI (upper)
Age of youngest occupier (adult)	1+ child aged <5	1.597	0.016	0.301	2.893
	1+ child aged 6–17	0.276	0.495	-0.516	1.067
Bedroom heating frequency (every day)	Most days	-0.484	0.436	-1.703	0.734
	Some days	-1.538	0.024	-2.875	-0.201
	Hardly ever	-2.192	0.000	-3.388	-0.995
	Never	-1.322	0.027	-2.493	-0.151
Household income (<$50,000)	$50k–$100k	1.252	0.030	0.124	2.381
	$100k–$150k	1.323	0.027	0.154	2.491
	$150k or above	0.816	0.181	-0.380	2.012
	Refused, not stated or prefer not to say	0.545	0.515	-1.097	2.186
Year built range (pre-1979)	1979–2007	0.223	0.621	-0.662	1.109
	2008 onwards	0.936	0.051	-0.006	1.878
Region (Auckland)	Northland	1.239	0.056	-0.031	2.509
	Bay of Plenty	-1.592	0.049	-3.175	-0.008
	Waikato	-0.029	0.962	-1.239	1.181
	Hawke's Bay	-0.704	0.258	-1.923	0.516
	Taranaki	-0.521	0.498	-2.029	0.986
	Manawatū-Whanganui	0.013	0.989	-1.938	1.965
	Wellington	-1.155	0.024	-2.155	-0.155
	Canterbury	-1.243	0.013	-2.218	-0.267
	Otago	-1.372	0.123	-3.114	0.370

As in the living area model, the marginal effects can be interpreted as the average net effect of each factor on the mean daily overnight temperature – controlling for the effect of all other factors in the model. The results suggest the following:

- Bedrooms occupied by children aged under 5 were on average ~1.6°C warmer (95% CI: 0.301–2.893) than those occupied only by adults. There was no such effect for older children.
- As with living areas, heating the bedroom on some days, hardly ever or never was associated with lower temperatures (~1.5–2°C lower) compared to heating every day. It should be noted that some bedrooms may obtain heat from daytime solar gain or via airflow from other spaces that are heated.
- The income differences observed in Figure 24 remained even when the other factors were controlled. Overnight bedroom temperatures in households with annual incomes between $50,000 and $100,000 were on average ~1.3°C higher than those in the lowest income group and this was also true for the $100,000–$150,000 group.
- Bedrooms in houses built since 2007 were on average ~1°C warmer than those built before 1979 and this was statistically significant at the 90% level (p=0.051, 95% CI: -0.006–1.878).

- When controlling for other factors, bedrooms in the HEEP2 winter 2023 sample in Bay of Plenty, Wellington and Canterbury were substantially colder compared to Auckland. The marginal effects for other regions tend to follow the expected geographic distribution but it should be noted that the (very) small sample sizes for regions other than Auckland, Wellington and Canterbury mean these results should be viewed with caution (see Annex Table 14).

The goodness of fit for this model is reasonable, with 25% of variance explained.

As with the living room model, these results are largely to be expected and echo the descriptive analysis presented in earlier sections of this report. The strong effect for younger children suggests that their bedrooms are being heated, while the effect for income groups reinforces the indication that households in the lowest income group in this sample are exposed to lower bedroom temperatures. However, the extent to which this is due to a lack of financial resources, a lack of suitable appliances, poorer-performing housing or normative conceptions of whether or not to heat bedrooms is currently unclear.

8. Discussion

This report presents the first substantive results from the second BRANZ Household Energy End-use Project (HEEP2) with a focus on winter heating and observed internal temperatures in living areas and occupied bedrooms.

The report shows that the 423 HEEP2 Medium and Full homes that underwent detailed in-home household, building and appliance surveys are predominantly owner-occupied. Their distribution across regions matches the national private dwelling distribution with the exception of two regions (Gisborne and Tasman) where fieldwork faced distinct difficulties. HEEP2 household respondents tend to be slightly older than the national population and this is also the case when we consider all household occupants, with a slightly higher proportion aged over 65 and a slightly lower proportion aged 18–64, potentially reflecting the lack of renters in the sample. Despite this, the employment status of respondents is similar to the national population with 50% in full-time work, although, reflecting the age distribution of respondents, slightly more are not in the labour force (retired). However, there are differences between this HEEP2 sample and the national picture for owner-occupiers in terms of overall household income, with the HEEP2 sample having a higher proportion of those earning $100,000–$150,000 a year and especially of those earning $150,000 or more. Perhaps as a partial consequence, HEEP2 respondents were more likely to report being in very good or excellent health.

In terms of dwelling type and size, the HEEP2 Medium and Full homes are consistent with previous housing surveys: 62% are stand-alone single-storey dwellings and 41% have a floor area of 100–150 m². Larger houses (>200 m²) comprise 20% of the sample and while the sample has slightly fewer pre-1920 and post-2000 homes than would be expected, it has slightly more that were built between 1940 and 1979. While 59% had roof space insulation to a depth of 120 mm or more, 17% had less than 70 mm. Aluminium remains the most common window framing material (71%), and with gaps around windows being more common in timber-framed windows, over 25% of homes had gaps with potential for heat loss and draughts. As previous housing surveys have shown, double glazing is becoming more common with 36% of homes in this sample having at least some double glazing. However, 51% are still almost entirely single glazed.

