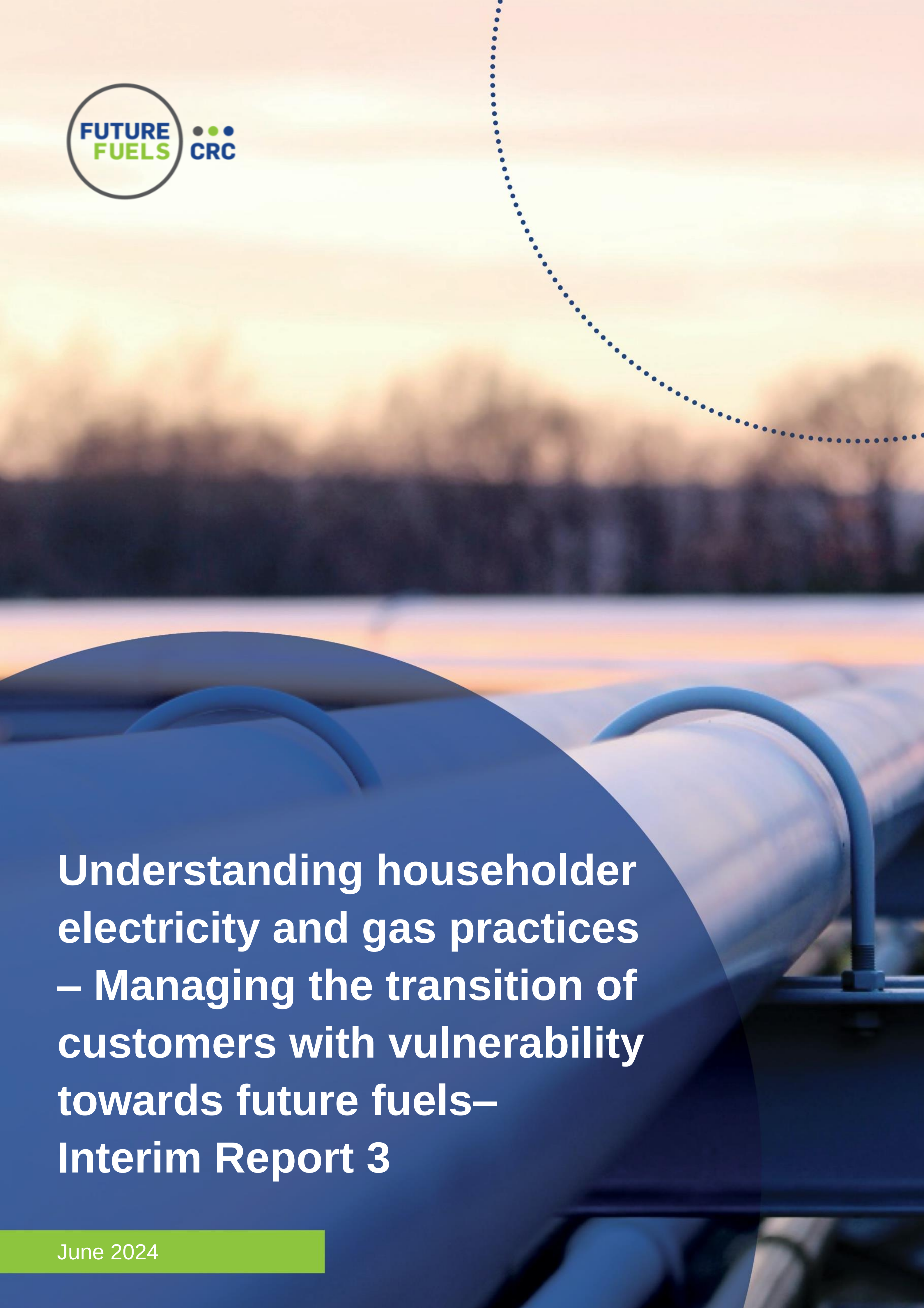

# Understanding householder electricity and gas practices – Managing the transition of customers with vulnerability towards future fuels– Interim Report 3

June 2024

Project number: RP2.1-10

Understanding householder electricity and gas practices – Managing the transition of customers with vulnerability towards future fuels


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## IMPORTANT DISCLAIMER



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| **Research Provider** | RMIT University |
| **Project Leader and Team** | Professor Jan Hayes (Project Manager)<br>Dr Nicola Willand (Lead Researcher)<br>Professor Sarah Holdsworth<br>Associate Professor Trivess Moore<br>Associate Professor David Oswald<br>Dr Pabasara Wijeratne<br>Priyanka Erasmus |
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# Summary of Report

This interim report presents preliminary findings from a project which utilizes a mixed-methods approach, incorporating energy use (both gas and electricity) and indoor temperature monitoring, semi-structured interviews with householders, and field observations. The project investigates 48 households with both gas and electricity connected, located in the northwestern suburbs of Melbourne and chosen to cover a wide range of demographic categories. The aim is to gain a better understanding of how and why householders balance electricity and gas services in the home, and what connections there may be to the affordability of energy services and pre-existing vulnerabilities.

The objective of this study is to develop:

- a better understanding of householders' balancing of electricity and gas services.
- a better understanding of how householder energy practices shape, or are shaped by, vulnerabilities and affordability.
- the implications of this new knowledge for the transition to future fuels and the electrification of residential energy.

This interim report #3 covers research findings based on the analysis of indoor temperatures and energy use data collected during September 2023 and householder interviews. The indoor temperatures and energy use data of 32 homes were analysed with respect to efficiency of the dwelling, household size, annual income, and cultural and linguistic diversity.

Regarding the efficiency of the dwellings, the findings revealed:

- Energy efficient houses use less gas and electricity on average than non-efficient houses.
- The highest gas use households usually live in non-efficient houses, but there is some overlap between the two groups (efficient vs non-efficient dwellings).
- Household behaviours play a significant role in determining gas and electricity use.
- Both efficient and non-efficient households typically show an evening peak in gas and electricity use. Non-efficient households also show a distinct morning peak in gas use.
- The difference in gas use between efficient and non-efficient homes is greatest at the lowest outdoor temperatures.
- Householders with non-efficient homes tend to be older and have a preference for a warmer home.
- Efficient households show higher electricity consumption in the evenings, likely due to higher use of electronic entertainment and communication devices.
- The efficiency of the home design is not a good predictor of indoor temperature.

Regarding the household size, the findings revealed:

- Household size is a predictor of gas use on average (i.e. larger households use more gas), but specific circumstances can have a significant impact.
- Non-low households (3 or more occupants) show a distinct morning peak in gas usage, while households with low size tend to be older people beyond working age who have a less standard morning routine and so there is no morning peak shown for this group.
- Overall electricity use is not a function of household size in the sample.
- Electricity use is dominated by other factors such as use of electric heating or other high demand appliances.
- Variation in electricity usage during the day follows a similar pattern to gas usage.

Regarding the annual income of the household, the findings revealed:

- On a typical September day, gas consumption does not vary widely between income groups.
- High income households use much more gas on very cold days than low- or mid-income households.
- All income categories showed morning and evening gas usage peaks.
- The low income group shows a more pronounced dip between these two peaks indicating little or no gas use in most low income households during the day.
- The low income group has a pronounced 2.00 am gas use peak, perhaps indicating they are most likely to have hot water services with an anti-legionella cycle running late at night.
- Middle income group are the largest users of electricity on average.
- Low income households tend to try to use less electricity due to concerns about bills.
- High income households have more discretionary spending power and have chosen to invest in energy efficient options.
- Household income was not a good predictor of indoor temperature.

Regarding cultural and linguistic diversity, the findings revealed:

- CALD status is not a strong determinant of gas consumption but there were some differences between CALD and non-CALD groups.
- CALD households tend to use more gas as the outdoor temperature drops, particularly those who come from warmer places and find Melbourne winters hard.
- Both CALD and non-CALD households show morning and evening gas usage peaks with no major differences.
- Non-CALD households show higher electricity consumption, but also more variation in use within the group.
- Electricity consumption falls with increasing outdoor temperature for both groups.
- CALD households are younger on average and more likely to be away from home during the working day, while non-CALD households include more older and retired people who are at home all day.
- CALD status is not a good predictor of living room temperature, but CALD households appear to be somewhat more likely to heat their bedrooms. The coldest bedrooms are those in non-CALD households.

Four vignettes that illustrate the four householder archetypes representing the varied attitudes of householders to the use of natural gas in the home were developed:

- Entrenched in gas: Bob – non-energy efficient dwelling, low household size, middle income, non-CALD.
- Energy agnostic: Lily - non-energy efficient dwelling, non-low household, high income, CALD.
- Moving to all electric- cost: Kylie – non-energy efficient dwelling, low household size, medium income, non-CALD.
- Moving to all electric: Kathy – non-energy efficient dwelling, low household size, low income, non-CALD.

In summary, this study has established that common categories of energy vulnerability, such as energy efficiency ratings of homes, income, CALD status and household size, offer incomplete explanations of gas and electricity use and indoor temperatures. This suggests that any assessment of vulnerability in household in the low carbon transition should consider a more comprehensive and nuanced approach to vulnerability.

While affordability of fuel played a role in householder practices, and energy price increases had signalling effects, values such as duty of care for older or disabled people and very young children were more important than economic priorities and manifested in warmer homes. Considering that Australia has an ageing population, and that the Ageing in Place policy is favoured by older people and policy makers, keeping people warm in their homes will require more energy in the future unless there are interventions that improve the energy efficiency of dwellings and appliances.

Interestingly, heating in all areas and overnight was seldom considered essential. This perception contradicts regulatory assumptions (NatHERS) and the WHO's public health recommendations. Consequently, cold homes were a common phenomenon. This means that, in general, householders were under consuming energy and that achieving adequate or healthy temperatures, even in energy efficient dwellings, requires more energy use or the improvement of the thermal performance of building envelopes and appliances. The bi-modal shape of daily gas use, with peaks in the mornings and night and a trough during the day, may have implications for considering equity in a possible time of day gas tariff as is currently offered by the electricity sector. Real time gas monitoring should be a requirement should demand-side tariffs ever be employed for gas usage to allow householders control over the costs of running their home.

Many householders were actively engaged in home energy improvements ranging from simple draft proofing and garden design to provide shading, through to technology improvements. In the selection of appliances perceptions of efficiency, safety, energy security, and sensory stimuli such as noise of appliances, smell of cooking, feeling of radiant warmth and the sight of flames shaped the householders' choices. In general, householders operated a combination of appliances be it for heating, cooling and cooking. Only hot water provision relied on a single system. This is an important finding for policy makers and the industry as a pure focus on quantitative, environmental or economic benefits of home energy intervention schemes may be less effective than appeals to people's ethical values.

Further, we emphasise that considerations in decision making on energy carriers, e.g. gas, electricity and wood, extended beyond the individual household to wider societal outcomes, such as resource conservation or waste avoidance and resilience of the electricity grid. Resource conservation included admiration for the longevity of appliances and the desire to extend their life cycle through regular maintenance and repairs. Replacements were generally linked to the breaking down of appliances rather than being proactive. While there was strong evidence of optimism in technology and that government incentives precipitates appliance upgrades and the installation of solar panels, the distrust and suspicion among a few householders that the push towards technological changes included a certain level of commercial avarice should not be dismissed. Policy makers and the industry may consider building trust in the technological and regulatory processes that are part of the transition to low carbon housing.

The next step of this study is to explore the summer household interviews and quantitative data findings and to confirm winter findings with a full data set (not just one month).

# 1 Introduction

The aim of this research is to understand how and why householders balance electricity and gas services in the home and what connections there may be to the affordability of energy services and pre-existing vulnerabilities. Specifically, the project has three primary objectives: 1. To provide a better understanding of householders' balancing of electricity and gas services; 2. To provide a better understanding of how householder energy practices shape, or are shaped by, vulnerabilities and affordability and 3. To provide the implications of this new knowledge for the transition to future fuels and the electrification of residential energy. In order to achieve the above objectives, this study takes a mixed method approach. Mixed method research (MMR) incorporates the elements of both quantitative and qualitative research methods into a single study which involves collecting and analysing both numerical data (quantitative) and visual, textual or narrative data (qualitative) to gain a comprehensive understanding of a research question (Creswell and Creswell 2018).

The study is based on 48 households in Victoria, Australia. The households were categorised based on four predominant factors that were postulated to affect electricity and gas consumption.

- **Efficiency of the dwelling**: Energy efficiency of the dwelling in this research is represents the age of the dwelling. Houses built after 2005 with a five-star energy rating can be considered more energy efficient than older houses. Hence, the category 'non-energy efficient dwellings' refers to dwellings built pre-2005; dwellings built post-2005 are considered in this study as energy efficient dwellings.
- **Household size**: Households with 1-2 occupants were defined as low household size and households with 3 or more occupants were defined as non-low household size.
- **Annual income**: In this research, we classified households into three income groups based on the reported annual income: $50,000 or less as low-income households, $50,000 – $150,000 as mid income households, and $150,000 or more as high-income households.
- **Cultural and linguistic diversity (CALD)**: In this research, we define CALD households as households in which a language other than English is spoken and/or if the participants report to have an ethnic background other than Anglo-Australian or Anglo-Saxon.

For more detailed description and justifications, please refer to interim report #1 and interim report #2.

This interim report (#3) presents research findings based on the analysis of 32 households with installed gas data loggers of the overall 48 households. For a more detailed description of gas logger installation, please refer to interim report #2. This interim report #3 focuses on analysis of the gas consumption, electricity consumption and indoor temperature in September 2023 with respect to efficiency of the dwelling, household size, annual income and cultural and linguistic diversity. September 2023 was chosen as the month for analysis because it was the first month where all three gas, electricity, and indoor temperature data sets were available for 32 homes. This allowed for a comprehensive quantitative analysis to be conducted at a time when space heating was still widely used. Further, the analysis could be used as a template for analysing the summer and upcoming winter data. The report commences with the research method employed in Section 2. Section 3 presents the household, dwelling, and participant characteristics. Research findings on efficiency of the dwelling are presented in Sections 4 and Section 5 presents the findings on household size. Sections 6 discuss the findings on annual household income and Section 7 presents the findings regarding cultural and linguistic diversity. Section 8 presents material on householder archetypes. The research findings are discussed in Section 9, followed by the conclusions in Section 10. Section 11 highlights their implications for the energy industry, and the next steps in this research project are presented in Section 12.

# 2 Method

This interim report #3 covers the findings for the quantitative research component for September 2023 combined with findings from the qualitative research component. The qualitative component used semi-structured interviews, observations during home tours, photographs and videos of the homes and energy-related activities to explore conditions that shaped heating, hot water cooling and cooking practices. The quantitative component involved monitoring of energy (electricity and gas) use, indoor temperatures and humidity in the living room and main bedroom in households to identify the patterns of householder energy use. This report presents the findings for the quantitative research component on the energy use and indoor temperatures across 32 homes in the September 2023 and investigates how the four categories ‘energy efficiency of the dwelling’, ‘household size’, ‘annual income’ and ‘cultural and linguistic diversity’ has shaped these outcomes. Figure 1 presents the classification of the 32 homes based on the four categories. The research methods employed in this study such as home visits and householder interviews in the qualitative research component, and energy use and indoor temperature monitoring as the quantitative research component, are described below.

## 2.1 HOME VISITS AND HOUSEHOLDER INTERVIEWS

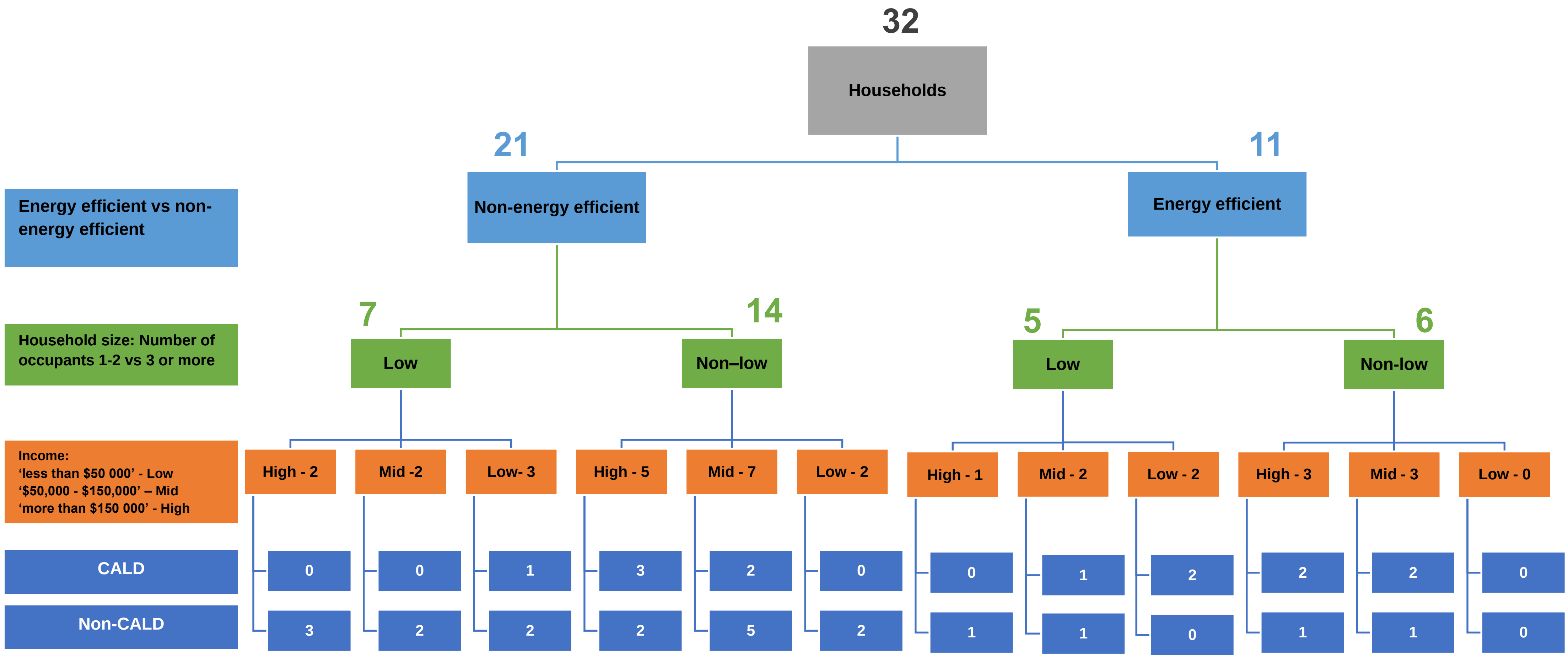
### 2.1.1 Data collection

Home visits and household interviews for the winter period were carried out from 1.5.2023 – 30.9.2023 and summer period were carried out from 12.01.2023- 30.04.2023 and 11.01.2024 – 04.04.2024. The researchers visited the participants at home to conduct the face-to-face semi-structured interviews. A home tour was done after the interview to observe, take photos and record videos. The householder was presented with a gift voucher as a thank you for their participation. The winter home visit explored the householders’ practices and experiences related to keeping warm and use of hot water. An interview guideline was developed for the winter interviews to ask questions during the interview. The key topics of the interview questions for the winter interviews include 1. Introduction to the interview, 2. Heating characteristics and experiences, 3. Hot water system characteristics and experiences 4. Energy affordability, 5. Energy assistance and 6. Low carbon energy transition. The summer home visit explored householders’ practices and experiences related to keeping cool and cooking. The summer interview guideline to ask questions during the interview. The key topics of the interview questions for the summer interviews include 1. Introduction to the interview, 2. Cooling characteristics and experiences, 3. Indoor cooking characteristics and experiences 4. Outdoor cooking characteristics and experiences and 5. Income and concessions.