These housing conditions reflect the survey findings on winter comfort with almost half (48%) of respondents saying their home felt colder than they would like at least some of the time in winter, around 1 in 5 saying they could see their breath and 1 in 5 (21%) reporting that their home was cold enough that they shivered at least some time in winter. Respondents generally attributed these experiences to the house not retaining heat (31%) and attempts to keep energy costs down (31%). However, 18% stated that they habitually did not heat, and a similar proportion stated that they had insufficient heating to do so adequately. Those who felt cold were more likely to have gaps around their windows (a potential source of draughts), while those whose homes were predominantly double glazed were much less likely to report feeling cold in winter. Damp (33%), condensation (75%) and mould (48%) were frequently reported. These levels are similar to previous comparable results from national surveys, with the exception of mould, which appears more commonly reported in the HEEP2 sample.

In terms of heating, 85% said they heated their main living area every day or most days in winter, which corresponds to the original HEEP1 finding that 89% heat living rooms on weekday evenings in winter (but only 26% during the day). While 41% of HEEP2 respondents reported never heating their bedroom, this is lower than the original HEEP1 finding of 50% and also lower than the comparable Stats NZ 2018 GSS result (48%). This may be a result of the higher proportion of higher income households in the overall HEEP2 Full sample. More detailed analysis shows that occupied bedrooms are more likely to be heated if the youngest occupant is aged under 5, with 41% reporting these are heated every day in winter compared to under 25% for other age groups. Nevertheless, just over 30% of young children's bedrooms were never heated.

These experiences of damp, mould, draughts and cold might be expected to contribute to expressed attitudes on heating and energy use. As a reflection of the 48% who stated their home was colder than they would like at least some of the time, 44% said they would like their homes to be warmer. Similarly, aligning with the discussion of the main reasons for feeling cold, 70% of respondents said they paid attention to energy bills and 79% reported making some form of change to their home to provide a more comfortable temperature. However, despite the prevalence of feeling cold, of experiencing damp, condensation and mould and of wanting their house to be warmer, 92% of respondents felt their home was a healthy place to live.

Households adopted a range of different practices to help keep warm in their home in winter. A high proportion reported good energy-efficient practices such as closing curtains, using extra blankets, wearing extra clothes and closing off unused rooms. However, practices such as having a hot shower/bath to warm up, which is a less-effective way of using energy to keep warm, were also reported by around a quarter.

These findings illuminate the more detailed analysis of internal living area and occupied bedroom temperatures for a subset of the Full sample homes monitored over winter 2023. These houses differ slightly from the overall Full sample in terms of respondent age (fewer aged 35–44 or 65+) and household income (less likely to be earning over $150,000 a year). Further, the Full sample from which they are drawn has a higher proportion of single-storey joined houses and a higher proportion of those built since 1960 compared to the Medium sample. This means that we should be cautious about generalising these results to all owner-occupier homes.

Compared to the first study of internal temperatures in New Zealand homes in 1971, mean living area temperatures observed in the HEEP2 winter 2023 sample were higher, with an average (mean) temperature of just under 20°C in the evening (17:00–23:00). This is especially notable for Christchurch and the Southern South Island, although the small numbers of households in the initial sample mean these results should be viewed with extreme caution. A large part of this apparent change appears to have taken place over the 20 years since the original HEEP1 (2001–2004), which reported average evening living room temperatures of 16.1°C.

More detailed analysis of this preliminary dataset by time period shows that mean living area temperatures in the HEEP2 winter 2023 sample were 3.1°C (23%) higher in the mornings, 2.6°C (16%) higher during the day and 2.1°C (12%) higher in the evenings compared to the HEEP1 2001–2004 sample. As a result, mean living area temperatures during the day and in the evenings in the HEEP2 sample are above the WHO-recommended 18°C healthy temperature threshold. However, despite these improvements, 25% of living area temperature observations in the HEEP2 winter 2023 sample were still below 16°C.

In contrast, while the mean night-time temperature in bedrooms in the (preliminary) HEEP2 winter 2023 sample was 2.5°C (18%) higher than HEEP1 (16.1°C compared to 13.6°C), bedrooms still appear around 2°C below the WHO 18°C threshold. Indeed, 43% of HEEP2 winter 2023 overnight occupied bedroom observations were below 16°C and 6% were below 12°C. These were sufficiently spread across the sample that 67% of households experience occupied bedroom temperatures of below 12°C at least once.

While mornings remain the coldest time of day for each room type, comparisons of the change in mean temperature for each suggests that, while bedrooms are still being ‘allowed’ to cool overnight, living areas may now be heated to at least closer to comfortable temperatures in the morning period. In both cases, increased insulation levels may be helping reduce overnight heat loss so that the rooms are not cooling as far as was previously the case. As a result, living areas may require less morning heat input to be comfortable while bedrooms do not get as cold.

Further analysis will explore trends over time, once the complete set of monitoring data is available, including looking in more detail at the comparability of the three New Zealand studies – Department of Statistics 1971–1972, HEEP1 2001–2004 and HEEP2 2022–2025.