### 2.1.2 Data analysis

The interviews which lasted between 1.5 hours and 2.5 hours were audio-recorded and transcribed professionally. The 48 transcripts were read against the audio recording of the interviews to ensure the completeness and accuracy of the contents. This report considers 32 of the 48 transcripts of the homes which have gas data loggers installed.

**Figure 1 Classification of the 32 householders**



## 2.2 MONITORING OF ENERGY USE AND INDOOR TEMPERATURES

### 2.2.1 Data collection

The study monitors the gas consumption, electricity usage and indoor temperatures to identify patterns related energy usage in the selected households.

**Household electricity consumption:** Records of half hourly smart meter electricity data are collected from each household from 1st September to 30th September 2023.This data is obtainable via each householder's smart meter records, which are collected by the respective electricity distributors, and does not require any additional field measurement. Smart meter electricity data was available for 30/32 homes (the data was unavailable for two homes, HH35 and HH43 for the selected period).

**Indoor temperatures:** The study uses UbiBot WS1 Pro 2.4GHz (WiFi and SIM Version) temperature and relative humidity loggers (Figure 2) to monitor indoor temperatures and relative humidity in the living room and one bedroom of the selected households. The loggers were placed in the households during the first home visit, and they will be removed at the end of the study. The loggers collect half hourly temperature and humidity data. Further, the loggers can sync to a protected Cloud server every 10 hours where the collected data can be downloaded. Living room temperature data was available for 30/32 homes (the data was unavailable for two homes, INT13 and INT19) and bedroom temperature data was available for 26/32 homes (the data was unavailable for INT3, INT5, INT6, INT7, INT19 and HH40).

**Figure 2 UbiBot WS1 Pro 2.4GHz temperature and relative humidity logger**


**Outdoor temperatures:** Half hourly temperature data from the Bureau of Meteorology was collected for seven weather stations that were identified as being closest to the locations of the selected households and in the same NatHERS (National Home Energy Rating System) climate zone (Table 1).

**Table 1 Weather stations**

| Weather station | Station ID |
|---|---|
| **Essendon Airport** | 086038 |
| **Melbourne Airport** | 086282 |
| **Melbourne (Olympic Park)** | 086338 |
| **Laverton RAAF** | 087031 |
| **Point Cook RAAF** | 087185 |
| **Bendigo Airport** | 081123 |
| **Avalon Airport** | 087113 |

**Household gas consumption:** Landis+Gyr Smart Dataloggers with Embedded VodaFone Esim (Figure 3) are used to monitor the half hourly gas consumption of each household. The gas loggers were approved by AusNet as being intrinsically safe and compatible with the existing gas meters. The gas usage data of 32 dwellings for September 2023 was collected from the gas logger provider.

**Figure 3 : Landis+Gyr Smart Dataloggers for monitoring gas usage of the 32 households**


**Electricity and gas bills**: The photos or digital copies of the participants' latest gas and electricity bills are collected at each home visit. The gas bill contains the calorific value per volume of the reticulated gas, which varies by location. This information is needed to translate the gas logger data, which measures volume, into the heat or energy values that are the variable of interest. In addition, the electricity and gas consumption information displayed on the bills will validate the logged or smart meter-recorded information and serve as a backup in the rare event of a data logger or smart meter failure.

### 2.2.2 Data analysis

The half hourly monitored electricity, gas, and indoor temperature data were analysed using statistical methods to gain insights and draw meaningful conclusions about householders' energy usage patterns. The analysis of the gas electricity and indoor temperatures in the 32 homes focused on September 2023 (1st September to 30th September 2023).

#### *2.2.2.1 Data cleaning process*

**Outdoor temperatures**

Half-hourly outdoor temperature data from the weather station nearest each home was obtained from the Australian Bureau of Meteorology (BOM) as discussed in section 2.2.1. Table 2 shows the allocation of the 32 homes to BOM weather stations. The raw data sets of the ambient temperature recordings at the BOM weather stations were examined for missing data and outliers. The missing data were derived by adopting the pattern changes in the temperature from the closest weather station.

**Table 2 Allocation of the 32 homes to BOM weather stations**

| Weather station name | Station ID | No of homes | % |
|---|---|---|---|
| Essendon Airport | 086038 | 10 | 31 |
| Melbourne Airport | 086282 | 11 | 34 |
| Melbourne (Olympic Park) | 086338 | 2 | 6 |
| Laverton RAAF | 087031 | 6 | 19 |
| Point Cook RAAF | 087185 | 2 | 6 |
| Bendigo Airport | 081123 | 1 | 3 |

**Electricity smart meter data**

The electricity smart meter data from 30 households were collected from the electricity distributor by the researchers. Nine householders agreed to download the data themselves and email to the researchers. Twenty-one homes have Jemena as their electricity provider, 11 homes have Powercor as the electricity provider. For each household, the 30-minute interval smart meter data for September 2023 were extracted and organised in MS Excel files. Two dwellings (HH35 and HH43) were excluded from the analysis due to the unavailability of smart meter data for September 2023.

**Indoor temperature data**

The indoor temperature data for each household were downloaded in two ways. The loggers which are online were downloaded from the Cloud server. The data from the loggers which were offline were downloaded manually during the winter home visits. The Jupyter Notebook and python programming language were used to check downloaded csv files for missing or duplicate values and processed them to a MS Excel file with date and 30-minute interval columns to facilitate the analysis of data. The homes with the missing data were excluded from the analysis.

**Gas usage data**

The gas data are organised under the logger number. Therefore, the data were assigned to each household and organised in MS Excel. The data was checked for missing or duplicate values and processed them with date and 30-minute interval columns to facilitate the analysis of data. The gas usage data were not available for 15th September for all 32 dwellings. Therefore, the 15th of September was excluded from the analysis (including electricity and indoor temperature analysis).

#### *2.2.2.2 Data processing and statistical analysis*

**Standardisation of energy consumption and indoor temperatures to daily mean outdoor temperatures**: Mean daily energy consumption and indoor temperature data were normalised to mean daily outdoor temperatures to ensure comparability, as the climatic conditions among the postcode areas of the 32 housing areas varied. This study utilized the standardisation method developed by Willand et al. (2019) to standardise mean daily energy consumption and daily mean indoor temperatures to daily mean outdoor temperatures. Please refer to interim report #2 for further details of this standardisation method. For the September data, the gas consumption, electricity consumption and indoor temperatures were standardised to a daily mean outdoor reference temperature of 11ºC. This reference temperature was chosen as it was the most frequent daily mean outdoor temperature in September 2023. Hence indices for the reference temperature of 11ºC were interpreted as the levels of gas consumption, electricity consumption and indoor temperature on a ‘typical’ September day. In this report, we report the main indices that captured the average of the whole day. In addition, the 48 half-hourly timestamps during September for days with a reference temperature of 11ºC were used to show the diurnal variations of gas consumption, electricity consumption and indoor temperatures.

**Outdoor temperatures:** The daily mean outdoor temperature was calculated from the weather station closest to the site. The cleaned half-hourly September 2023 outdoor temperature data from the five-weather station were organised in MS Excel files. The daily mean outdoor temperatures were calculated from the 48 half-hourly time stamps of each day as provided by the Bureau of Meteorology.

**Electricity smart meter data:** The smart meter data of thirty dwellings were considered in the analysis. For each dwelling, the 30-minute interval smart meter data relevant to September 2023 were organised in MS Excel files. The data were presented in kilowatts-hour (kWh). The mean daily half-hourly electricity use was calculated and converted to megajoules (MJ) using the equation below:

$$megajoules = kilowatt\ hours\ x\ 3.6$$

The mean daily half-hourly electricity use in (MJ) for September month was mapped with the mean daily half-hourly outdoor temperature relevant for the month. The data were categorised based on the dwelling type, household size, annual income, and cultural and linguistic diversity. Descriptive statistics and charts were used to analyse the data.

**Gas usage data:** The gas data of 32 dwellings were considered in the analysis. The mean daily half-hourly gas use was calculated for each home. The gas usage data were presented in cubic meters ($m^3$). Following equation were used to convert $m^3$ to MJ:

$$megajoules = m^{3}x \text{ heating factor x correctional factor}$$

The heating factor and correctional factor were identified from the gas bills of each home. The mean daily half-hourly gas use in (MJ) was mapped with the mean daily half-hourly outdoor temperatures of September. The data processed were categorised based on dwelling type, household size, annual income, and cultural and linguistic diversity. Descriptive statistics and charts were used to analyse the data. The homes INT13 and INT14, only had one ‘typical’ September day, Therefore, they were excluded from the box plot and diurnal comparison of the gas usage.

**Indoor temperature data:** The living room temperature data was available for 30 homes for September 2023. The bedroom temperature data was available for 26 homes for September 2023. The data were organised in MS Excel under each month and calculated the mean daily half hourly living room temperature and the mean daily half hourly bedroom temperature. The mean temperature was mapped with the mean daily half-hourly outdoor temperatures of each month. The data were categorised based on the dwelling type, household size, annual income, and cultural and linguistic diversity. Descriptive statistics and charts were used to analyse the data.

# 3 Household, dwelling and participant characteristics

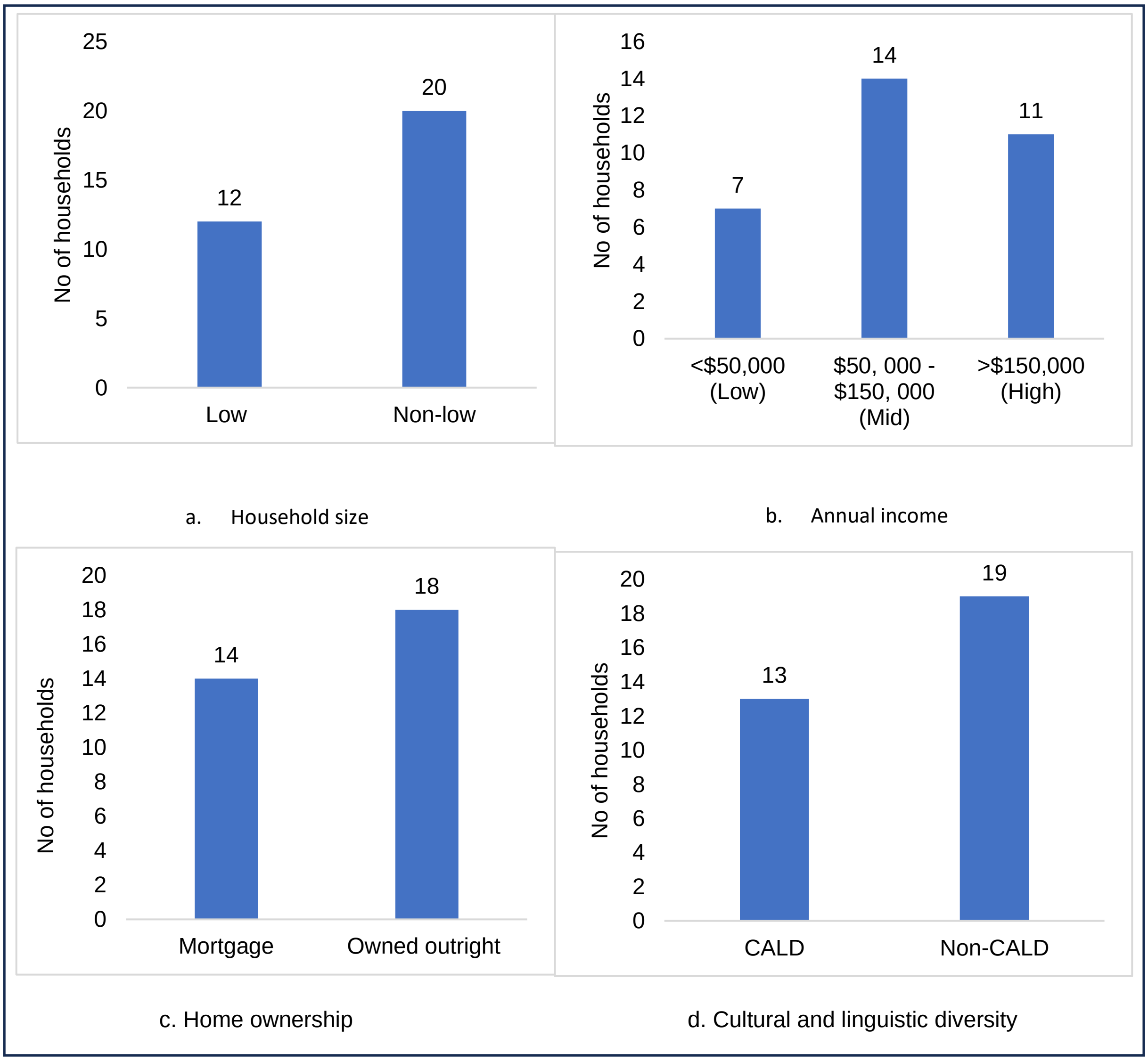
This section presents the characteristics of the 32 households, their dwellings and the research participants.

## 3.1 HOUSEHOLD CHARACTERISTICS

The sample presented a diversity across the main household characteristics of interest that were household size, household annual income, cultural and linguistic diversity, home ownership and occupancy patterns of the 32 householders considered in this analysis. Most households (20) had three or more occupants. As shown in Appendix 1, the household composition included adults and children. In terms of income, seven householders were low-income level, 14 were mid-income, and 11 were in the high-income category. Only 14/32 homes had a mortgage. Thirteen households were categorised as CALD households and 19 as non-CALD. When looking at home occupancy patterns, most householders (26) were at home always or most of the time during weekdays as shown in Appendix 1. Further, most houses (26) were also substantially occupied during the weekend.

The details of householder characteristics of the 32 householders are presented in Appendix 1 and Figure 4.

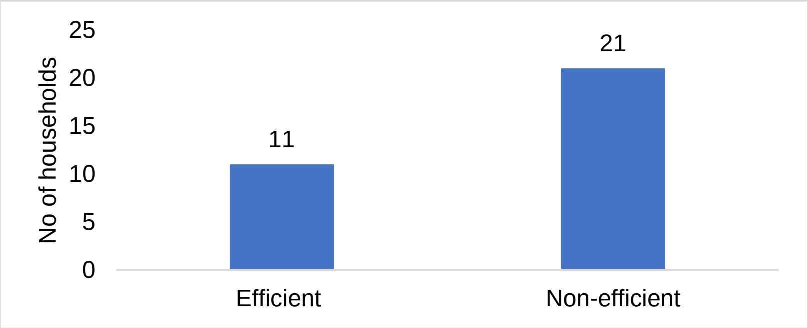
**Figure 4 Household characteristics**



## 3.2 DWELLING CHARACTERISTICS

Thirty-one dwellings were detached houses and only one dwelling (INT4) was a townhouse. As shown in Figure 5, eleven dwellings (34%) may be considered relatively energy efficient, as they were built after the introduction of the 5-star minimum home energy rating in 2005. There are 21 households (64%) built before 2005 when the National Construction Code (NCC) did not specify any energy performance requirements. Among the houses built after 2005, there are five houses built to a 5-star standard, five houses built to a 6-star standard and one house which was renovated in 2015. The design of the newer houses was typically open plan with a combined living, dining, and kitchen space.

**Figure 5 Dwelling efficiency**




As shown in Figure 6, most efficient dwellings were reported to have wall and roof insulation. Nonetheless, all non-efficient dwellings except two reported to have roof/ceiling insulation. However, floor insulation was rare (only HH29 reported there might be floor insulation), which may be a reflection of the dominance of concrete slabs on ground. As shown in Figure 7, most efficient houses (10) have been constructed with a timber frame and brick veneer external primary wall on a concrete slab. However, only eight dwellings in the non-efficient category have used brick veneer as the external skin. Eight dwellings in the group were constructed solely from brick, three dwellings had weatherboard. One home had sandstone and one had cedar as the external skin of the dwelling. Among the energy efficient dwellings, the largest dwelling is 446 $m^2$ and belonged to HH29; the dwelling with the smallest floor area was HH32 with 214 $m^2$. Under non-efficient dwellings, the largest dwelling is 680 $m^2$ and belonged to HH43; the dwelling with the smallest floor area was INT20 with 90 $m^2$. The average homes in the energy efficient category were slightly bigger (305 $m^2$) than those in the non-energy efficient category (294 $m^2$). Fourteen householders were not aware of the dwelling size. The details of dwelling areas can be found in Appendix 2.

**Figure 6 Insulation reportedly present in the dwellings**

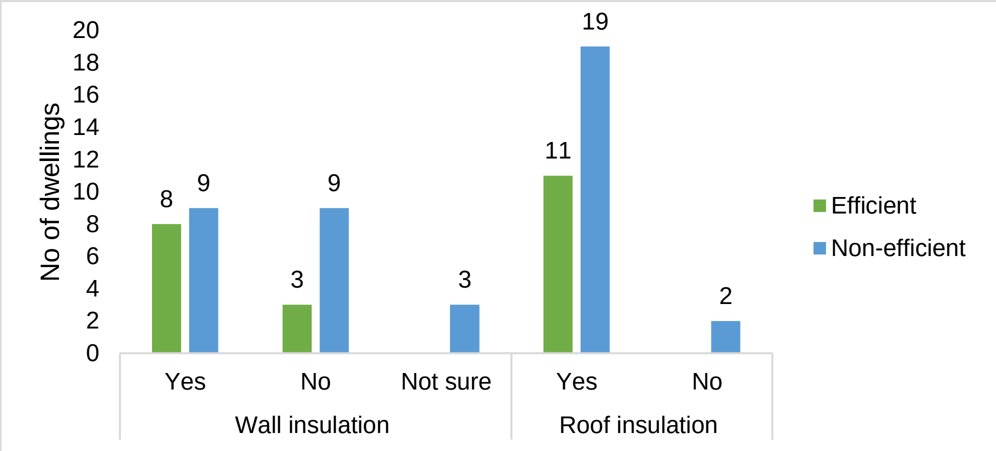
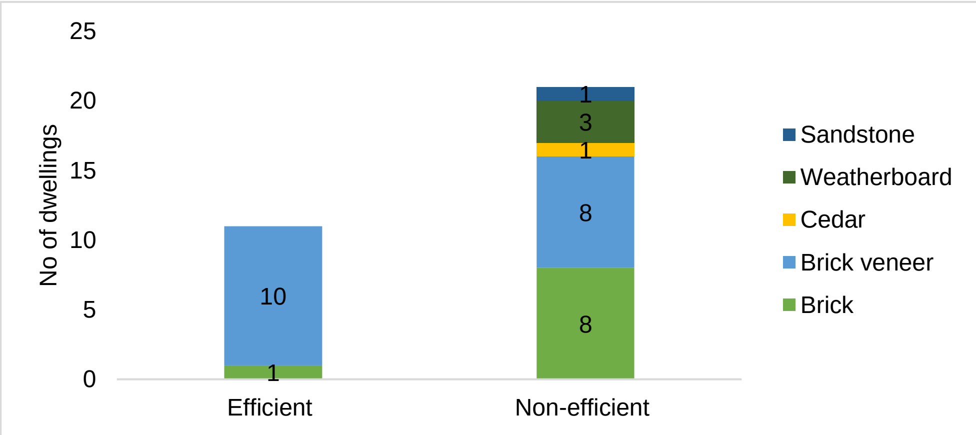



**Figure 7 Wall materials reportedly used in the dwellings**




As shown in Figure 8, in all the non-efficient and six efficient dwellings, windows were single glazed. However, five dwellings with energy star rating 6 or higher had double glazed windows. As shown in Figure 9, a lower number of efficient and non-efficient houses were fitted with outside shutters. Figure 10 shows the usage of internal window covering in dwellings. More blinds were used in efficient dwellings. However, in non-efficient dwellings both blinds and indoor heavy curtains with pelmets were used.

**Figure 8 Window glazing in dwellings**

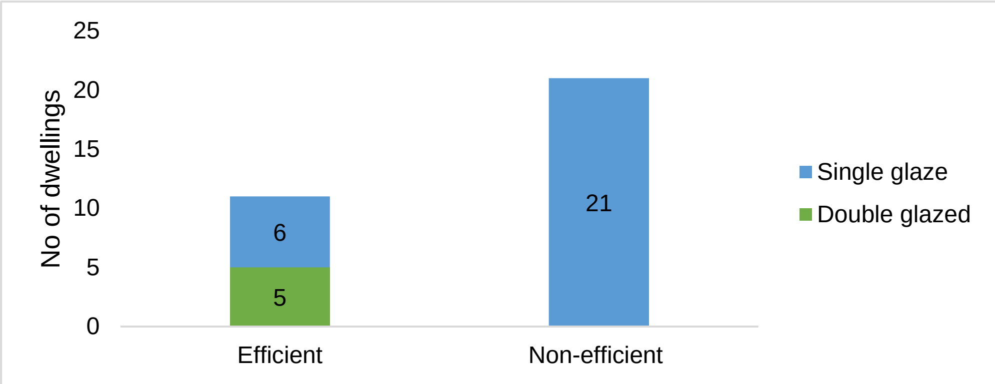



**Figure 9 External shading in dwellings**

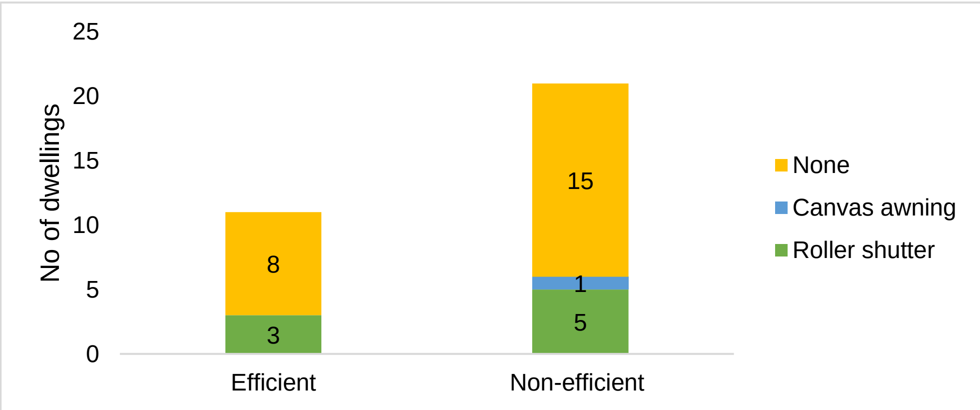
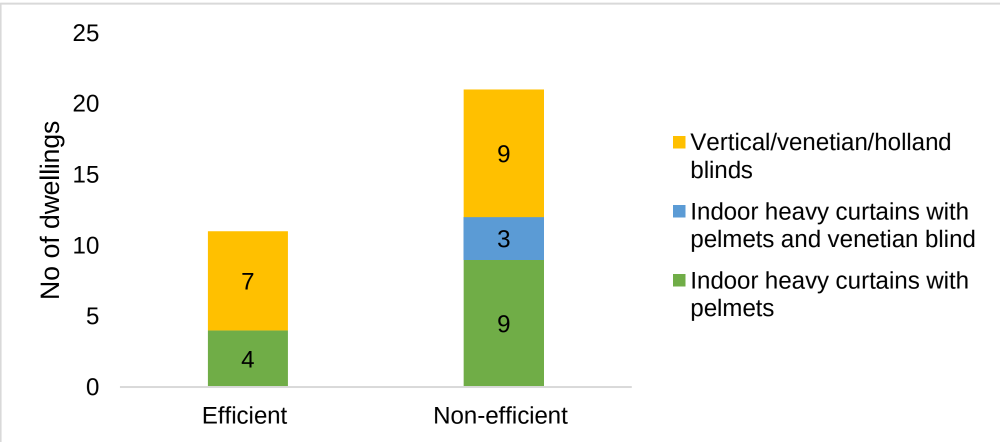
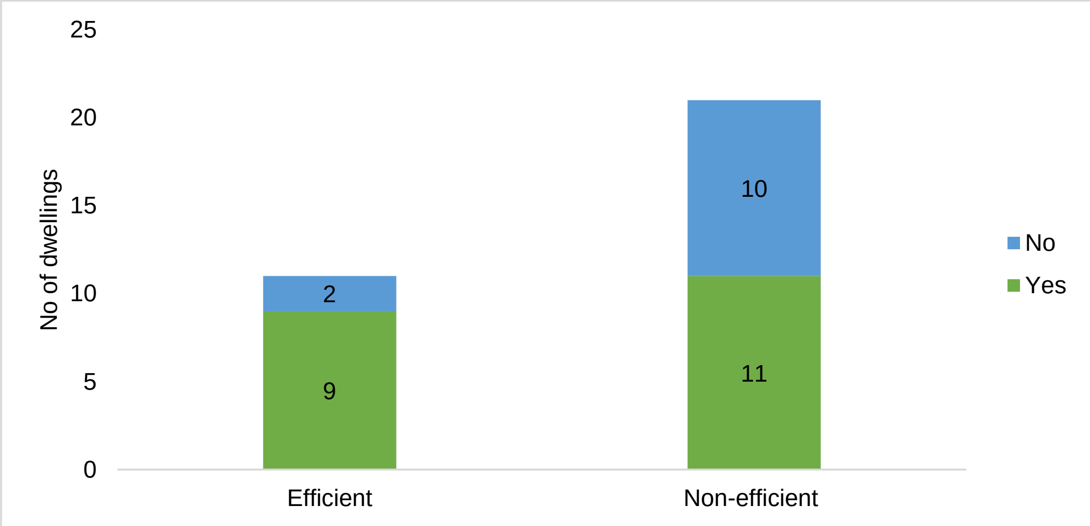



**Figure 10 Internal window covering in dwellings**




Additionally, energy efficient lighting (e.g., LEDs) were used in most of the efficient and non-efficient dwellings (31 dwellings). However, four houses had a mixture of LED and non-LED lighting in their homes. As shown in Figure 11, solar PV systems were available in nine efficient dwellings and 11 non-efficient dwellings. None of the houses with solar PV had a solar battery.

**Figure 11 Solar PV in dwellings**




## 3.3 PARTICIPANT CHARACTERISTICS

There were 38 participants, as in some households there were two people participating. There were 20 (53%) male participants aged 33-81 years and 18 (47%) women participants aged 32-71 years. Most participants were in active work. Seventeen (45%) participants were full time employed. There were eight participants (21%) who worked part time, one participant (3%) did casual work, and twelve participants (32%) were retired. The sample was mostly well educated. Eight participants had a bachelor's degree as the highest qualification, with fourteen participants also having a Master's degree, and one participant who was retired having a PhD. Further, there were nine participants who had a diploma and four participants had completed Year 10-12 as their highest education level. The participants' characteristics such as age, gender, occupation, work status, highest level education of the 38 participants considered in the analysis are presented in Table 3.

**Table 3 Participant characteristics**

| Household | Age | Gender | Occupation | Work status | Highest level education |
|---|---|---|---|---|---|
| INT1a | 56 | Male | Banker | Retired | Masters Degree |
| INT1b | 54 | Male | University administration | Retired | Masters Degree |
| INT2 | 71 | Female | Administrator | Retired | Year ten |
| INT3 | 49 | Female | Administrator | Part time | Associate Diploma |
| INT4a | 71 | Male | University academic | Retired/voluntary work | Postgraduate DipEd |
| INT4b | 70 | Female | IT Professional | Retired/voluntary work | Graduate certificate |
| INT5 | 56 | Female | Nurse- retired, carer | Full time | Diploma |
| INT6 | 69 | Male | Technician | Retired | Graduate diploma |
| INT7 | 82 | Male | Engineer | Retired | Diploma |
| INT8a | 70 | Male | Dog show judge | Part time | Diploma |
| INT8b | 52 | Female | Dog show judge | Part time | Diploma |
| INT9a | 81 | Male | Engineer | Retired, volunteer | Bachelor degree |
| INT9b | 80 | Female | Insurance industry | Retired, volunteer | Diploma |
| INT10 | 44 | Female | Office Administrator | Part time | Bachelor degree |
| INT12 | 34 | Female | Drug and alcohol counsellor. | Full-time | Bachelor's degree |
| INT13a | 37 | Male | IT professional | Fulltime | Masters Degree |
| INT13b | 39 | Female | IT professional | Full time | Masters Degree |
| INT14 | 49 | Female | Education support | Part time | Bachelor's degree |

| Household | Age | Gender | Occupation | Work status | Highest level education |
|---|---|---|---|---|---|
| INT15 | 43 | Female | Did not mention | Part time | Masters Degree |
| INT16 | 70 | Male | Pensioner | Retired | School |
| INT17a | 32 | Female | Business Development Manager | Fulltime | Masters degree |
| INT17b | 33 | Male | Researcher | Fulltime | Masters Degree |
| INT18 | 34 | Male | Did not mention | Fulltime | Bachelor |
| INT19 | 67 | Male | Financial planner | Retired | Bachelor |
| INT20 | 38 | Female | Neuropsychologist | Fulltime | Masters Degree |
| HH22 | 37 | Male | IT | Full-time | Bachelor degree |
| HH28 | 38 | Female | Teacher | Full-time | Bachelor degree |
| HH29 | 65 | Male | University Academic | Retired | Doctor of Philosophy |
| HH32 | 42 | Male | IT Consultant | Full-time | Masters Degree |
| HH34 | 54 | Female | Cleaner | Part-time | Year 11 |
| HH35 | 45 | Female | Accountant | Full-time | Masters Degree |
| HH39 | 50 | Female | Office Assistant | Part-time | Year 12 |
| HH40 | 42 | Male | IT professional | Full-time | Masters Degree |
| HH41 | 41 | Male | State public servant | Full-time | Masters Degree |
| HH42 | 51 | Female | CSR manager | Full-time | Masters Degree |
| HH43 | 34 | Male | Account manager | Full-time | Bachelor degree |
| HH44 | 41 | Male | Community support worker | Casual | Bachelor degree |
| HH45 | 34 | Male | IT Professional | Full-time | Masters Degree |

## 3.4 SUMMARY

Section 3 presented the characteristics of the 32 households, their dwellings and the research participants. The following sections explore the research findings on energy consumption and indoor temperatures based on the dwelling type, household size, annual income, and cultural and linguistic diversity.

# 4 Dwelling type – efficient and non-efficient

This section provides the results from the analysis of the electricity and gas consumption data and indoor temperature data of September 2023 with respect to efficient and non-efficient homes.

## 4.1 GAS USAGE

This section presents the gas consumption data with respect to efficient and non-efficient homes. Gas data was available for 32 homes (11 efficient and 21 non-efficient) for September 2023. As shown in Table 4, the range of daily mean total gas consumption of energy efficient dwellings was higher than the non-efficient group on the coldest days. The range of daily mean total gas consumption of non-efficient homes was slightly higher than the energy efficient homes on the warmest days. However, the group of efficient homes presented lower minimum consumption values during coldest and warmest days. The group of non-efficient homes presented a lower maximum consumption value during coldest and the typical' September days. The average consumption of the efficient homes was higher in the coldest days.

**Table 4 Descriptive statistics of daily mean total gas consumption in relation to daily mean outdoor temperatures**

| Daily mean outdoor temperature (°C) | Daily mean total gas consumption (MJ/day) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Efficient group (n=11) | | | | Non-efficient group (n=21) | | | |
| | Min | Ave. | Max | Range | Min | Ave. | Max | Range |
| **8** | 5 | 245 | 649 | 644 | 100 | 211 | 315 | 215 |
| **11 ('typical' September day)** | 1 | 149 | 602 | 600 | 0 | 184 | 564 | 564 |
| **23** | 4 | 31 | 56 | 52 | 2 | 50 | 87 | 85 |

The box plot for daily mean gas usage on days with a daily mean outdoor temperature of 11°C for each group (efficient/non-efficient dwelling) is based on 30 of the 32 households. Two households (INT13, INT14) were excluded from this analysis because they only experienced one 'typical September' day.

**Figure 12 Box plot for mean gas usage on days with a daily mean outdoor temperature of 11 $^{0}$C**

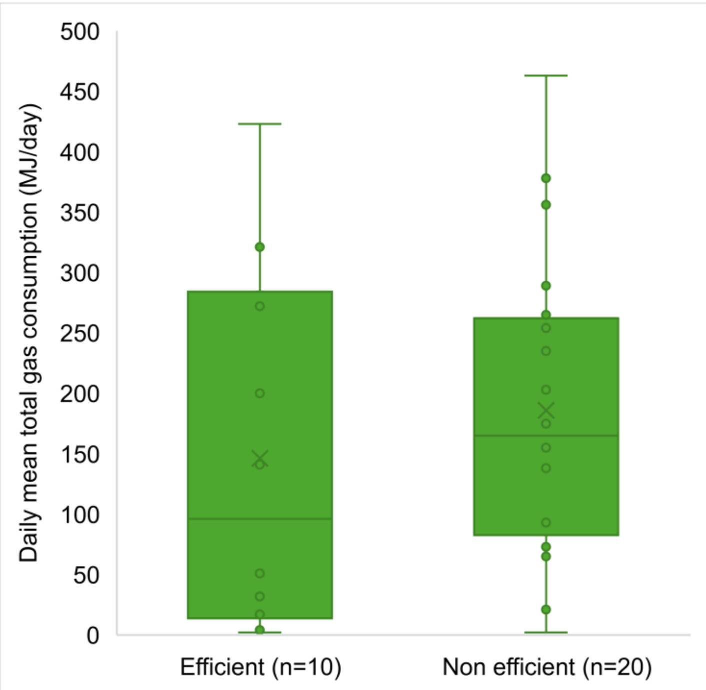


Figure 12 presents box plots comparing the daily mean total gas consumption between the groups on days with a daily mean outdoor temperature of 11 $^{0}$C. Gas consumption data of 30 homes (10 efficient and 20 non-efficient) for September 2023 was considered for the box plot. The interquartile range of the efficient group is higher than the non-efficient group. However, the non-efficient group showed a higher dispersion of mean gas consumption than those for homes in the efficient group. Though both groups of data appear to be right skewed (positively skewed), the daily mean gas consumption of efficient homes is more right skewed than that for non-efficient homes. The mean gas use in efficient homes is lower than the non-efficient homes on a ‘typical’ September day.

### 4.1.1 Explanations of highest and lowest gas usages on days with a daily mean outdoor temperature of 11 $^{0}$C in each group (efficient/non-efficient homes)

HH45 had the lowest daily mean gas consumption (4.4MJ) in the ‘efficient dwelling’ group as they were replacing central gas heating with room based electric heating and compromising on spatial warmth. HH45 was a middle-income, CALD household, with 2 adults mostly working from the 5 star rated home. The diurnal gas consumption pattern reveals that they were zero gas at most times on typical days with low usage at 6.00 am, 8.00 am-11.00 am and 10.30 pm to midnight (daily average of 0.09MJ/30min). The householders noted that the gas central heating was expensive to run and “wasting resources” given the open plan nature of their house. During the day they used mostly extra clothing (”three layers in the winter because we are from a warmer country, so we find the cold a bit much”) and small portable electric heaters (one fan, one tower heater) in the rooms that they occupied. The householder shared that they would only “turn on the [central gas] heating to take the chill off the room for like two hours, and then in two hours it warms up and then we turn it off” which may have been reflected in the slight use of gas between 8.30 am and 10,00 am (0.4 – 0.3MJ/30min), yet this may have also indicated they were using hot water in the mornings.

They chose electric room-based heaters to utilise their self-generated solar electricity, which may partly explain why their grid electricity use was also among the lowest in this group of households. It seems that any warmth from the two electrically heated rooms did not reach the living area, as their home was the coldest home in the ‘efficient dwelling’ group. Even though the couple shared that the temperature setting in the morning was “21-22”, this was not reflected in the diurnal temperature patterns. On average September days, the highest achieved living room temperature was 16.3°C, that is almost two degrees below the recommended minimum of 18°C. The bedroom achieved a slightly higher temperature of 17.2°C in the afternoon, likely due to solar gain.

The diurnal gas consumption pattern of HH45 also revealed a peak of 0.9MJ/30min at 3.00 am. This ten-fold increase in half hourly gas consumption may have been due to an automatic anti-legionella hot water cycle in their solar boosted gas storage hot water system. An anti-legionella hot water cycle heats tanked hot water to above 60°C and distributes it through the system for an hour a day to kill any Legionella [1]. This cycle is often scheduled in the early hours of the morning on the assumption that few people will be using hot water at that time and that hence the risk of scalding may be low [2]. By the time of the interview in October, the solar boosted gas hot water system had broken down and been replaced by an electric heat pump. The change in fuel was driven by a rebate that made the electric option cheaper than the gas one.

HH28 had the highest daily mean gas consumption of the efficient homes on a ‘typical’ September day (423MJ), that is almost ten times that of the household with the lowest usage in this group. In this household, continuous central heating provided adequate temperatures throughout the home around the clock. HH28 was a high income, non-CALD household with a family of four. Their 6-star rated home was often occupied throughout the day and night as one of the adults was a shift worker. Their only heating system was the central ducted gas heating, and electricity use was one of the lowest in the

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[1] https://hamworthy-heating.com/Knowledge/Articles/Managing-the-risk-of-legionella-in-domestic-hot-water-systems#:~:text=This%20cycle%20involves%20raising%20the,Legionella%20is%20unable%20to%20survive.

[2] https://www.pkc.gov.uk/media/51248/Mitsubishi-Air-Source-Heat-Pump-User-Guide/pdf/Heat_Pump_Tenant_User_Guide.pdf?m=638230281544870000

group of efficient homes during the day and night. The system had two zones, one for the downstairs bedrooms and one for the living areas, which included a theatre, living, dining and rumpus room, upstairs. Both zones were heated “pretty much … 24/7” during winter, even when they were not at home. The partners seemed to have contrasting opinions on whether it was more efficient and thus cheaper to leave the heating on at a lower temperature or to turn it off completely when no one was at home. The diurnal pattern of their gas use showed a steady increase in gas use from the early hours of the morning to 10.00 pm at night. Thermal comfort perceptions also varied, yet the heating was reportedly mostly set at 22°C. The living and bedroom temperature pattern revealed that the daytime set point may have been closer to 20°C. The main bedroom and living rooms presented adequate temperatures between 16.3°C (BR, 6.00 am) and 20.4°C (BR, 8.30 pm) throughout the day. The steady drop in indoor temperatures after 8.30 pm suggested that the heating set point between 8.30 pm and 6.00 am was lower as indoor temperature steadily declined during this time and gas consumption was low (average 1MJ/30min between midnight and 7.00 am). “Even pay”, that is payment of equal monthly amounts to balance the dynamics of high winter and low summer gas expenses over the year, eased the householder’s nervousness over high winter bills.