Descriptive analysis of daytime temperatures in the living areas of the HEEP2 winter 2023 sample showed no clear differences by income group or building age but (unsurprisingly) did show differences by frequency of heating. This was confirmed by statistical analysis that showed mean weekday daytime temperatures in living areas that were not heated every day were on average about 2°C lower. The statistical analysis also suggested that living areas in homes built since 2007 had higher mean weekday daytime temperatures during this period than those built before this. However, there is considerable uncertainty due to the small sample size.

In contrast, there were more distinct differences in temperatures in occupied bedrooms by income group, age of dwelling, frequency of heating and age of occupants. Those in the lowest income group in the winter 2023 sample experienced overnight winter mean temperatures up to 1.3°C lower than those in higher income groups. Given that 70% of this group are aged over 65 and 80% are not in the labour force, this suggests that older retired respondents in the HEEP2 winter 2023 sample were experiencing much lower night-time bedroom temperatures.

Occupied bedrooms in houses built since 2007 were on average 1°C warmer overnight than those built before 1979. Given that bedrooms are still less likely to be heated than living areas, it may be that the insulation requirements associated with these thresholds are playing a role in preventing occupied bedrooms from becoming even colder by early morning.

The analysis does suggest the bedrooms of children aged under 5 in the HEEP2 winter 2023 sample were warmer than bedrooms used by any other age group, with half-hourly temperatures in these rooms never falling below 16°C and an indication of evening heating. These bedrooms were much more likely to be heated than adults’ or older children’s bedrooms and consequently were on average 1.6°C warmer than those occupied only by adults. In contrast, mean overnight temperatures in bedrooms that were not heated every day were unsurprisingly 1.5–2.2°C lower.

9. Conclusions

Overall, the results reported in this initial analysis of HEEP2 data related to winter heating and comfort show considerable consistency with recent comparable studies. The HEEP2 national sample of predominantly owner-occupied homes has similar distributions of dwelling ages, types, glazing and insulation and similar or slightly higher levels of (occupant-reported) damp, condensation and mould. However, respondents are likely to be slightly older, more likely to be in higher income groups and more likely to be in excellent health compared to the general population.

A very high proportion of respondents (92%) considered their home was a healthy place to live, yet nearly half said their home was colder than they would like in winter at least some of the time, a third reported damp and nearly half reported mould. Research and studies in New Zealand and internationally have shown cold, damp, mouldy homes can adversely impact the health and wellbeing of occupants. These apparently conflicting results from the HEEP2 survey therefore raise questions around what people think about when considering if their home is a healthy place to live.

While the findings presented in this report are interim based on only around half the complete HEEP2 dataset, when compared to earlier New Zealand studies, there are indications that internal temperatures in living areas and bedrooms have increased over time (since the first reported results in 1971 and with greater differences over the last 20 years since the original HEEP1 study). Factors driving this change are not clear from the analysis undertaken so far – for example, the extent to which changes are a consequence of higher energy efficiency standards (for new builds and through retrofit), availability of more efficient and effective heating (such as heat pumps) and/or associated increased propensity to heat (shifting norms around heating). Furthermore, while results indicate an improvement, mean and median bedroom temperatures in the HEEP2 winter 2023 sample still remain at or below the World Health Organization’s healthy home thresholds. This could be driven by a combination of habit (41% never heat occupied bedrooms), a lack of financial resources (the lowest income group has notably colder bedrooms), poor heat retention (bedrooms in older houses are generally colder) and lack of heating appliances in bedrooms.

While these preliminary results suggests bedrooms are still below healthy minimum temperatures on average, bedrooms occupied by young children in the HEEP2 winter 2023 sample were more likely to be heated. As a consequence, these rooms were substantially warmer than those occupied by adults or teenagers, even allowing for household income and dwelling age as a proxy for insulation levels.

In conclusion, this report provides early and, in the case of the internal temperature results, preliminary results from the HEEP2 study. The results generally confirm findings from previous comparable studies while also indicating potential change over time in internal temperatures. The results draw attention to the differences between socio-demographic groups, the continued exposure to unhealthy night-time temperatures (for low income households in particular) and the apparent prioritisation of young children’s bedroom temperatures. They also give some indicators of the potential role of improved insulation thresholds and heating appliances in contributing to higher room temperatures, although this requires further research and analysis.

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Annexes

Annex Table 1. Regional distribution of HEEP2 samples.

	Full	Medium	Census dwellings
Auckland	24.8	23.4	29.8
Bay of Plenty	6.6	9.5	6.7
Canterbury	18.5	25.5	13.7
Gisborne			0.9
Hawke’s Bay	2.4	4.4	3.5
Manawatū-Whanganui	7.7	5.8	5.3
Marlborough	1.0	0.0	1.2
Nelson	1.4	1.5	1.1
Northland	2.1	2.9	4.3
Otago	5.9	4.4	5.5
Southland	2.1	0.7	2.3
Taranaki	3.1	3.6	2.6
Tasman			1.3
Waikato	8.4	8.0	10.5
Wellington	14.7	9.5	10.5
West Coast	1.0	0.7	0.9

Annex I: Full winter 2023 sample description

It is important to establish if the homes in the Full (winter 2023) sample were substantively different on key demographic and other dimensions compared to the overall sample from which they are drawn and that was used for the initial survey analysis. If key differences are apparent, results from the winter 2023 sample may not be representative of the overall HEEP2 sample. It is also important to understand the extent to which the winter 2023 sample differs from the remaining Full sample. This will indicate whether the results of future analysis including the whole Full sample are likely to differ.