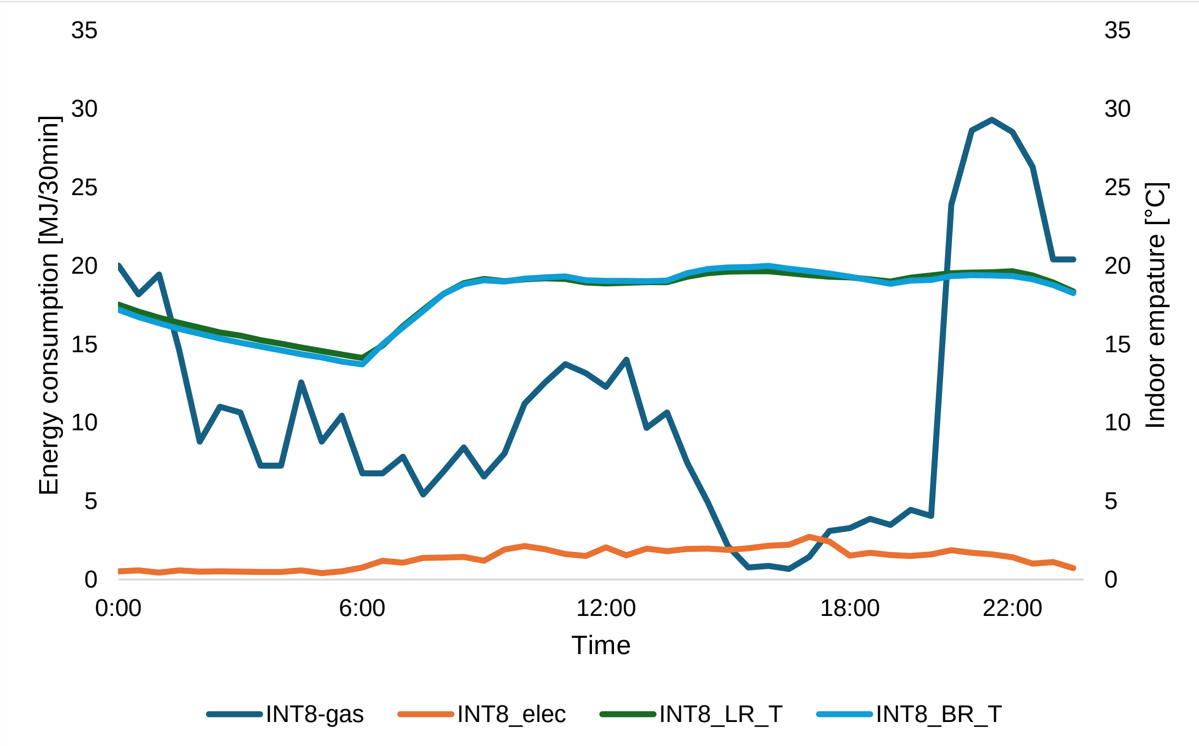
INT18 had the lowest daily mean gas consumption of all homes in the non-energy efficient dwelling group (1.9MJ) because gas was only used for cooking. INT18 was a high income, CALD household with three adults and one child. The householders had switched fuels between the first (summer) and the second (winter) interview in September 2023, exchanging the instant gas hot water system with an electric heat pump and swapping the 20-year-old and reportedly expensive and ineffective central gas central heating, which was only really warming up one room, with a split system air conditioner. The participant explained: “I’ve taken out all the gas except cooking.” Their diurnal gas consumption pattern confirmed that they were using minimum levels gas for an hour in the early hours of the morning (1.30 am-2.30 am; avg. 0.15MJ/30min) and in the mornings with a maximum of 0.5 MJ/30min (10.30 am-11.00 am). The retrofits also included a 10.2kW solar PV system as part of the home electrification journey: “ideally, I want to electrify the whole house”. The grid electricity use in this home was about average during the evenings and night and approached zero during the day. In this uninsulated weather board house, the lack of energy use resulted in inadequate indoor temperatures. The living room temperatures dropped as low as 13.5°C (7.30 am) and only achieved a high of 16.9°C (3.00 pm). Bedroom temperatures ranged between 13.7°C (8.00 am) and 15.7°C (9.30 pm). The 34-year-old Chinese man admitted that in general he did not turn on the central heating when he was the only one at home and working as he could not restrict the heating to his study. Occasionally he would use an electric space heater that would be “basically free” when the solar system was generating electricity, but most of the time he would only use a jacket to keep warm. Other members of the household used an electric blanket but not him. He reported switching on the house heating occasionally if the young child was feeling cold. He reportedly would set the thermostat to 18°C during the day and 20°C during the night. The higher temperature setting during the night may be explained by the poor thermal envelope, because the participant stated that the loss of warmth through the air leaks and uninsulated building envelope was noticeable. These set points, were however, not reflected in the monitored levels of warmth. According to the World Health Organization (WHO)’s Housing and Health Guideline (2018), the cold home may have put the child’s health at risk, but the child was “run[ing] pretty warm. He kicks the blankets off and stuff at night even though it’s freezing. I don’t know. Yeah, if it feels a bit cold, I will turn it on.”

INT8 had the highest daily mean gas consumption of the non-efficient homes on a ‘typical’ September day (463MJ). Despite the high gas usage, the home was underheated for much of the day, which may be explained by the low thermal performance of the building envelope. INT8 was a middle-income household in a 50-year-old brick veneer house with single glazing in windows and gas central heating. The heating system had no zoning, and the under-floor ducted gas heating system runs mornings “just to take the chill off” and evenings (and sometimes during the day) during the winter. The male septuagenarian was very sensitive to the cold due to his blood thinning prescriptions and felt it more than his wife. Preference for the thermostat set point varied (18°C -23°C) but, judging from the achieved living room temperature, was probably set to 20°C with the man using a jumper and blanket to keep warm. A recent free draught proofing initiative had made him feel more comfortable.

The householders were concerned about the cost of heating and actively control their use: “we try and be conscious of how much it’s costing; we try and turn it off as soon as we can.” The diurnal gas use pattern shows continuous gas usage during the day and night with a pronounced peak in use between

8.30 pm and 1.00 am (23.9 – 20.02MJ/30min). However, this energy barely heated the living room temperature to the comfort level of 20°C that is assumed in the National Housing Energy Rating System (NatHERS). Most of the day, the living room did not achieve the recommended minimum of 18°C. This underheating may be interpreted as a health risk for the older and thermosensitive householders who are at home most of the time. The bedroom temperatures presented a similar yet slightly warmer pattern showing a rapid temperature rise after 6.00 am with the warmest point in time found in the afternoon. Electricity use during the day was also amongst the highest in this group of non-efficient dwellings, yet the householders did not report the use of electric heating systems. The warmth in the rooms during the afternoon despite the comparatively low gas usage may be explained by high solar gains from the single glazed windows. The variation in gas use, electricity use, living area temperature and bedroom temperature for household INT8 is shown in Figure 13.

**Figure 13 INT8 – Diurnal variation of energy consumption and indoor temperatures throughout a 'typical September' day.**




### 4.1.2 Relationship of daily mean total gas consumption at daily mean outdoor temperatures - efficient/non-efficient dwellings

Figure 14 shows the comparison of the daily mean total gas consumption for the efficient and non-efficient dwelling groups in relation to the daily mean outdoor temperatures. On average, the daily mean total gas consumption in both energy and non-energy efficient dwelling groups presented a negative association with the mean outdoor temperatures. The visual analysis of the graph reveals that the daily mean total gas consumption in the energy efficient homes appeared to have been lower than those in non-efficient homes across all outdoor temperature levels. The difference in daily mean total gas consumption between the two groups appeared to be higher during colder and warmer days in September. When the outdoor temperature was 8⁰C, the mean total gas consumption of non-efficient homes was lower than the efficient homes. However, this result should be interpreted with caution due to the comparatively low number of data points at this lower end of the outdoor temperature range.

**Figure 14 Comparison of daily mean total gas consumption at daily mean outdoor temperatures - efficient/non-efficient dwellings**

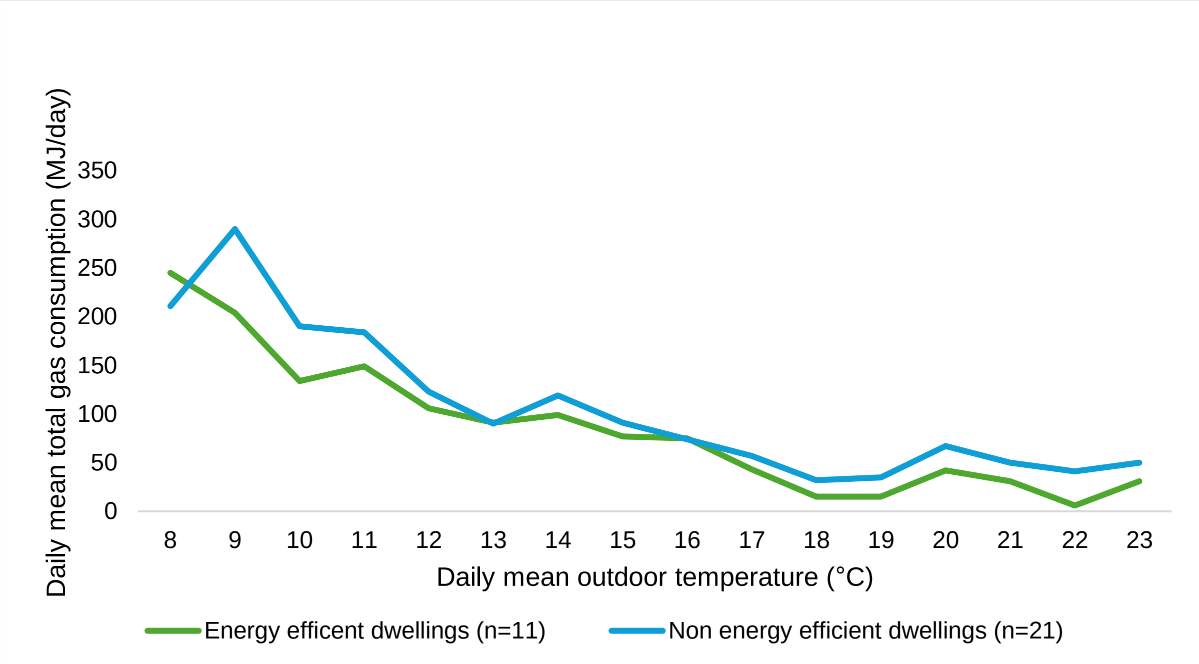
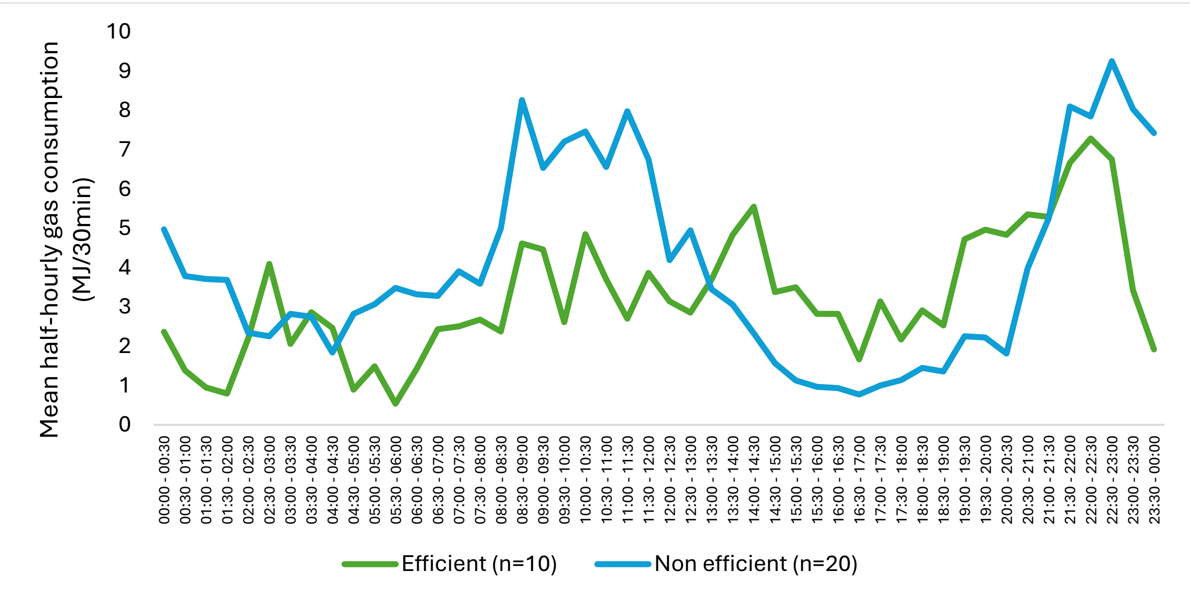



Figure 15 compares the diurnal variations in average half-hourly gas consumption on 'typical' September days of efficient and non-efficient dwellings. The distribution of half-hourly gas use in both groups is bi-modal. The evening peak in the non-efficient group of homes is slightly higher than its morning peak. The efficient dwellings group also exhibits a higher peak in the evening. The average half-hourly gas consumption appears to be higher in the non-efficient dwellings group except for the afternoon period and the early morning period (1.00 am - 4.30 am). Appendix 3 presents the diurnal variations of mean half-hourly gas consumption on days with a daily mean outdoor temperature of 11°C in the selected efficient and non-efficient dwellings respectively.

**Figure 15 Comparison of diurnal variations of mean half-hourly gas consumption in efficient and non-efficient dwellings on days with a daily mean outdoor temperature of 11 $^{0}$C**



### 4.1.3 Explanations of diurnal variations of mean half-hourly gas consumption in efficient and non-efficient dwellings on days with a daily mean outdoor temperature of 11°C

Diurnal gas usage patterns were characterised by single or recurrent spikes at varied times of the day and night. In particular there were two peaks, one in the morning and one at night, that did not easily relate to outdoor temperature. The rise in usage in the early mornings was explained by heating "to take the chill out of the air" that was practiced in efficient and non-efficient homes (efficient HH23, HH35, INT14; non-efficient - HH45, INT3, INT8, INT9, INT10). The only household that presented a steady increase in gas usage during the day with a drop overnight in the efficient dwelling group was HH28. As explained earlier, this household used continuous, thermostat controlled central gas heating over the whole 24h day. The steady increase in gas use is likely a reflection of the increased heating demand as solar gain decreased in the afternoon.

In non-efficient dwelling group, middle income non-CALD household INT15 presented continuously higher gas use in the afternoon hours and lower usage overnight. The participant stated that she aimed to maintain adequate temperatures to safeguard her son's health:

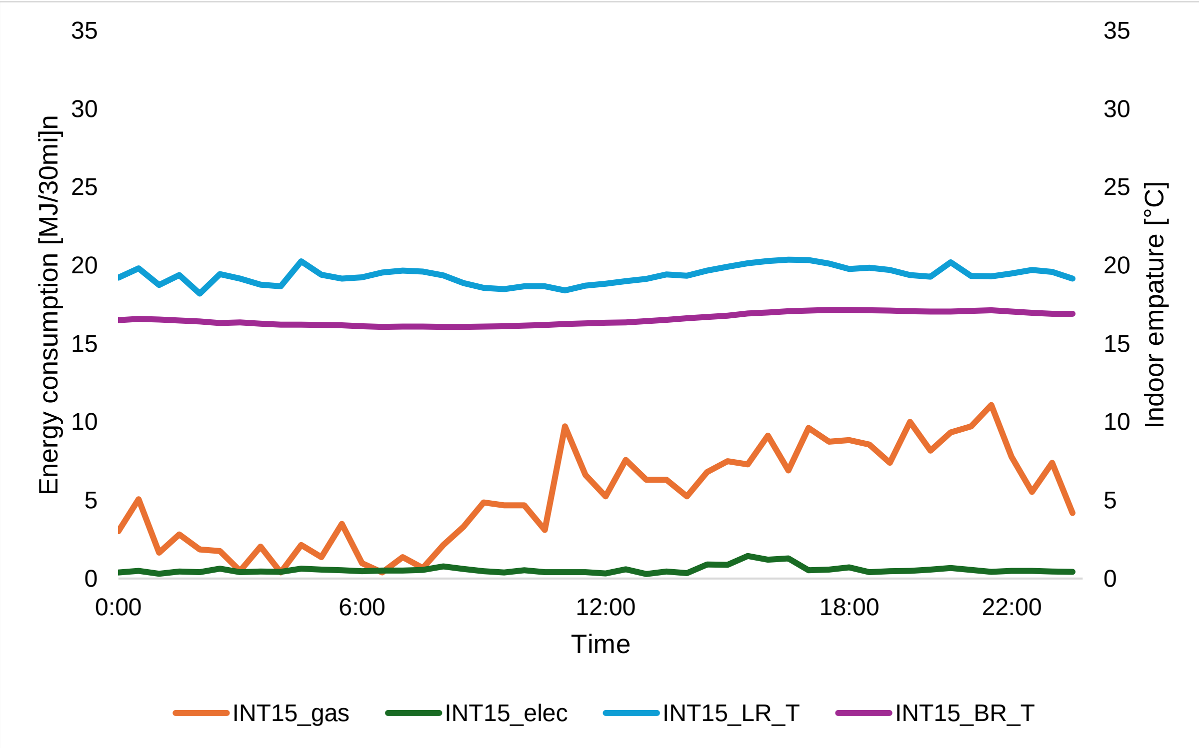
*"I like to keep the house around 18 just mostly for my son because he already catches enough colds from kindergarten and stuff, so there's nothing - no reason to try and add more bugs and stuff."*

However, she seemed to feel conflicted over this practice. She reported that she:

*"tried to use the heating as minimal as possible, just because of cost. So, if it's anything below 18, we just put jumpers on and things like that" adding "I was using the heating at night, which was a really bad habit, so I've stopped that now."*

The variation in gas use, electricity use, living area temperature and bedroom temperature for household INT15 is shown in Figure 16.

**Figure 16 INT15 – Diurnal variation of energy consumption and indoor temperatures throughout a 'typical September' day**



INT9 and INT12 in the non-efficient dwelling group presented pronounced peaks in gas use in the morning (31.3MJ/30min; 8.30 am-9.00 am and 27.09MJ/30min; 8.30 am-9.00 am respectively) which were likely to be associated with showering and inefficient gas hot water systems.

INT9 were an older low-income couple who lived with their adult daughter in a 20-year-old brick veneer home. They were mostly at home but reportedly only switched on their central gas heating “late in the afternoon”. They explained this routine with their ethnic background: “Being English, we’re tough. So, it doesn’t probably go on until 3.00 pm, even later.” The thermostat setting was reportedly 21°C-23°C. The living room temperature curve seems to confirm this heating use: the temperature rose slowly during the day from a low of 13.9°C (7.00 am) and faster after 6.00 pm to a high of 19.8°C. Hence, the morning peak may have been due to their use of their reportedly old instantaneous gas hot water system[3].

The morning gas use peak in INT12 seemed to be linked to showering routines, too. INT12 was a high-income Vietnamese family with two young children who lived in a 20-year-old brick veneer home. The dwelling had gas central heating without the option of zoning. The heater reportedly ran throughout the day during the cold weather and was only turned off when they went to bed. It seemed that on typical September days, the heating was not switched off at night. INT12 was one of the warmest homes in this group with the living room temperature on typical September days being around 19.6°C throughout the day and night and the bedroom around 20.4°C. The morning peak may thus be explained by their hot water system and showering practices. The participant did not know their type of hot water system but when touring the property we saw a large gas fired tank system. Her assurance that “it's always there when we need it” and their twice a day showering habits is reflected in their gas use profile. The wife showered “in the morning and then before bed”, her ‘husband' after work and before bed” and her son “after dinner”. The evening shower routine may then also explain the second pronounced gas use peak (36.05MJ/30min; 10.30 pm-11.00 pm).

INT5 presented a pronounced use of gas use in the morning at 1.30 am – 2.00 am (28.9MJ/30min). This peak may be explained by the anti-legionella hot water cycle, too. This dwelling had an “old tank thing” that was an estimated “30, 35 years old”. It should be noted that this was also the daily peak in gas usage. The ducted gas heating system had been upgraded but the participant tended to use a wood fire to keep her disabled daughter warm. The gas heating was only used overnight on very cold days and at a set point of 17°C. The participant was very excited to share that the old gas hot water system was about to be replaced with a new electric heat pump. Thanks to a government rebate, she could cover the cost of $2000 with her holiday/emergency savings.