The following tables suggest that the winter 2023 sample may have minor differences in terms of duration of occupancy, respondent age, whether the house was colder than respondent would like, the dwelling type and the dwelling's floor area.

Annex Table 2. Tenure (column % and column total).[16]

Tenure	Full (winter 2023)	Total
Not owner-occupied	4.8	5.7
Owner-occupied	95.2	94.3
Total number	145	422

Annex Table 3. Length of time lived in current home (column %).

	Full (winter 2023)	Total
Less than 1 year	0.7	3.3
1 to 3 years	15.9	15.6
3 to 5 years	10.3	12.5
5 to 10 years	26.2	25.5
10 years or longer	46.2	42.8

Annex Table 4. Age of interview respondent (column %).

Age band	Full (winter 2023)	Total
02 – 25–34 years	9.7	7.8
03 – 35–44 years	13.1	18.4
04 – 45–54 years	20.7	19.1
05 – 55–64 years	22.8	17.7
06 – 65–74 years	17.9	20.1
07 – 75 years or over	15.2	15.9
66 – Prefer not to say	0.00	0.2
9 – Don't know	0.00	0.2
99 – Not stated	0.7	0.5

Annex Table 5. Work status of respondent (column %).

	Full (winter 2023)	Total
Employed full-time	50	50
Employed part-time	13	14
Unemployed	0	1
Not in labour force	36	34

[16] Column total is the same of all subsequent tables, hence only shown once here.

Annex Table 6. Annual household income group (column %).

	Full (winter 2023)	Total
$50k or below	19.3	19.4
$50k–$100k	24.8	21.0
$100k–$150k	22.8	23.2
$150k or above	25.5	26.2
Refused, not stated or prefer not to say	7.6	10.2

Annex Table 7. Home colder than would like in winter (column %).

	Full (winter 2023 monitoring)	Total
01 – Yes – always	3.4	4.5
02 – Yes – often	4.8	9.5
03 – Yes – sometimes	37.2	33.6
04 – No	53.1	50.8
05 – I have not spent a winter living in this house or flat	0.7	0.9
9 – Don't know	0.0	0.2
99 – Not stated	0.7	0.5

Annex Table 8. Dwelling type (column %).

	Full (winter 2023)	Total
01 Stand-alone house single storey	57.9	62.2
02 Stand-alone house 2 or more storeys	26.9	24.8
03 Attached house single storey	6.2	5.9
04 Attached house 2 or more storeys	4.8	4.3
05 Apartment or flat	4.1	2.8

Annex Table 9. Floor area grouped (column %).

	Full (winter 2023 monitoring)	Total
1 Small <100 m^2	13.1	16.1
2 Medium 100–150 m^2	41.4	40.4
3 Large 151–200 m^2	24.8	22.9
4 Very large >200 m^2	20.0	19.9
Unknown	0.7	0.7

Annex II: Comparison of sample characteristics

The following analysis uses a logistic regression approach to test whether a selection of the factors reported above were associated with being in the:

1. Full sample compared to the Medium sample
2. Full (winter 2023) sample compared to the remaining Full respondents.

In the case of model 1, statistically significant factors would suggest that the Full and Medium samples differ along these dimensions. In the case of model 2, it would suggest that **the results of the internal temperature analysis reported for the winter 2023 sample may change when the complete Full sample is included**.

The factors used in the models were:

- respondent age group (contrast category = 25–34)
- household income group (contrast = <$50k/year)
- house tenure (contrast = not owner-occupied)
- length of time of occupancy of this house (contrast = <1 year)
- house type (contrast = single storey, detached)
- house age (grouped, contrast = built before 1920)
- floor area (grouped, contrast = small <100)
- NZ area level deprivation index quintile (1–5, 5 being most deprived)
- region (contrast category = Auckland).

Full vs Medium sample

Annex Table 10 shows the model results for the first model (Full vs Medium) and Annex Table 11 shows the model performance. Note that many of the confidence intervals are wide, indicating the level of uncertainty around the estimate, most likely due to the small sample size. The results suggest that:

- owner-occupiers were slightly more likely to be in the Full than the Medium sample but the effect is marginal
- homes that were stand-alone with multiple storeys were less likely to be in the Full sample compared to stand-alone single-storey homes while attached single-storey houses were more likely
- houses built since 1960 were more likely to be in the Full sample
- houses in the Canterbury region were less likely to be in the Full sample – this is likely to reflect the high response rates in the Canterbury region (see Figure 4) such that a smaller proportion of the total recruited homes in Canterbury were required for the Full sample and a higher proportion could be used for the Medium sample.