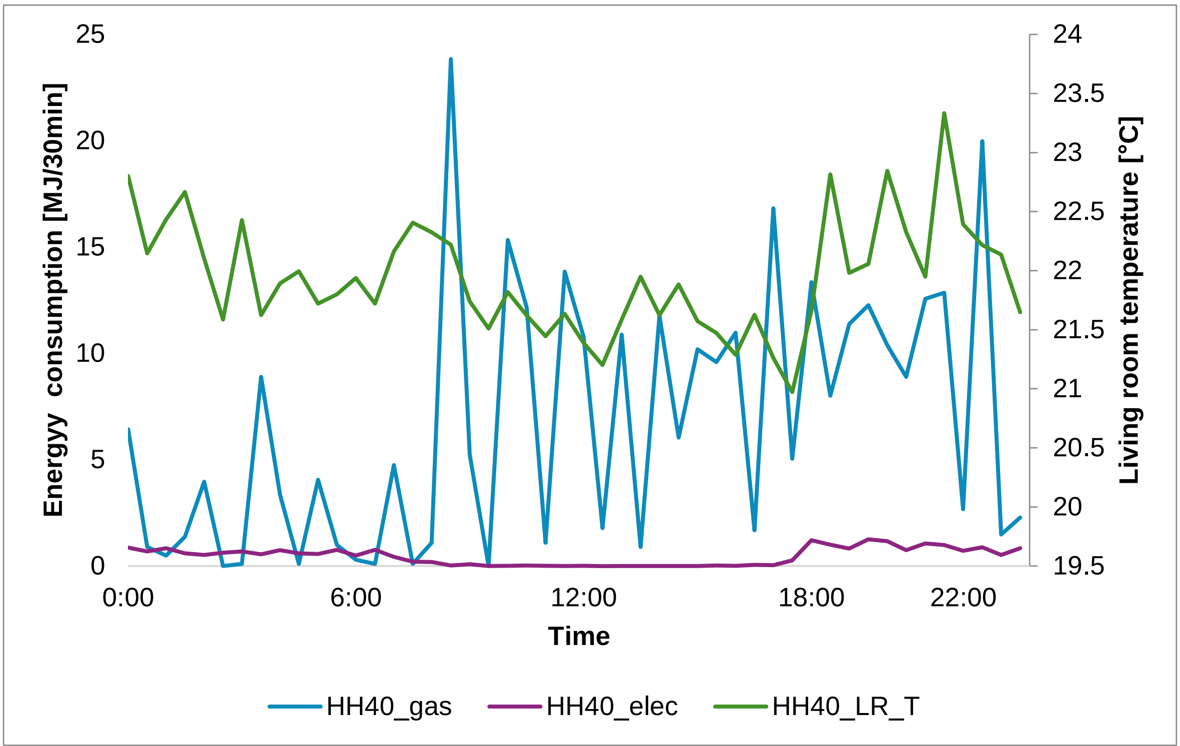
In the ‘efficient dwelling’ group, HH40 presented an early morning spike in gas usage (23.8MJ/30min; 8.30 am-9.00 am. HH40 had a tank system but we did not learn about the showering practices. HH40 presented several gas usage spikes throughout the day which may be explained by an anti-legionella hot water cycle (21.85MJ/30min; 2.30 am-3.00 pm) and showering in the morning (18.7MJ/30min; 6.30 am-7.00 am) and evening (average 19.8MJ/30min; 7.00 pm-8.00 pm). However, the highest peak (30.6MJ/30min; 1.30 pm-2.00 pm) was not easily explained. Importantly, though the gas heating in this Indian household (couple with child) ran all day and night. The participant explained:

*“We have a gas heater, which pretty much 24/7 runs and don’t switch it off – it’s on a thermostat. […] I have tiles, so they get very cold in winter. [..] I’m decrease the temperatures. In the night we put it 23. I know it’s a lot, but given where we are, 23 is only where we can be a little bit more comfortable, live freely more around, like that. But currently it’s 24 now.”*

[3] “Instantaneous water heaters […] have a nominal gas consumption equal to or less than 250 megajoules per hour, and have a heat output equal or greater than 13.1 kilowatts. https://www.energyrating.gov.au/industry-information/products/gas-water-heaters#:~:text=Instantaneous%20water%20heaters%20that%20have,or%20greater%20than%2013.1%20kilowatts.

The variation in gas use, electricity use, living area temperature and bedroom temperature for household HH40 is shown in Figure 17.

**Figure 17 HH40 – Diurnal variation of energy consumption and indoor temperatures throughout a 'typical September' day.**




INT1 in the 'efficient dwellings' groups also showed an unexpected daily gas use pattern. In this household, the gas usage in the evening (34.7MJ/30min;10.00 pm – 10.30 pm) was more than ten times the half hourly average over the 24 hours (3.2MJ/30min). This peak coincided with the time that this retiree on a low income reportedly switched off his central heating. The peak may, thus, be explained by showering using the instant gas hot water heater.

## 4.2 ELECTRICITY USAGE

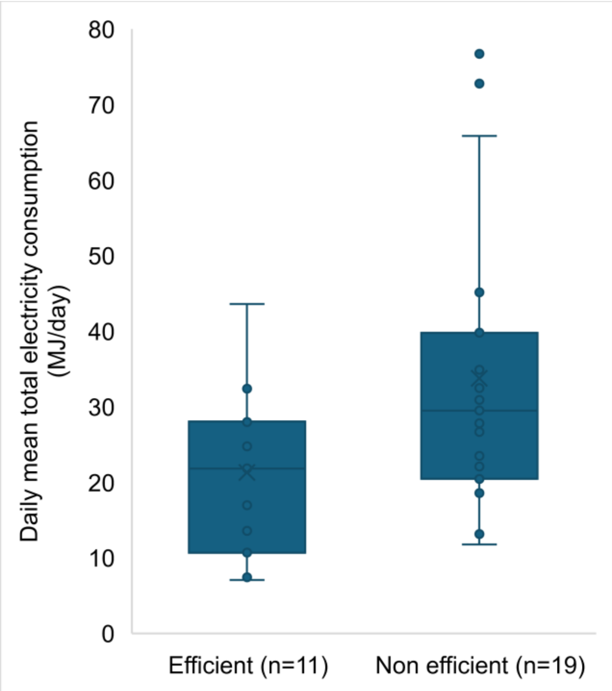
This section presents the electricity consumption data with respect to efficient and non-efficient homes. Electricity data was available for 30 homes (11 efficient and 19 non-efficient) for September 2023.

**Table 5 Descriptive statistics of daily mean total electricity consumption in relation to daily mean outdoor temperatures**

| Daily mean outdoor temperature (°C) | Daily mean total electricity consumption (MJ/day) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Efficient group (n=11) | | | | Non-efficient group (n=19) | | | |
| | Min | Ave. | Max | Range | Min | Ave. | Max | Range |
| **8** | 8 | 24 | 45 | 37 | 18 | 43 | 85 | 67 |
| **11 ('typical' September day)** | 6 | 21 | 65 | 59 | 8 | 33 | 93 | 85 |
| **23** | 10 | 16 | 19 | 9 | 15 | 37 | 55 | 40 |

In general, electricity usage was lower than gas usage and the difference between energy efficient and non-efficient dwellings more pronounced. The range of daily mean total electricity consumption on the coldest and warmest days was higher in the groups of non-efficient dwellings (Table 5). The group of efficient dwellings presented lower minimum, average and maximum consumption values on the coldest and warmest days. Figure 18 presents a box plot comparing the daily mean total electricity consumption between the groups. The interquartile range of the efficient group is lower than the non-efficient group. However, the non-efficient group shows a higher dispersion of mean electricity consumption than the efficient group. The daily mean electricity consumption of efficient homes is right (positively) skewed than that for non-efficient homes. It shows that the daily mean electricity use in efficient homes is substantially lower than the non-efficient homes on ‘typical’ September day. Two outliers are visible above the whiskers of the box plot of the non-efficient dwelling group.

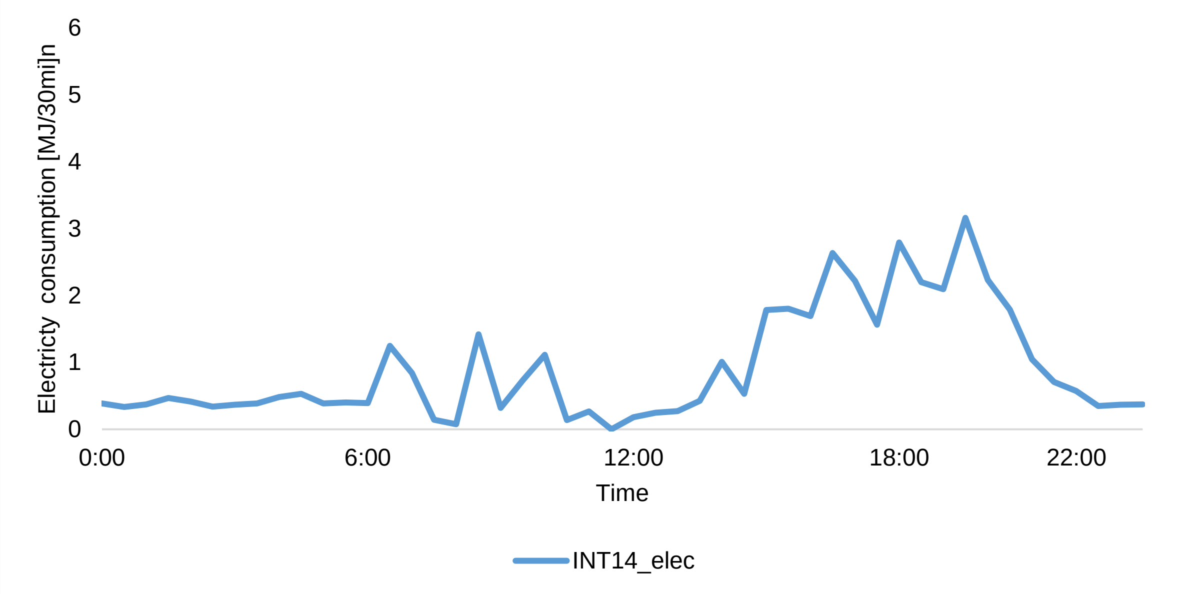
**Figure 18 Box plot for mean electricity usage on days with a daily mean outdoor temperature of 11 $^{0}$C**




### 4.2.1 Explanations of highest and lowest electricity usages on days with a daily mean outdoor temperature of 11 $^{0}$C in each group (efficient/non-efficient homes)

Electricity use was driven by appliance use rather than heating in energy efficient homes. In the ‘efficient’ dwelling group, HH28 and HH32 presented the lowest daily mean electricity consumption (7.4MJ/day and 7.1MJ/day respectively). HH28 was a 6-star rated home, a rating that includes a limit to the lighting demand below 5 W/m². In addition, three of the four household members were not at home during school hours. The low electricity use of HH32, which was almost continuously occupied, was most likely due to the household’s efforts into energy saving around the home and the solar panel array (5.5kW). INT14 had the highest daily mean electricity consumption of the efficient homes on a ‘typical’ September day (43.6MJ/day), probably because of high electricity usage when the yield of their solar array was low. This observation was surprising as this 5-star rated home was fitted with a 6kW solar panel array, their ”saving grace”. INT14 was a middle income 6-person family household. Because of the large household size, the fridge and other appliances had to be generously sized. The mother reported that she used the washing machine, dryer and dishwasher alternately during the day to make use of the free electricity. The morning peak (Figure 19) may be explained by such domestic appliance uses.  The high afternoon and evening electricity use probably reflected the use of communication technology and other appliances when the family members returned from school and work and the sunset around 6.00 pm. The participant was not monitoring their electricity use. She had never used her Powerpal application, and their solar PV application was not functioning. Because her electricity bills remained fairly constant, she was not concerned about their electricity costs.

**Figure 19 INT14 – Diurnal variation of electricity consumption and indoor temperatures throughout a 'typical September' day.**




In the non-efficient dwelling group, INT13 (11.8MJ/day) had the lowest daily mean electricity consumption on ‘typical’ September days and INT8 (65.8MJ/day) was the highest.

INT13 was a high-income Indian family with a baby. Their diurnal electricity use showed zero use during daytime, suggesting that their 7.6kW solar panel system and their practice of running appliances such as the washing machine on sunny days were effective energy saving measures. The household reported that “there were months where we didn’t have any bills.”

On the other hand, INT8 was occupied continuously by older people. Despite their high electricity usage, they did not use electric heating. Older appliances appear to explain their high daytime electricity usage. They were using an old fridge outside as a second “bar or drink fridge” and were full of admiration for its longevity and its effectiveness “That fridge is 49 years old. I never had one thing done to it. They don't make them like that anymore.” They adhered to the motto “Don’t fix what’s not broken”, which they associated to their age. Their dishwasher had also been 25 years old when they replaced it. The indoor fridge had been replaced twice and, thus, would have been more efficient. Their most recent bill (“almost $1000”) had been more than double that their usual bill, which was “normally about $400”. The couple said that they had used less during that time and that the bill had been based on an estimate. They were paying $150/month to smooth over the seasonal variations to pay off the bill. The pensioners were ”watching every penny” and admitted: “$1,000.00, Jesus in one hit, we couldn’t afford it”. The house had solar panels, but the householders suggested that nearby trees had grown and were reducing their yield. They could not afford additional panels on a different side of the house.

The non-efficient dwelling group also presented two outlier households. These extraordinarily high electricity uses on ‘typical September’ days may have been due to a combination of inefficient thermal envelope, intensive and prolonged electric heating and inefficient appliances in one case and relatively high hot water use in the other.

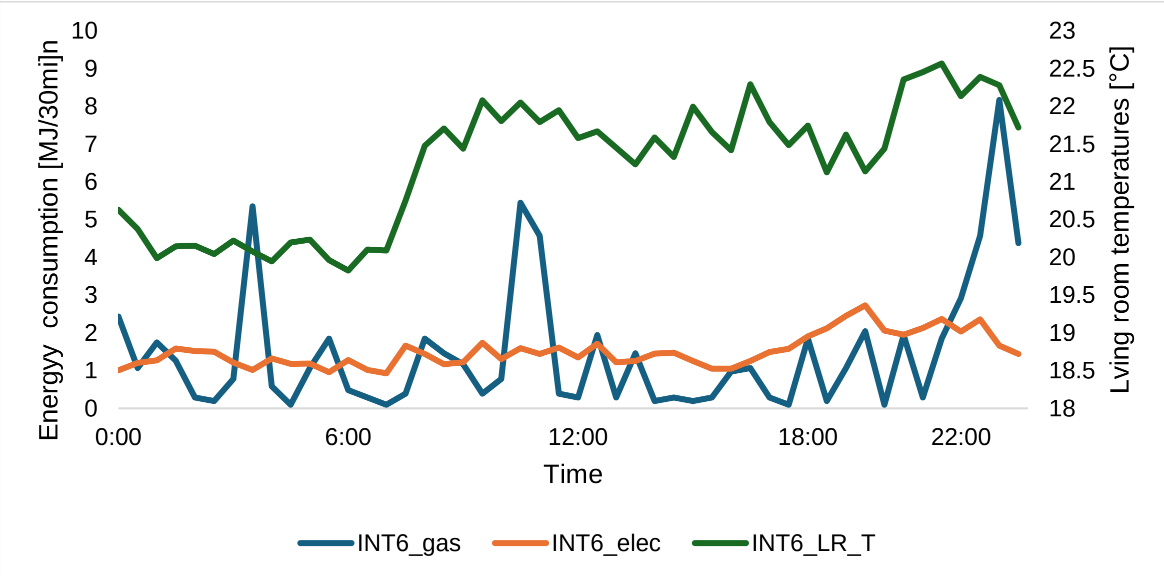
INT6 (73 MJ/day) was a middle-income non-CALD household of two retirees living in a weatherboard home with single glazing and LED lighting but no solar PVs and being at home most of the time. Their half-hourly electricity use (cf. Figure 20) did not drop below 0.9 MJ and peaked in the evening (2.7MJ/30min; 7.30 pm-8.00 pm). Even though they had an 18-year-old gas room heater, they only used an electric split system to heat the living room. The split system was set to 21-22°C during the day and 17°C at night “because it’s been a bit cold this winter, I’ve had it on overnight actually […] And as you get a bit older, it's just nice to wake up to a slightly warmer house, and why not?" Indeed, with an average 21.7°C, the INT6 living room was one of the warmest in this group. Bubble wrap on the living room windows may have protected from even higher electricity use. The householder noted that it "made all that difference" even though "it's not very aesthetically pleasing".

The new but relatively inefficient washing machine may also have contributed to the high electricity use. The woman rationalised her - perhaps poor - choice by pointing out that behaviours were more important than ratings:

*"I went for the features and the price. And I think it's only got two and a half stars or something, I looked at that later and thought, oh, no, whatever. And then it might really have five stars but then it is how you use it too. You can be zapping it every day and then if you go and do your washing, manage your washing, you can wash one shirt, so it goes through a fifty-minute cycle. What - those stars are - yeah, it's a guide but it doesn't make, I don't bother with them."*

The bedroom (no monitored data available) was unheated or rather "just [by] convection". In the bathroom, the couple kept warm with the help of heat lamps.

**Figure 20 INT6 – Diurnal variation of energy consumption and living room temperatures throughout a 'typical September' day.**

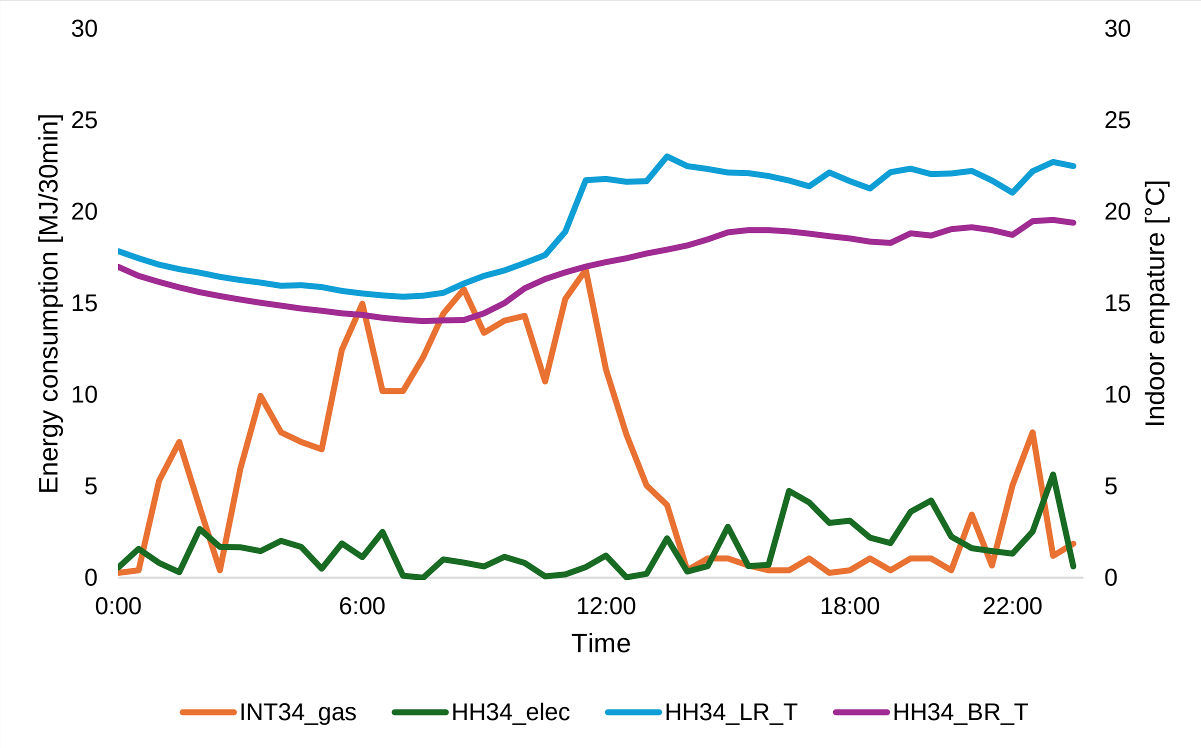



The highest electricity use, however, was found in HH34 (77 MJ/day). HH34 was a low-income non-CALD household with six adults and one child living in a brick veneer home with reported wall and roof insulation and solar PVs. The home was continuously occupied. They only used the six months old gas ducted heating to achieve spatial warmth. They were very satisfied with the heating, which they set at 21°C. They reportedly "only put the heater on in the evening at about four or 5 o'clock", which, however, did not easily agree with the predominant gas use during the first half of the 24h day.

The high electricity usage seemed surprising consider the 18 solar panels, which were reportedly "working fine", and the reported practice of using "more or less we're washing during the day, not at night" and the limited use of the clothes dryer. The householder explained the persistently high bills with the private hot tub:
*"The solar panels heat the spa, so our electricity bill is still quite high because we have a spa which is running electricity all the time keeping it hot, it's always heating so we still have a bill."*

The spa was “set to 37 degrees. That is 37 in summer and 38 in winter”. The electricity usage presented three pronounced peaks (Figure 21) that were higher than any other household’s half-hourly electricity usage in this group: 4.7MJ/30min (4.30 pm-5.00 pm), 4.2MJ/30min (8.00 pm-8.30 pm), and 5.6.7MJ/30min (11.30 pm-12.00 am). These peaks may have been associated with spa use. High electricity bill caused her anxiety: “Sometimes I freak”. The Powerpal application on the householder’s phone told her that they spent “about $3.55 per day”. Winter energy concession would have reduced her bills. The evening peak in gas may have been due to her three sons’ reportedly 10-min long showers. The house had a gas hot water storage system.

**Figure 21 HH34 – Diurnal variation of energy consumption and indoor temperatures throughout a 'typical September' day.**




### 4.2.2 Relationship of daily mean total electricity consumption at daily mean outdoor temperatures - efficient/non-efficient dwellings

Figure 22 shows the comparison of the daily mean total electricity consumption for the efficient and non-efficient dwelling groups in relation to the daily mean outdoor temperatures. On average, the daily mean total electricity consumption in both energy and non-energy efficient dwelling groups presented a negative association with the mean outdoor temperatures. The visual analysis of the graph reveals that the daily mean total electricity consumption in the energy efficient dwellings appeared to have been lower than those in non-efficient dwellings across all outdoor temperature levels. However, the difference in daily mean total electricity consumption between the two groups appeared to remain even during colder and warmer winter days.

**Figure 22 Comparison of daily mean total electricity consumption at daily mean outdoor temperatures - efficient/non-efficient dwellings**

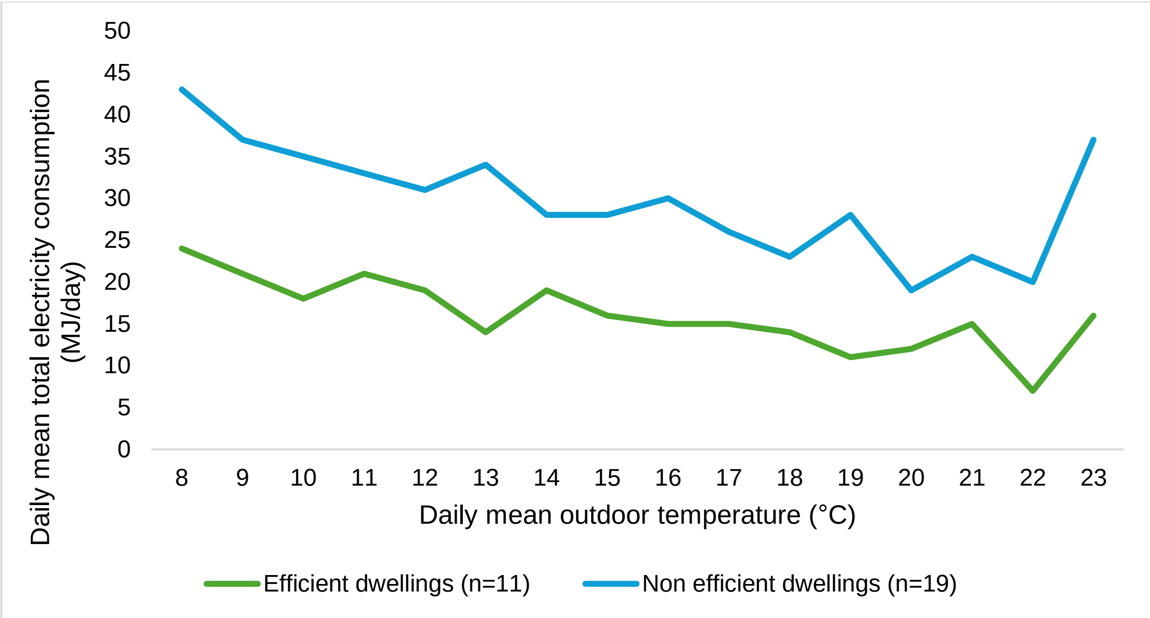
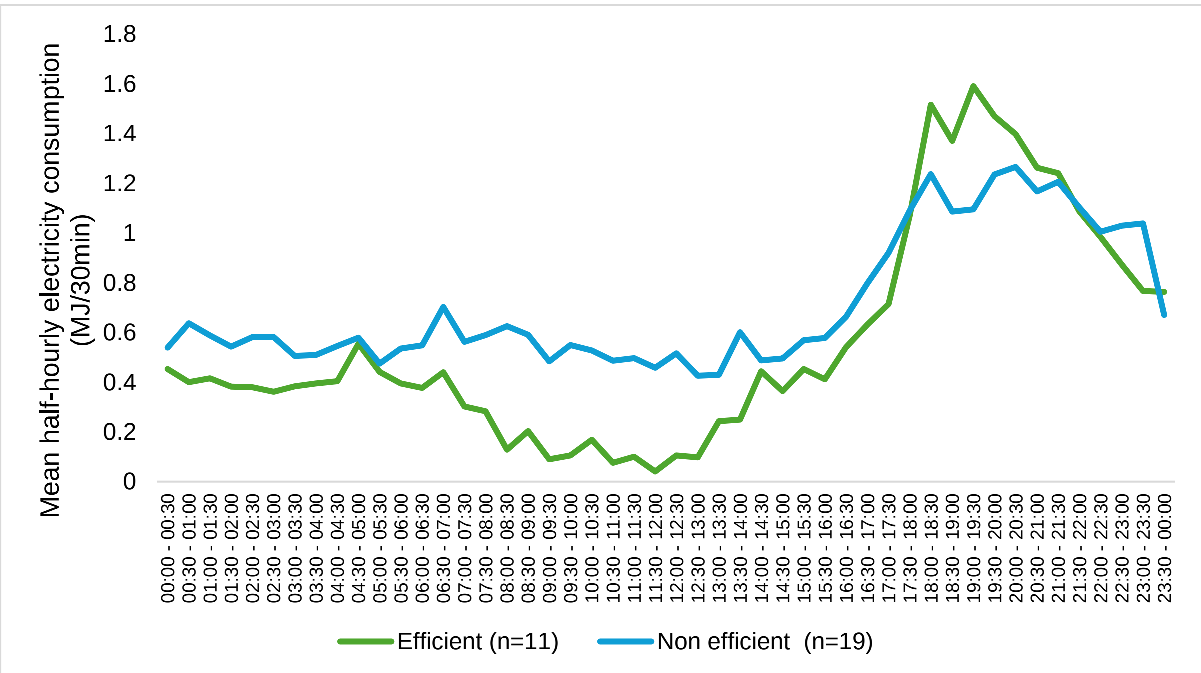



Figure 23 compares the diurnal variations in average half-hourly electricity consumption on typical' September day of efficient and non-efficient dwellings. The distribution of electricity use in both groups shows a peak in the afternoon. The average electricity consumption appears to be higher in the non-efficient dwellings from midnight to the evening. However, the average electricity consumption becomes higher and the peaks more pronounced in the efficient dwellings group in the evening (6.00 pm – 9.30 pm).

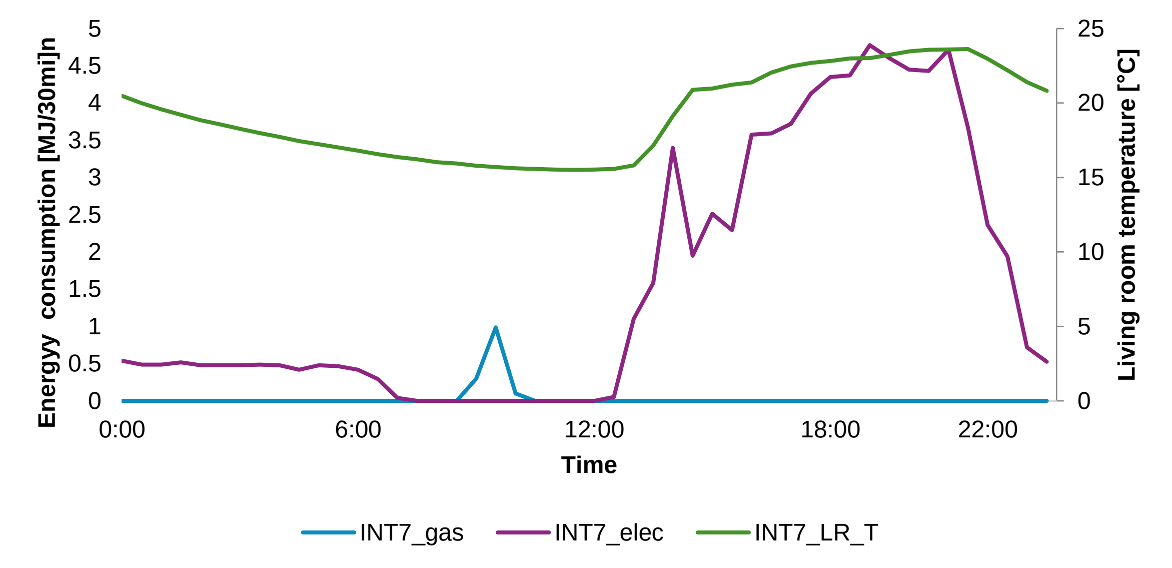
**Figure 23 Comparison of diurnal variations of mean half-hourly electricity consumption in efficient and non-efficient dwellings on days with a daily mean outdoor temperature of 11$^0$C**



### 4.2.3 Explanations of diurnal variations of mean half-hourly electricity consumption in efficient and non-efficient dwellings on days with a daily mean outdoor temperature of 11°C

INT7 in the efficient dwelling group presented high electricity use in the afternoon till 9.30 pm in the evening. INT7 used the electric system split system as a default. The high electricity use coincided with the times of warmth in the living room (Figure 24). The octogenarian switched on the ducted gas heating system only occasionally to heat their daughter's bedroom. As a consequence, gas usage was low in this home.

**Figure 24 INT7 – Diurnal variation of energy consumption and indoor temperatures throughout a 'typical September' day.**




## 4.3 INDOOR TEMPERATURES

This section provides the results from the analysis of the indoor temperature data in September 2023 with respect to efficient and non-efficient homes. Living room temperature data was available for 11 efficient homes and 19 non-efficient homes. The range of daily mean living room temperatures on the coldest days and warmest days was bigger in the efficient group of dwellings than in the non-efficient group of dwellings (Table 6).

**Table 6 Descriptive statistics of daily mean living room temperatures in relation to daily mean outdoor temperatures**

| Daily mean outdoor temperature (°C) | Daily mean living room temperatures | | | | | |
|---|---|---|---|---|---|---|
| | Efficient group (n=11) | | | Non-efficient group (n=19) | | |
| | Min (°C) | Max (°C) | Range (°C) | Min (°C) | Max (°C) | Range (°C) |
| **8** | 13 | 22 | 9 | 13 | 21 | 8 |
| **11 ('typical' September day)** | 13 | 24 | 11 | 14 | 22 | 8 |
| **23** | 20 | 25 | 5 | 21 | 22 | 1 |

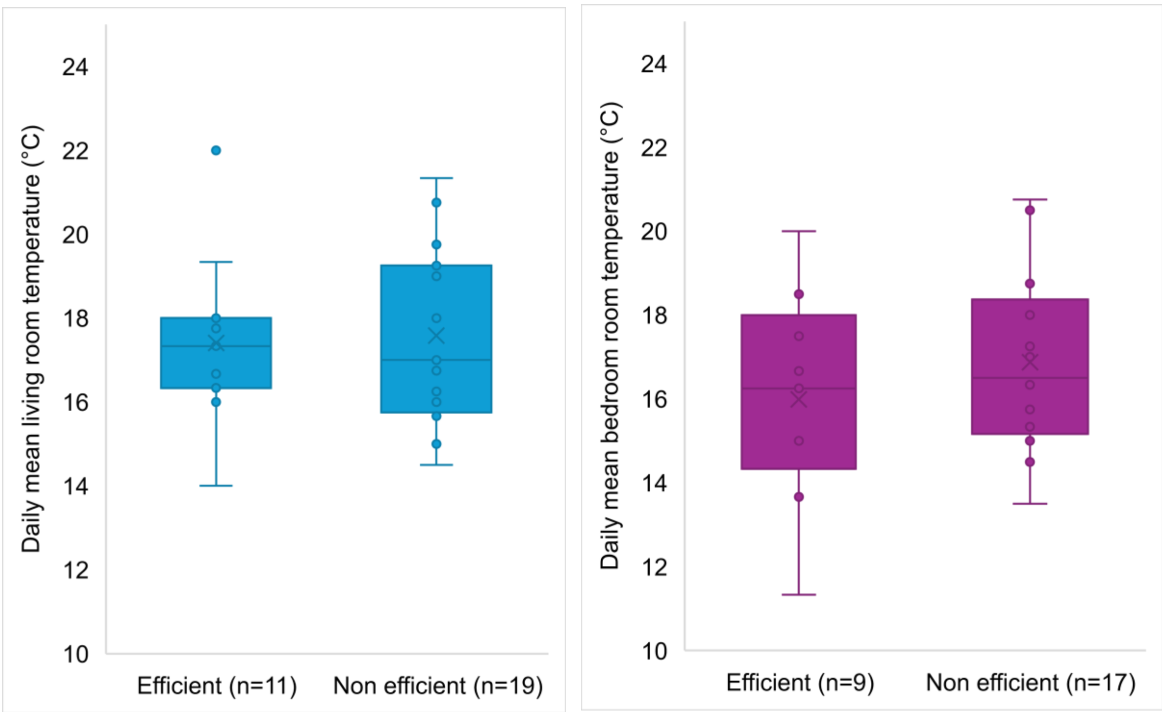
The bedroom temperature data was available for 11 efficient homes and 17 non-efficient homes. The range of daily mean bedroom temperatures on the coldest days was bigger in the non-efficient group of dwellings than in the efficient group of dwellings (Table 7). However, the range of daily mean living room temperatures on the warmest days was higher by one degree of Celsius in the efficient group of dwellings than in the non-efficient group of dwellings (Table 7).

**Table 7 Descriptive statistics of daily mean bedroom temperatures in relation to daily mean outdoor temperatures**

| Daily mean outdoor temperature (°C) | Daily mean bedroom temperatures | | | | | |
|---|---|---|---|---|---|---|
| | Efficient group (n=11) | | | Non-efficient group (n=17) | | |
| | Min (°C) | Max (°C) | Range (°C) | Min (°C) | Max (°C) | Range (°C) |
| **8** | 14 | 19 | 5 | 12 | 21 | 9 |
| **11 (‘typical’ September day)** | 13 | 20 | 7 | 13 | 21 | 8 |
| **23** | 21 | 24 | 3 | 20 | 22 | 2 |

Figure 25 presents the box plots comparing the daily mean living room and bedroom temperatures between the groups. The interquartile range of the efficient group is lower than the non-efficient group in the daily mean living room temperatures. However, the efficient group has a higher interquartile range than the non-efficient in daily mean bedroom temperatures. With regards to the daily mean living room temperatures, the non-efficient group shows a higher dispersion than those for homes in the efficient group. As shown in Figure 25, daily mean living room temperatures of efficient homes and non-efficient homes are right skewed. The daily mean bedroom temperatures of non-efficient homes are right skewed which indicates higher daily mean bedroom temperatures on ‘typical’ September days. An outlier is presented above the whiskers of the box plot of the daily mean living room temperatures of efficient homes: HH40 (22$^0$C) was the Indian family that heated their home all day and night to 23-24°C.

**Figure 25 Box plot for mean indoor temperature on days with a daily mean outdoor temperature of 11 $^0$C**



### 4.3.1 Explanations of highest and lowest living and bedroom temperatures on days with a daily mean outdoor temperature of 11 0C in each group (efficient/non-efficient homes)

In the efficient dwellings group, INT7 had the highest daily mean living room temperature (19$^{0}$C) on a 'typical' September day. As explained above, the older householder ran the electric heating all day in the winter. HH45 had the lowest daily mean living room temperature (14$^{0}$C) on a 'typical' September day in the efficient dwellings group because the household compromised on spatial warmth. INT2 and INT6 had the highest daily mean living room temperature (21$^{0}$C) on a 'typical' September day in the non-efficient dwellings group. These households are both older people who are at home during the day and run the heating all day on a thermostat set around 21$^{0}$C.

HH39 and HH43 had the lowest daily mean living room temperature (15$^{0}$C) on a 'typical' September day in the non-efficient dwellings group. HH39 was a middle-income non-CALD household with four adults. Even though someone was home almost all of the time, they had little functional heating. The split system in the back lounge room was "too noisy" for use, and the electric wall mounted radiant panel heater was not effective, so that the participants just used a blanket at night. The gas wall heater in the main lounge room was also broken, which explained the cold in the home. HH43 were a family and included people who worked from home. Even though the household was classified as a high income, they tended to use extra clothes and an electric lap blanket rather than running the gas heating during the daytime to reduce costs.

With regards to the daily mean bedroom temperatures, the efficient group shows a higher dispersion than those for homes in the efficient group. INT1 had the highest daily mean bedroom temperature (20$^{0}$C) on a 'typical' September day in the efficient dwellings group. The layout of the house meant that the bedroom was effectively heated with the living area. They only ran the gas heating in the mornings and evenings, but the energy efficiency of the house seemed to have helped retain the heat during the day.

INT14 had the lowest daily mean bedroom temperature (11$^{0}$C) on a 'typical' September day in the efficient dwellings group. INT14 was a large house, and the participant repeatedly made reference to the home's high ceilings, and they did not heat the bedrooms. The participant described the cold in the bedrooms:

*"The kids spend a lot of time sitting in bed with their doonas up watching their devices, so they sit under their doonas. And it's, "Pop on a jumper", or "Pop on your socks", or whatever the case may be."*

INT12 and HH44 had the highest daily mean bedroom temperature (21$^{0}$C) on a 'typical' September day in the non-efficient dwellings group. As explained earlier, INT12 was a family with young children. They heated the bedrooms of their house due to concerns about children's health. HH44 were a CALD household who felt the cold at night and ran their ducted gas heating all night.

HH39 had the lowest daily mean bedroom temperature (14$^{0}$C) on a 'typical' September day in the non-efficient dwellings group. As explained above, HH39 had little functional heating, and the participants judged the heating of her home to be inadequate. Bedrooms were only heated indirectly through convection from the living area, but that was, as presented above, very low, too.