Annex Table 10. Full vs Medium – logistic regression model results.[17]

	term	estimate	std.error	statistic	p.value	conf.low	conf.high
	(Intercept)	-2.526	1.314	-1.922	0.055	-5.188	0.002
Respondent age (25–34)	35–44 years	-0.678	0.537	-1.263	0.207	-1.772	0.348
	45–54 years	-0.419	0.546	-0.767	0.443	-1.523	0.632
	55–64 years	0.119	0.569	0.209	0.834	-1.021	1.223
	65–74 years	-0.134	0.596	-0.225	0.822	-1.329	1.022
	75 years or over	-0.261	0.651	-0.401	0.689	-1.562	1.004

[17] Estimates with extremely large standard errors indicate categories with very small cell counts.

	term	estimate	std.error	statistic	p.value	conf.low	conf.high
Household income (<$50k/yr)	$50k–$100k	0.140	0.416	0.337	0.736	-0.678	0.959
	$100k–$150k	-0.182	0.442	-0.412	0.681	-1.053	0.684
	$150k or above	0.159	0.491	0.324	0.746	-0.811	1.121
	Refused, not stated or prefer not to say	-0.915	0.524	-1.746	0.081	-1.954	0.110
Tenure (not owned)	Owner-occupied	1.204	0.580	2.076	0.038	0.083	2.383
Occupancy duration	1–3 years	1.066	0.766	1.391	0.164	-0.437	2.607
	3–5 years	0.720	0.784	0.919	0.358	-0.819	2.292
	5–10 years	1.092	0.739	1.477	0.140	-0.360	2.580
	10+ years	1.098	0.734	1.496	0.135	-0.348	2.574
House type (stand-alone single storey)	Stand-alone house 2 or more storeys	-0.694	0.320	-2.167	0.030	-1.327	-0.068
	Attached house single storey	2.093	0.910	2.299	0.021	0.525	4.201
	Attached house 2 or more storeys	-0.414	0.624	-0.663	0.507	-1.615	0.865
	Apartment or flat	-0.092	1.197	-0.077	0.939	-2.162	2.972
Year built	1920–1939	0.706	0.814	0.867	0.386	-0.880	2.365
	1940–1959	0.903	0.764	1.181	0.238	-0.584	2.471
	1960–1979	1.731	0.758	2.284	0.022	0.260	3.290
	1980–1999	1.614	0.761	2.121	0.034	0.136	3.179
	2000 onwards	2.435	0.786	3.100	0.002	0.915	4.048
Floor area (grouped: small <100 m²)	2 medium 100–150 m²	0.407	0.399	1.018	0.309	-0.380	1.192
	3 large 151–200 m²	-0.173	0.455	-0.380	0.704	-1.072	0.719
	4 very large >200 m²	0.075	0.508	0.147	0.883	-0.925	1.075
NZ area level dep index (quintiles)		0.012	0.105	0.110	0.912	-0.194	0.218
Region	Bay of Plenty	-0.574	0.503	-1.140	0.254	-1.560	0.424
	Canterbury	-0.850	0.372	-2.287	0.022	-1.587	-0.127
	Hawke's Bay	-0.780	0.675	-1.156	0.247	-2.118	0.563
	Manawatū-Wanganui	0.197	0.553	0.356	0.722	-0.854	1.337
	Marlborough	14.220	761.753	0.019	0.985	-84.596	NA
	Nelson	-0.269	1.230	-0.219	0.827	-2.448	2.826
	Northland	-0.408	0.775	-0.527	0.598	-1.908	1.187
	Otago	0.829	0.621	1.335	0.182	-0.331	2.137
	Southland	0.897	1.197	0.749	0.454	-1.175	3.958
	Taranaki	-0.440	0.662	-0.664	0.507	-1.711	0.926
	Waikato	-0.262	0.482	-0.543	0.587	-1.197	0.706
	Wellington	0.175	0.438	0.401	0.689	-0.672	1.055
	West Coast	-0.144	1.304	-0.110	0.912	-2.494	3.048

Annex Table 11. Full winter 2023 sample – logistic regression model performance.

null.deviance	df.null	logLik	AIC	BIC	deviance	df.residual	nobs
502.888	397	-217.587	517.175	680.619	435.175	357	398

Full winter 2023 vs Full non-winter 2023

Annex Table 12 shows the results for the second model (Full winter 2023 vs Full non-winter 2023) and Annex Table 13 shows the model performance. The results suggest that the winter 2023 sample may differ from the remaining Full sample along a number of key dimensions:

- Household respondents aged 35–44 and 65+ were less likely to be in the winter 2023 sample. Note that this is not necessarily an indicator of the age range of all occupants.
- Households with an annual income of $150k or above were less likely to be in the winter 2023 sample.
- Households who had occupied the dwelling for 1–3, 5–10 or 10+ years were more likely to be in the winter 2023 sample than those who had lived in the house for <1 year.
- Households in higher NZ area deprivation quintiles (more deprived areas) were less likely to be in this sample.