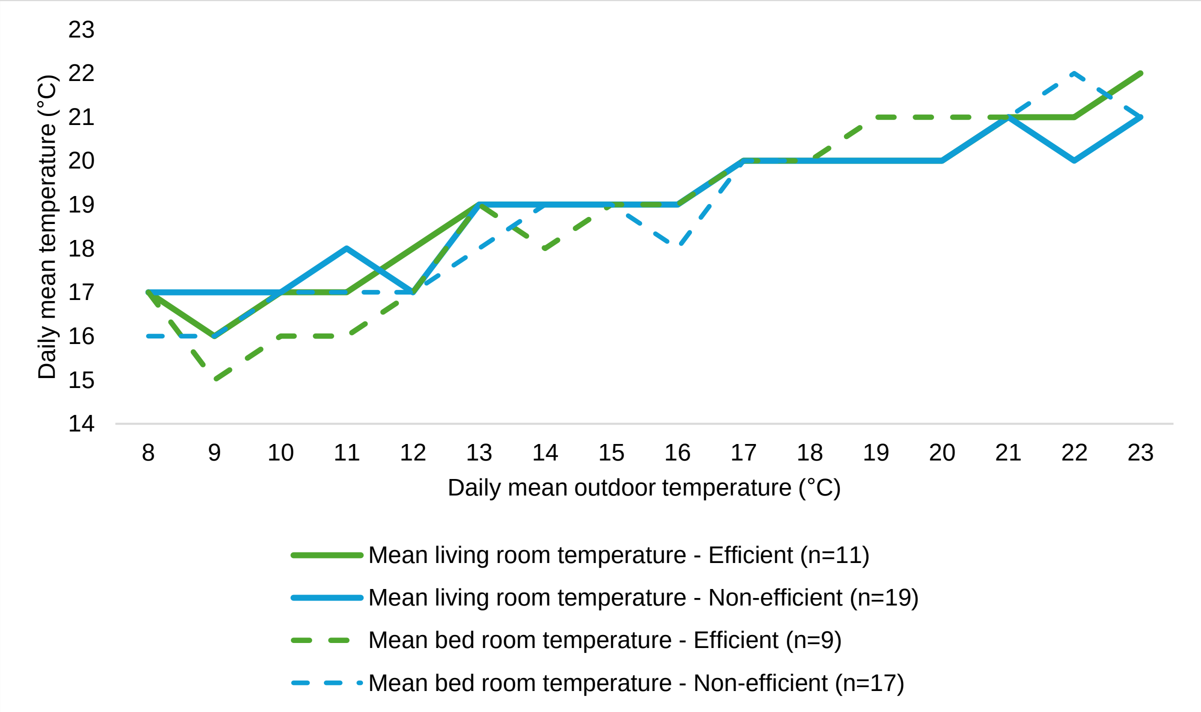
### 4.3.2 Relationship of average daily mean living room temperatures and bedroom temperature at daily mean outdoor temperatures - efficient/non-efficient dwellings

Figure 26 shows the comparison of the average daily mean living room temperatures and bedroom temperatures for the efficient and non-efficient dwelling groups in relation to the daily mean outdoor temperatures. On average, the mean daily living room temperatures and bedroom temperatures in both energy and non-energy efficient dwelling groups presented a positive association with the daily mean outdoor temperatures. The visual analysis of the graph reveals that the mean indoor living room temperatures in the non-energy efficient dwellings appeared to be higher than those in efficient dwellings in lower outdoor temperature levels. The mean indoor living room temperatures in the energy efficient dwellings appeared to be higher than those in non-efficient dwellings in warmer outdoor temperature levels. However, there is no difference in living room warmth between the two groups when the outdoor temperature was between 13°C to 21°C. During periods of "typical' September days with a daily mean outdoor temperature of 11°C, the difference in warmth between these two dwelling groups was 1°C.

Many homes in both groups presented daily mean living room temperatures below the recommended threshold of 18°C at lower temperatures (e.g. efficient homes - INT1, HH45 and HH29, non-efficient homes NT9, HH43 and HH39). The mean bedroom temperatures in the energy efficient dwellings appeared to be higher than the non-efficient dwellings at 8°C, 13 °C, 15-17°C, 19-20 °C and 23°C. During periods of "typical' September days with a daily mean outdoor temperature of 11°C, the difference in warmth between these two dwelling groups is 1°C which seemed to be negligible. The mean indoor bedroom temperatures of HH39 (non-efficient dwelling) were the same as the daily mean outdoor temperature at 13°C, 15°C and 16°C. The near equalness of indoor and outdoor temperatures reflected the lack of a functional heating system in this dwelling.

Further, it was observed that several homes had mean bedroom temperatures less than the daily mean outdoor temperature. For example, INT18 (non-efficient dwelling) presented a mean indoor bedroom temperature of 15°C when the daily mean outdoor temperature was 16°C. This seeming paradox may perhaps be explained by the lack of heating in this bedroom and possibly the lack of solar gain. On a 'typical September' day, the bedroom temperatures did not reach 16°C. If the room window was not facing north or was shaded by blinds or curtains drawn in this room, the room may have missed out on solar heat gain. HH42 (efficient dwelling) presented a mean indoor bedroom temperature of 21°C at a daily mean outdoor temperature of 23°C. Mean outdoor temperatures of 23°C are more common in the Melbourne summer than in winter. Hence the recently retrofitted dwelling of HH42 demonstrated good summer performance by keeping the bedroom cool. [4]

**Figure 26 Comparison of daily mean indoor temperature at daily mean outdoor temperatures - efficient/non-efficient dwellings**




[4] https://en.climate-data.org/oceania/australia/victoria/melbourne-764100/
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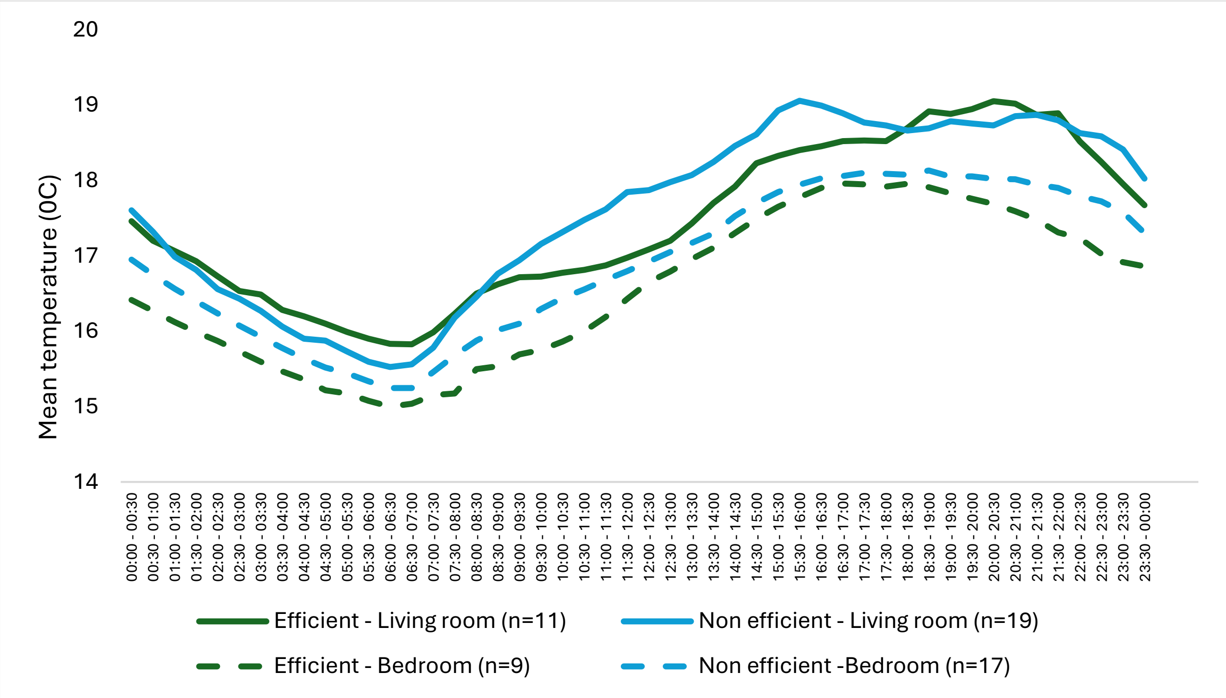
Figure 27 presents the diurnal variations of mean living room and bedroom temperature on 'typical' September days with a daily mean outdoor temperature of 11°C in efficient and non-efficient dwellings respectively. The living room temperatures in both groups dropped overnight until about 6.30 am. The kink in the graphs suggests that heating devices were switched on between 6.30 am and 7.30 am. The mean living room temperatures of the efficient dwellings group rose during the day and afternoon until they peaked in the evening. The peak in the efficient homes was more pronounced whereas the living room temperatures achieved a plateau around 6.30 pm and stayed at this level of warmth until about 9.30 pm. The mean living room temperatures of the non-efficient dwellings group rose during the day and afternoon until they peaked in the late afternoon at 3.30 pm. The living room temperatures of the non-efficient dwellings achieved a plateau around 6.00 pm and stayed at this level of warmth until about 10.00 pm.

Efficient homes such as HH40 (at all times) and INT7 (4.30 pm to 10.00 pm) presented higher living room temperatures than the other homes in the efficient group on typical September days as reflected in high gas usage (HH40) and high electricity usage (INT7). HH45 (an efficient dwelling) presented lower living room temperatures than the other homes in the efficient group at all times on 'typical' September days as reflected in low energy use. The non-efficient home INT2 presented higher living room temperatures (8.30 am -11.00 am and 5.30 pm – 11.00 pm), and HH39 presented lower living room temperatures on 'typical' September days. In both efficient and non-efficient homes, bedroom temperatures appeared to be lower than living room at all times. However, bedroom and living room temperatures appeared to be closer to one another in efficient than in non-efficient homes. The non-efficient group appears to present a higher bedroom temperature at any time of the day than the mean bedroom temperature of the efficient group. Efficient home INT1 presented higher bedroom temperatures and INT4 presented lower bedroom temperatures on 'typical' September days. Non-efficient home INT2 presented higher bedroom temperatures and HH39 presented lower bedroom temperatures on 'typical' September days. The diagram reveals that both groups include households in which the living rooms and bedrooms were underheated in the sense that they did not reach the minimum level of 18°C as recommended by the World Health Organisation (2018) to safeguard health.

**Figure 27 Comparison of diurnal variations of mean half-hourly indoor temperature in efficient and non-efficient dwellings on days with a daily mean outdoor temperature of 11$^{0}$C**



## 4.4 SUMMARY

Whether or not a household has an energy efficient house is a predictor of gas use on average i.e. households with an energy efficient design use less gas on average than those with a non-efficient design. Also, the highest gas use households live in non-efficient houses. Having said that there is substantial overlap between the two groups and household behaviours play a large role in determining gas use. The highest gas use in the energy efficient house category has a gas use close to double the average for the non-efficient houses group due to their practice of leaving the gas heating running continually through the winter. Energy efficient dwellings show lower gas use at all external ambient temperatures, but the difference is greatest at the lowest outdoor temperatures.

Both groups show a peak in gas use in the evenings when people tend to be relaxing at home and in need of ambient heating as the outside temperature falls. Non efficient households also show a distinct morning peak, likely due to the energy required to compensate for higher overnight heat loss. This is exacerbated by the apparent desire for householders with non-efficient homes to heat their houses to a slightly higher temperature and heat bedrooms as well as living areas. This is likely to be as a result of other demographic characteristics of this group. Householders with non- efficient homes tend to be older with a preference for a warmer home and often retirees who are at home during the day.

Whether or not a household has an energy efficient house is also a predictor of electricity use on average and this applies across all outdoor temperatures. Generally speaking, households with high electricity consumption are those that use (mainly) electric heating options, but this is not always the case. The household with the highest gas consumption (and gas heating) also shows the highest electricity consumption. Variation in electricity usage during the day follows a similar pattern to gas usage. Both groups show an evening peak and a much smaller morning peak. Electricity use in efficient homes is generally lower, possible due to design but also likely due to occupancy patterns as described above. This group has higher electricity consumption in the endings, likely due to higher use of electronic entertainment and communication devices than liked to the design of the home.

As noted above, the efficiency of the home design was not a good predictor of indoor temperature.

# 5 Household size – low and non-low household size

This section presents preliminary results for gas consumption, electricity consumption and indoor temperatures disaggregated by the size of the household.

## 5.1 GAS USAGE

This section presents the gas consumption data with respect to low and non-low household sizes. Gas data was available for 32 homes (12 low household size and 20 non-low household size) for September 2023. As shown in Table 8, the range of daily mean total gas consumption of non-low household size homes is higher than the low household size homes on the coldest days. However, the opposite can be observed on warmer days, where the range of daily mean total gas consumption of low household size homes is higher than the non-low household size homes. The group of low household size homes presented a lower minimum, average and maximum consumption value during coldest and the typical' September days. However, the minimum consumption on 'typical' September day of both low and non-low household size groups were zero consumption. However, the average and the maximum consumption on the 'typical' September day were higher in the non-low household size than the low household size group.

**Table 8 Descriptive statistics of daily mean total gas consumption in relation to daily mean outdoor temperatures**

| Daily mean outdoor temperature (°C) | Daily mean total gas consumption (MJ/day) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Low household size (n=12) | | | | Non-low household size (n=20) | | | |
| | Min | Ave. | Max | Range | Min | Ave. | Max | Range |
| **8** | 5 | 6 | 7 | 2 | 100 | 294 | 649 | 550 |
| **11 ('typical' September day)** | 0 | 105 | 564 | 564 | 0 | 210 | 602 | 602 |
| **23** | 4 | 35 | 87 | 83 | 2 | 44 | 61 | 59 |

Figure 28 presents box plots comparing the daily mean total gas consumption between the groups on days with a daily mean outdoor temperature of 11 $^{0}$C. Gas consumption data of 30 homes (12 low household size and 18 non-low household size) for September 2023 was considered for the box plot. The interquartile range of the non-low household size group is higher than the low household size group. Also, the non-low household size group showed a higher dispersion of mean gas consumption than those for homes in low household size group. INT7 had the lowest daily mean gas consumption[5] and INT2 had the highest daily mean gas consumption[6] of the low household size homes on a 'typical' September day. INT 18 had the lowest daily mean gas consumption[7] and INT 8 had the highest daily mean gas consumption[8] of the non-low household size homes on a 'typical' September day. Both groups of data appear to be right skewed. The low household size homes consumed gas less than the non-low household size homes. An outlier is presented above the whiskers of the box plot of the low household size group INT5 (378 MJ/day)[9].

[5] INT7 is an older person who runs electric heating all day in the winter but rarely uses gas heating.
[6] INT2 is an older people who runs the gas ducted heating all day on a thermostat set around 21C.
[7] INT18 has moved to a split air conditioning system for heating and a heat pump for hot water by September 2023.
[8] INT8 is a household of older people in a 50-year-old brick veneer house with gas central heating. It has no zoning and runs morning and evening (and sometimes during the day) during the winter.
[9] INT5 is a two-person household – a woman and her disabled daughter. In the very cold weather, they leave the gas heating on overnight at a set point of 17 C.

**Figure 28 Box plot for mean gas usage on days with a daily mean outdoor temperature of 11 $^0$C**

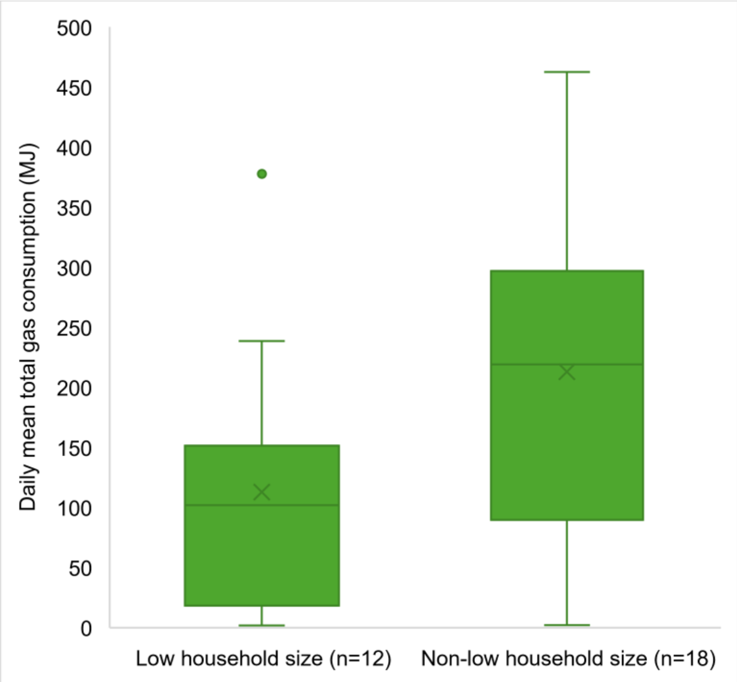



Figure 29 shows the comparison of the daily mean total gas consumption for the low and non-low household size groups in relation to the daily mean outdoor temperatures. On average, the daily mean total gas consumption in both low and non-low household size groups presented a negative association with the mean outdoor temperatures. The visual analysis of the graph reveals that the daily mean total gas consumption in the low household size homes appeared to have been lower than those in non-low household size homes across all outdoor temperature levels. The difference in daily mean total gas consumption between the two groups appeared to be higher during colder days than the warmer days in September. However, when the outdoor temperature is 8$^0$C, the mean total gas consumption of low household size group was very low. This is due to only two households in the group had 8$^0$C mean outdoor temperature (HH29 -7MJ/day and HH45-5MJ'day) and only on one day (2.9.2023). Both homes had lower gas consumption on the day with the outdoor temperature 8$^0$C which resulted in a lower daily mean total gas consumption. Similar occurrence can be observed when the outdoor temperature is 20$^0$C. Only the location of HH29 (9MJ/day) and HH45 (6MJ/day) had the mean outdoor temperature 20$^0$C (19.09.2023). From the non-low household size group, HH39 presented the lowest mean gas consumption of 100 MJ/day[10] and HH28 presented the highest mean gas consumption of 649 MJ/day[11] when the outdoor temperature was 8$^0$C.

[10] HH39 has little functional heating so this is not surprising.
[11] HH28 is an energy efficient home but they leave the gas heating running almost continually during winter (even when they are not at home) with a set point of 22 $^0$C.