Annex Table 12. Full winter 2023 sample vs remaining Full – full logistic model results.

	term	estimate	std.error	statistic	p.value	conf.low	conf.high
	(Intercept)	0.692	2.185	0.317	0.751	-3.923	5.057
Respondent age (25–34)	35–44 years	-1.286	0.642	-2.004	0.045	-2.594	-0.059
	45–54 years	-0.488	0.665	-0.733	0.463	-1.832	0.795
	55–64 years	-0.652	0.657	-0.992	0.321	-1.983	0.612
	65–74 years	-1.573	0.705	-2.231	0.026	-3.012	-0.230
	75 years or over	-1.737	0.775	-2.240	0.025	-3.318	-0.258
Household income (<$50k/yr)	$50k–$100k	0.325	0.474	0.686	0.493	-0.605	1.260
	$100k–$150k	-0.409	0.523	-0.782	0.434	-1.454	0.607
	$150k or above	-1.379	0.592	-2.329	0.020	-2.573	-0.241
	Refused, not stated or prefer not to say	-0.099	0.691	-0.143	0.887	-1.455	1.288
Tenure (not owned)	Owner-occupied	-1.714	0.982	-1.746	0.081	-3.915	0.072
Occupancy duration	1–3 years	2.805	1.336	2.100	0.036	0.424	6.046
	3–5 years	2.401	1.351	1.777	0.075	-0.016	5.661
	5–10 years	2.695	1.313	2.053	0.040	0.367	5.908
	10+ years	2.803	1.310	2.140	0.032	0.484	6.016
House type (stand-alone single storey)	Stand-alone house 2 or more storeys	0.485	0.410	1.182	0.237	-0.315	1.301
	Attached house single storey	-0.226	0.592	-0.381	0.703	-1.413	0.935
	Attached house 2 or more storeys	0.428	0.850	0.504	0.614	-1.183	2.238
	Apartment or flat	0.971	1.253	0.774	0.439	-1.256	4.098
Year built	1920–1939	0.330	1.575	0.209	0.834	-3.120	3.786
	1940–1959	0.916	1.538	0.595	0.552	-2.479	4.322

	term	estimate	std.error	statistic	p.value	conf.low	conf.high
	1960–1979	0.221	1.531	0.145	0.885	-3.162	3.619
	1980–1999	0.875	1.542	0.568	0.570	-2.521	4.292
	2000 onwards	0.628	1.563	0.402	0.688	-2.798	4.075
Floor area (grouped: small <100 m²)	2 medium 100–150 m²	0.262	0.465	0.564	0.573	-0.646	1.186
	3 large 151–200 m²	0.279	0.553	0.505	0.614	-0.803	1.374
	4 very large >200 m²	0.184	0.601	0.307	0.759	-0.998	1.371
NZ area level dep index (quintiles)		-0.341	0.123	-2.778	0.005	-0.587	-0.104
Region	Bay of Plenty	0.003	0.603	0.005	0.996	-1.197	1.187
	Canterbury	-0.121	0.461	-0.263	0.793	-1.028	0.785
	Hawke's Bay	-0.629	0.900	-0.699	0.485	-2.496	1.129
	Manawatū-Wanganui	-0.291	0.575	-0.506	0.613	-1.442	0.828
	Marlborough	-16.696	2252.255	-0.007	0.994	NA	275.660
	Nelson	-18.914	1771.679	-0.011	0.991	NA	182.701
	Northland	1.097	1.018	1.077	0.281	-0.836	3.308
	Otago	0.329	0.626	0.526	0.599	-0.889	1.591
	Southland	-1.496	1.270	-1.178	0.239	-4.648	0.750
	Taranaki	17.787	1196.086	0.015	0.988	-21.129	478.703
	Waikato	-0.205	0.590	-0.348	0.728	-1.382	0.947
	Wellington	0.332	0.486	0.684	0.494	-0.620	1.294
	West Coast	-17.699	2105.574	-0.008	0.993	NA	255.545

Annex Table 13. Full winter 2023 sample – logistic regression model performance.

null.deviance	df.null	logLik	AIC	BIC	deviance	df.residual	nobs
370.989	267	-149.676	381.351	528.582	299.351	227	268

Annex III: Data tables

This section contains data tables referred to elsewhere in the report.

Annex Table 14. Number of households and monitored spaces in the cleaned and filtered winter 2023 sample by region.

Region	Number of households	Number of spaces monitored
Northland	4	11
Auckland	38	115
Bay of Plenty	7	18
Waikato	9	28
Hawke's Bay	3	8
Taranaki	5	13
Manawatū-Wanganui	6	20
Wellington	21	73
Canterbury	24	63
Otago	10	32
Southland	1	1
Total	128	382

Annex Table 15. Number of households, mean living area temperatures (August – September 2023) and 95% confidence intervals by region used in Department of Statistics 1971 and HEEP1 comparisons.

Region	No. of households	Mean temperature	Standard error	95% CI (lower)	95% CI (upper)
Northern North Island	49	18.49	0.29	17.92	19.06
Southern North Island	36	18.16	0.33	17.52	18.81
Canterbury	18	18.60	0.34	17.94	19.26
Southern South Island	10	19.36	0.55	18.28	20.45

Annex Table 16. Preliminary percentage of observations below given WHO threshold (living areas June–August, winter 2023 sample).

	Morning 07:00–09:00	Day 09:00–17:00	Evening 17:00–23:00	Night 23:00–07:00
<18°C	65.0	44.4	25.8	62.2
<16°C	44.8	22.7	11.2	36.8
<12°C	6.7	1.6	0.2	3.3

Annex Table 17. Preliminary percentage of households with at least one observation below the given WHO threshold (living areas, June–August, winter 2023 sample).

Time of day	18°C	16°C	12°C
Morning 07:00–09:00	76.6	73.4	46.9
Day 09:00–17:00	76.6	71.9	39.8
Evening 17:00–23:00	74.2	61.7	15.6
Night 23:00–07:00	76.6	73.4	44.5

Annex Table 18. Preliminary percentage of observations below given WHO threshold (occupied bedrooms, June–August, winter 2023 sample).

	Morning 07:00–09:00	Day 09:00–17:00	Evening 17:00–23:00	Night 23:00–07:00
<18°C	80.7	64.4	51.8	71.1
<16°C	55.7	35.8	24.1	43.3
<12°C	10.4	4.2	2.1	6.0

Annex Table 19. Preliminary percentage of households with at least one observation below given WHO threshold (occupied bedrooms, June–August, winter 2023 sample).

Time of day	18°C	16°C	12°C
Morning 07:00–09:00	98.1	97.2	68.2
Day 09:00–17:00	98.1	97.2	67.3
Evening 17:00–23:00	97.2	94.4	37.4
Night 23:00–07:00	97.2	96.3	67.3

Annex Table 20. Number of households and rooms by household income (winter 2023 sample).

Room	Household income (excluding refusals)	Number of households	Number of rooms
Bedroom	$50k or below	20	26
Bedroom	$50k–$100k	25	38
Bedroom	$100k–$150k	27	48
Bedroom	$150k or above	29	54
Living area	$50k or below	24	25
Living area	$50k–$100k	22	23
Living area	$100k–$150k	21	22
Living area	$150k or above	25	27

Annex Table 21. Number of households and rooms in by age of dwelling (winter 2023 sample).

Room	Year built	Number of households	Number of rooms
Bedroom	Pre-1979	50	89
Bedroom	1979–2007	35	54
Bedroom	2008 onwards	18	30
Living area	Pre-1979	46	48
Living area	1979–2007	34	36
Living area	2008 onwards	17	18

Annex Table 22. Number of households and rooms by frequency of heating (winter 2023 sample).

Room	Frequency of heating	Number of households	Number of rooms
Bedroom	01 – Every day	23	32
Bedroom	02 – Most days	21	29
Bedroom	03 – Some days	21	27
Bedroom	04 – Hardly ever	22	23
Bedroom	77 – Never	49	66
Living area	NA	4	5
Living area	01 – Every day	55	56
Living area	02 – Most days	27	29
Living area	03 – Some days	9	10
Living area	04 – Hardly ever	5	5

Annex Table 23. Number of households and rooms in the analysis sample by age of bedroom users.

Category	Number of households	Number of rooms
1+ adult	124	103
1+ child aged 5–16	35	25
1+ child aged <5	18	16

Annex IV: Temperature multivariate regression models

This annex reports the results of two simple multivariate regression models that assess the extent to which a selection of factors are associated with daily mean temperatures in living areas and occupied bedrooms.

The dependent variable in both models is the daily mean winter temperature for each monitored room in an appropriate time period:

- Living areas: 17:00–23:00 on weekdays.
- Occupied bedrooms: 23:00–07:00 on all days.

The mean daily temperature was centred around the overall mean to remove potential structural collinearity.

The number of observations in each model will therefore be the number of days in the period (~92) multiplied by the number of rooms of the given type in the winter 2023 monitoring data. The exact number of valid observations depends on combined missingness of the factor categories.

Both models include the following factors (co-variates):

- Frequency of heating the living area/bedroom.
- Household income group.
- Year built (defined by insulation threshold changes – see section 7.7)
- Region – as a partial proxy for climate zone. A more robust control for local external temperatures is left to future work.

A robust linear regression approach[18] was used to estimate clustered standard errors since observations are clustered within rooms and houses and therefore cannot be considered independent. The reported 95% confidence intervals were then calculated using the clustered standard errors.

Living areas – weekdays 17:00–23:00

Annex Table 24 reports the results for the weekday evening living area model with selected combination of co-variates.

Annex Table 24. Multivariate regression on weekday daytime living area daily mean temperature (conf.low/conf.high = 95% confidence interval).

Factor (contrast)	term	estimate	std.error	statistic	p.value	conf.low	conf.high	df
	(Intercept)	1.060	1.028	1.031	0.316	-1.095	3.215	18.539
Heating frequency (every day)	02 – Most days	-1.854	0.594	-3.119	0.003	-3.052	-0.656	43.812
	03 – Some days	-1.700	0.925	-1.837	0.088	-3.685	0.286	13.960
	04 – Hardly ever	-2.170	1.204	-1.802	0.120	-5.095	0.755	6.182
Household income (<$50k/yr)	$50k–$100k	0.478	0.814	0.587	0.561	-1.175	2.131	35.005
	$100k–$150k	-0.522	0.750	-0.696	0.492	-2.055	1.011	29.729
	$150k or above	-0.520	0.798	-0.652	0.519	-2.140	1.100	34.785
	Refused	-0.363	0.927	-0.391	0.703	-2.396	1.671	11.301
Year built (pre-1979)	1979–2007	-0.056	0.505	-0.111	0.912	-1.075	0.962	43.341
	>2008	0.821	0.611	1.344	0.193	-0.448	2.090	21.382
Region (Auckland)	Northland	-0.619	2.131	-0.290	0.806	-12.897	11.659	1.548
	Bay of Plenty	-0.609	1.201	-0.507	0.633	-3.695	2.476	5.008

[18] Using the lm_robust command from the R package estimatr.

Factor (contrast)	term	estimate	std.error	statistic	p.value	conf.low	conf.high	df
	Waikato	0.199	1.044	0.191	0.852	-2.073	2.471	12.163
	Hawke's Bay	-0.028	1.627	-0.017	0.988	-8.854	8.798	1.621
	Taranaki	0.696	1.016	0.685	0.522	-1.864	3.256	5.350
	Manawatū-Wanganui	0.678	0.893	0.758	0.464	-1.294	2.649	10.758
	Wellington	-0.639	0.809	-0.790	0.435	-2.284	1.006	33.944
	Canterbury	-0.428	0.704	-0.608	0.547	-1.858	1.003	33.687
	Otago	0.627	0.933	0.671	0.511	-1.337	2.591	17.633

r.squared	adj.r.squared	statistic	p.value	df.residual	nobs	se_type
0.17	0.168	1.97	0.019	18.539	6335	CR2

Occupied bedrooms – all days 23:00–07:00

This model also includes the age of the youngest occupant and includes an interaction between the frequency of heating and the age of the occupiers given the finding that bedrooms with younger children are more likely to be heated. Annex Table 25 reports the results for the occupied bedroom multivariate model with the selected combination of co-variates.

Annex Table 25. Multivariate regression on occupied bedroom overnight daily mean temperature (conf.low/conf.high = 95% confidence interval).

	term	estimate	std.error	statistic	p.value	conf.low	conf.high	df
	(Intercept)	0.275	0.934	0.295	0.770	-1.612	2.163	40.060
Age of occupiers	1+ child aged <5	2.798	1.159	2.415	0.038	0.186	5.411	9.207
	1+ child aged 5–17	-0.503	1.320	-0.381	0.712	-3.465	2.460	9.478
Frequency of heating	02 – Most days	-0.933	0.794	-1.175	0.247	-2.542	0.676	36.892
	03 – Some days	-1.168	0.892	-1.310	0.198	-2.972	0.636	38.461
	04 – Hardly ever	-1.956	0.758	-2.580	0.014	-3.497	-0.415	33.445
	77 – Never	-1.428	0.775	-1.841	0.074	-3.001	0.145	35.521
Household income	$50k–$100k	1.252	0.576	2.175	0.035	0.093	2.412	45.042
	100k–$150k	1.323	0.596	2.218	0.031	0.123	2.522	47.445
	$150k or above	0.816	0.610	1.337	0.188	-0.411	2.044	47.175
	Refused	0.545	0.838	0.650	0.522	-1.189	2.279	22.654
Year built (<1979)	1979–2007	0.223	0.452	0.494	0.623	-0.677	1.123	74.615
	>2008	0.936	0.481	1.948	0.058	-0.034	1.907	40.976
Region (Auckland)	Northland	1.239	0.648	1.913	0.157	-0.886	3.365	2.848
	Bay of Plenty	-1.592	0.808	-1.970	0.084	-3.455	0.271	7.999
	Waikato	-0.029	0.617	-0.047	0.963	-1.303	1.244	24.093
	Hawke's Bay	-0.704	0.622	-1.131	0.265	-1.965	0.558	36.323
	Taranaki	-0.521	0.769	-0.678	0.524	-2.412	1.369	5.892
	Manawatū-Wanganui	0.013	0.996	0.013	0.990	-2.270	2.297	8.254
	Wellington	-1.155	0.510	-2.264	0.028	-2.178	-0.131	52.226
	Canterbury	-1.243	0.498	-2.497	0.015	-2.239	-0.246	57.451
	Otago	-1.372	0.889	-1.543	0.135	-3.198	0.454	26.306
Interaction effects	1+ child aged <5 * 02 – Most days	1.644	2.361	0.696	0.499	-3.494	6.782	12.136
	1+ child aged 5–17 * Most days	1.401	1.445	0.970	0.344	-1.622	4.425	19.138
	1+ child aged <5 * Some days	-3.615	1.673	-2.161	0.067	-7.569	0.338	7.024

	term	estimate	std.error	statistic	p.value	conf.low	conf.high	df
	1+ child aged 5–15 * Some days	0.043	1.661	0.026	0.980	-3.469	3.555	16.515
	1+ child aged <5* Hardly ever	-2.147	1.309	-1.640	0.118	-4.896	0.602	18.177
	1+ child aged 5–15: * Hardly ever	-0.057	1.641	-0.034	0.974	-3.994	3.881	6.541
	1+ child aged <5* Never	-1.744	1.771	-0.985	0.348	-5.686	2.197	10.075
	1+ child aged 5–15 * Never	1.457	1.460	0.998	0.332	-1.616	4.531	17.561

r.squared	adj.r.squared	statistic	p.value	df.residual	nobs	se_type
0.25	0.249	1.338145e+13	0	40.029	15824	CR2