**Figure 29 Comparison of daily mean total gas consumption at daily mean outdoor temperatures - low/non-low household size**

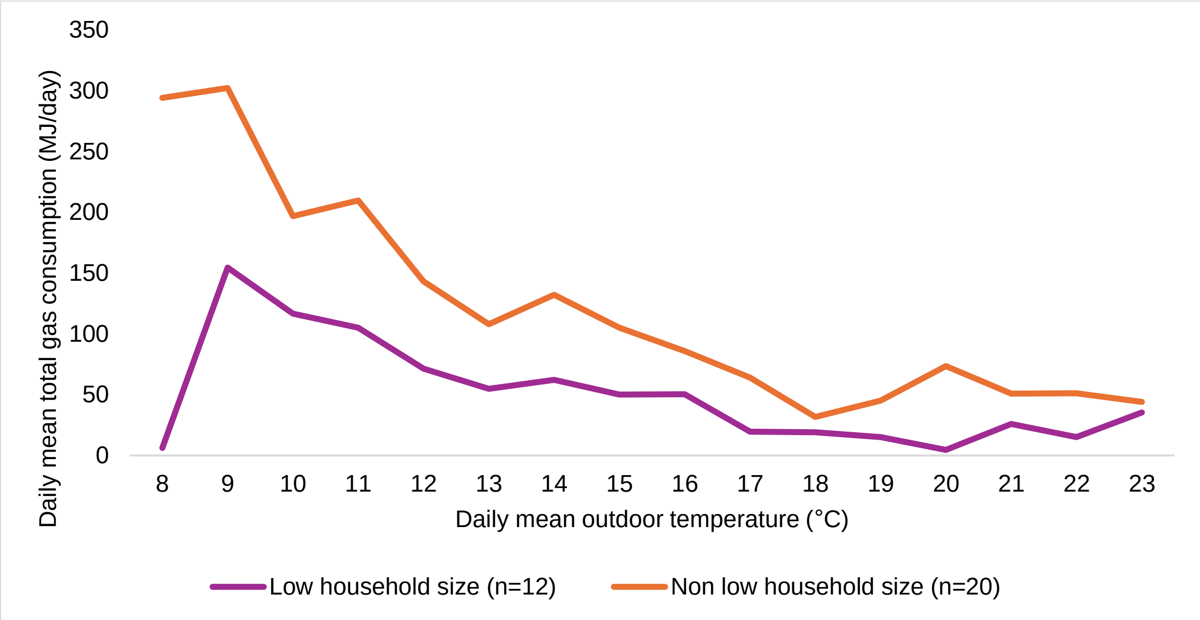
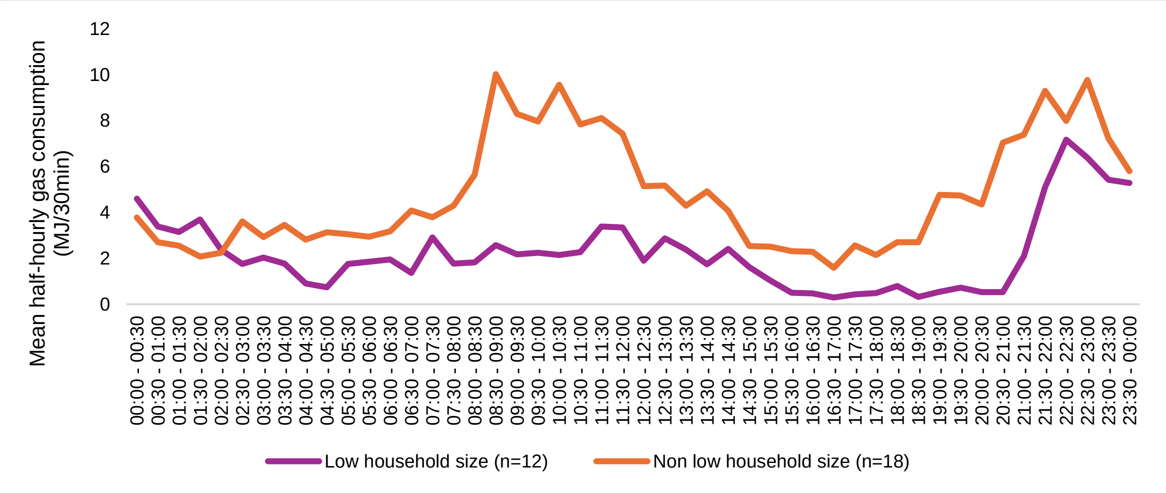



Figure 30 compares the diurnal variations in average half-hourly gas consumption on ‘typical’ September days of low and non-low household size homes. The distribution of half-hourly gas use in both groups is bi-modal. The evening peak in the low household size group of homes is higher than its morning peak. The non-low size group of homes exhibit a higher peak in the morning (starting from 7.00 am to 11.30 am) and evening (starting at 8.30 pm to midnight). The average half-hourly gas consumption appears to be higher in the non-low household size group except for the early morning period (midnight to - 2.30 am). HH41 which is a non-low household size home presented pronounced peaks several times throughout the day (2.30 am – 3.00 am, 6.30 am – 7.00 am, 1.30 am-2.30 am). This could indicate the times the gas heating automatically turned on. INT9 and INT12 in the non-low household size group presented pronounced peak of gas use in the morning. INT12 also presented a pronounced use of gas use in the evening between 10.30 pm and 11.00 pm. As already described in Section 4.1, these peaks are likely due to hot water usage. INT8 showed high use of gas in the evening 9.00 pm -10.30 pm. INT5 in the low household size group presented a pronounced use of gas use in the early morning at 1.30 am – 2.00 am, mid-morning 10.30 am to 12.00 pm, 1.00 pm to 2.30 pm. INT1 in the low household size group had a higher use of gas use in the evening between 10.00 pm and 10.30 pm. Detailed reasons for all of these trends were given in Section 4.1 and relate to heating and hot water use behaviours.

**Figure 30 Comparison of diurnal variations of mean half-hourly gas consumption in low and non-low household size on days with a daily mean outdoor temperature of 11 $^0$C**




## 5.2 ELECTRICITY USAGE

This section presents the electricity consumption data with respect to low and non-low household sizes. Electricity data of 30 homes (12 low household size 18 non-low household size) was considered in this analysis.

As shown in Table 9, The range of daily mean total electricity consumption on the coldest days was higher in the non-low household size group. However, the range of daily mean total electricity consumption on the warmest days was higher in the low household size group. The group of non-low household size homes presented lower minimum on the coldest days and 'typical' September days when the temperature was 11 °C. Further, the group presented a lower maximum on the 'typical' September days and the warmest days. Low household size group had the same average daily mean total electricity consumption on the coldest days and the 'typical' September days.

**Table 9 Descriptive statistics of daily mean total electricity consumption in relation to daily mean outdoor temperatures**

| Daily mean outdoor temperature (°C) | Daily mean total electricity consumption (MJ/day) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Low household size (n=12) | | | | Non-low household size (n=18) | | | |
| | Min | Ave. | Max | Range | Min | Ave. | Max | Range |
| **8** | 12 | 28 | 45 | 33 | 8 | 32 | 85 | 77 |
| **11 ('typical' September day)** | 8 | 28 | 93 | 85 | 6 | 29 | 85 | 79 |
| **23** | 10 | 27 | 55 | 45 | 15 | 23 | 49 | 34 |

Figure 31 presents a box plot comparing the daily mean total electricity consumption between the groups on days with a daily mean outdoor temperature of 11 $^0$C. The interquartile range of the low household size group is slightly higher (21MJ/day) than the non- low household size group (16MJ/day). However, the non- low household size group shows a higher dispersion of mean electricity consumption than those for homes in the low household size group. HH29[12] had the lowest daily mean electricity consumption and HH22[13] had the highest daily mean electricity consumption of the low household size

[12] HH29 is a two person CALD household originally from a cold part of the world. They run heating sparingly, have solar panels and are generally very energy conscious.
[13] HH22 is a two person household, but it is a share house so effectively two households in one.

group of homes on a 'typical' September day. HH32[14] and HH28[15] had the lowest daily mean electricity consumption and HH44[16] had the highest daily mean electricity consumption of the non- low household size group of homes on a 'typical' September day. The daily mean electricity consumption of low household size homes is right skewed, and the daily mean electricity consumption of the non-low household size homes appears to be right skewed as well. An outlier is presented above the whiskers of the box plot of the low household size group: INT6[17] (73 MJ/day). Further, two outliers are presented above the whiskers of the box plot of the non-low household size group: INT8[18] (66 MJ/day) and HH34[19] (77 MJ/day).

**Figure 31 Box plot for mean electricity usage on days with a daily mean outdoor temperature of 11 $^0$C**

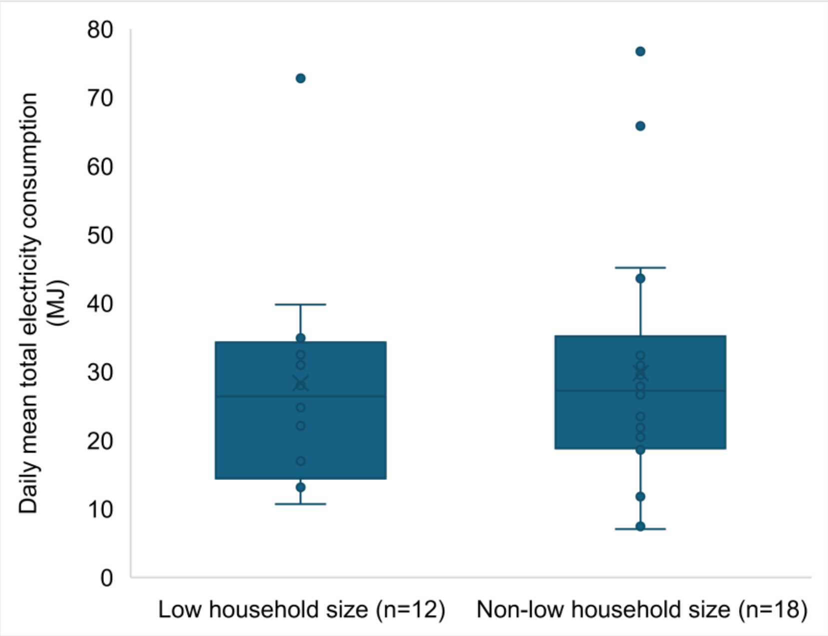



Figure 32 compares the daily mean total electricity consumption for the low and non-low household size groups in relation to the daily mean outdoor temperatures. On average, the daily mean total electricity consumption in both low and non-low household size groups presented a negative association with the mean outdoor temperatures. The visual analysis of the graph reveals that the daily mean total electricity consumption in the low household size group appeared to have been lower than those in the non-low household size group at mean outdoor temperatures such as 8$^0$C, 9$^0$C, 11$^0$C, 14$^0$C, 15$^0$C, 17$^0$C and 20$^0$C. A high peak in the low household size group's daily mean total electricity consumption is shown when the daily mean outdoor temperature is 16$^0$C. There is no significant difference in daily mean total electricity consumption between the two groups across all outdoor temperature levels except 16$^0$C,

[14] HH32 is a household of four people that is almost continuously occupied. It has solar panels (5.5kW). The householders have put a lot of effort into energy saving around the home.
[15] HH28 is an energy-efficient house with very high gas consumption. They run the gas heating continually during the winter so there is never any supplemental electric heating used.
[16] HH44 are a CALD household who feel the cold at night and run their ducted gas heating all night. They are generally not conservative in their energy usage.
[17] INT6 mostly uses a split air conditioning system to provide heating.
[18] INT8 is a household of older people in a 50 year old brick veneer house with gas central heating. It has no zoning and runs morning and evening (and sometimes during the day) during the winter.
[19] HH34 runs a spa with an electric heater. This gives them high electricity usage despite gas heating and solar panels.

17°C, and 22°C. However, the difference in daily mean total electricity consumption between the two groups was minimal during the warmest days of September 2023.

**Figure 32 Comparison of daily mean total electricity consumption at daily mean outdoor temperatures - low/non-low household size**

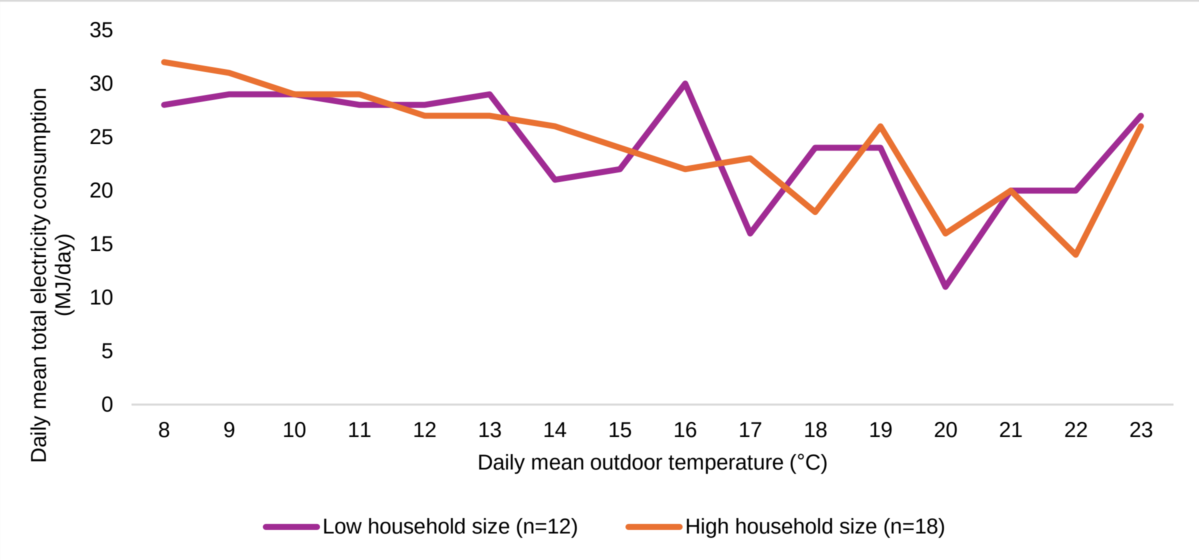
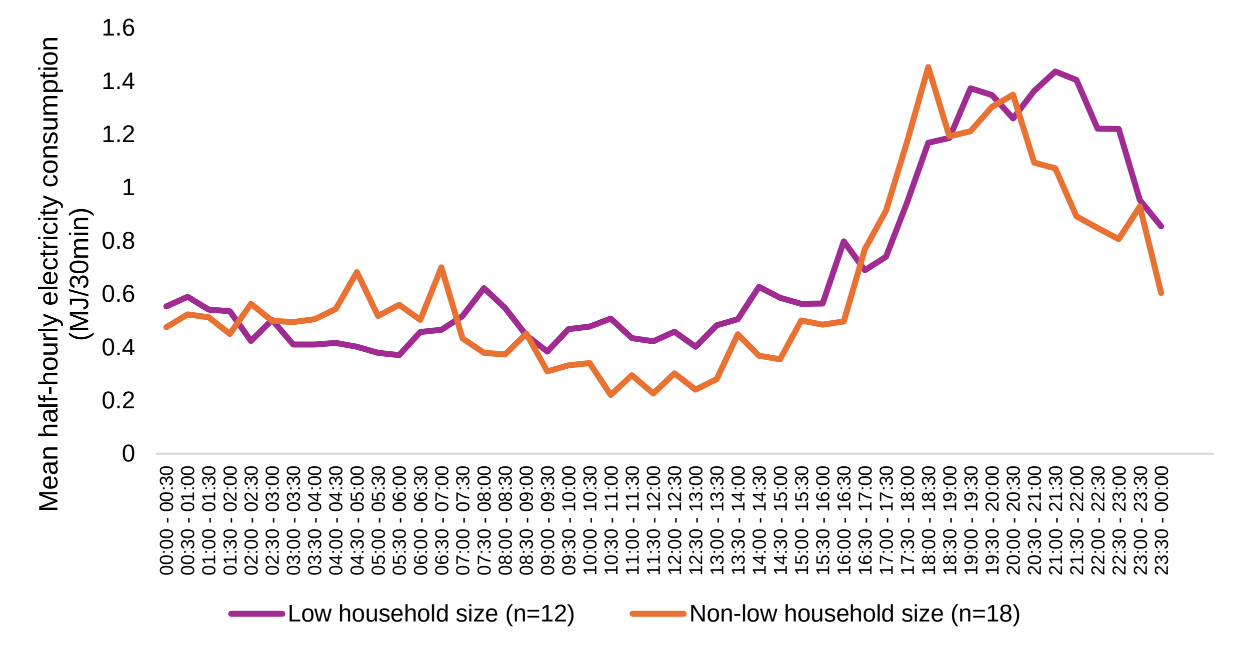



Figure 33 compares the diurnal variations in average half-hourly electricity consumption on 'typical' September day of the low and non-low household size groups. The distribution of electricity use in both groups is bi-modal in both groups with the second, higher peak in the afternoon. The average electricity consumption appears to be higher in the non-low household size from 2.00 am to 7.30 am in the morning and 4.30 pm to 7.00 pm and 8.00 pm to 8.30 pm in the evening. However, the average electricity consumption appears to be higher in the low household size group from midnight to 2.30 am, 7.00 am to 9.00 am, 9.30 am to 4.00 pm, 6.30 pm to 8.30 pm and 9.00 pm to midnight. The findings show that the occupants in the low household size homes are present at home or work from home during the day time and the occupants in non-low household size homes are at work or school during the day time. The average electricity consumption peaks are more pronounced in the non-low household size group from 4.30 pm to 7.00 pm in the evening. Whereas in the low household size group, the peaks are more pronounced from 6.30 pm to 11.00 pm in the evening. INT7 in the low household size group presented pronounced peak of electricity use in the afternoon till 9.30 pm in the evening[20]. INT6 also presented a higher electricity consumption during the evening. INT17 showed a spike in electricity consumption from midnight to 2.00 am and 4.00 pm to 5.00 pm. HH22 presented a spike in electricity usage from 6.30 am to 8.00 am and INT16 presented a spike in the electricity consumption from 8.30 pm to 10.30 pm. HH34 in the non-low household size group presented high electricity use from 4.30 pm to 11.30 pm (4.30 pm-6.00 pm, 7.00 pm-9.30 pm, 10.30 pm-11.30 pm). HH34 also presented spikes in electricity use from midnight to 1.00 am, 2.00 am to 7.00 am. HH42 also presented high electricity use from 5.30 pm to 7.00 pm in the evening. INT8 in non-low household size

[20] INT7 is an older person who runs electric heating all day in the winter.

group presented high electricity use from 8.00 am to 12.30 pm. Detailed reasons for these are given in Section 4.1 and generally relate to the use of electric heating and hot water.

**Figure 33 Comparison of diurnal variations of mean half-hourly electricity consumption in low and non-low household size on days with a daily mean outdoor temperature of 11 $^{0}$C**




## 5.3 INDOOR TEMPERATURES

This section presents the indoor temperature data with respect to low and non-low household sizes. Living room temperature data was available for 12 low household size homes and 18 non-low household size homes. The range of daily mean living room temperatures on the coldest days and warmest days was bigger in the non-low household size group than in the low household size group (Table 10). However, the minimum temperature of the low household size group and the non-low household size group is the same on the coldest days. The maximum living room temperature of the low household size on the warmest days is less than the daily mean outdoor temperature (e.g., HH29 & INT6).

**Table 10 Descriptive statistics of daily mean living room temperatures in relation to daily mean outdoor temperatures**

| Daily mean outdoor temperature (°C) | Daily mean living room temperatures | | | | | |
|---|---|---|---|---|---|---|
| | Low (n=12) | | | Non-low (n=18) | | |
| | Min (°C) | Max (°C) | Range (°C) | Min (°C) | Max (°C) | Range (°C) |
| **8** | 13 | 15 | 2 | 13 | 22 | 9 |
| **11('typical' September day)** | 13 | 22 | 9 | 14 | 24 | 10 |
| **23** | 20 | 21 | 1 | 21 | 25 | 4 |

The bedroom temperature data was available for nine low household size homes and 17 non-low household size homes. The daily mean bedroom temperature range on the coldest days was bigger in the non-low household size homes than in the low household size group (Table 11). However, the range of daily mean living room temperatures on the 'typical' September and warmest days were the same in both groups. Both groups had the same minimum and maximum temperatures on the 'typical' September days. However, during the warmest days, the minimum temperature of the low household size group was the same as the maximum temperature of the non-low household size group.

**Table 11 Descriptive statistics of daily mean bedroom temperatures in relation to daily mean outdoor temperatures**

| Daily mean outdoor temperature (°C) | Daily mean bedroom temperatures | | | | | |
|---|---|---|---|---|---|---|
| | Low (n=9) | | | Non-low (n=17) | | |
| | Min (°C) | Max (°C) | Range (°C) | Min (°C) | Max (°C) | Range (°C) |
| **8** | 14 | 16 | 2 | 12 | 21 | 9 |
| **11 ('typical' September day)** | 13 | 21 | 8 | 13 | 21 | 8 |
| **23** | 22 | 24 | 2 | 20 | 22 | 2 |

Figure 34 presents the box plots comparing the daily mean living room and bedroom temperatures between the low and non-low household size groups. The interquartile range of the low household size group is the same as the non-low household size group in the daily mean living room temperatures ($3^0$C). Further, both groups show a similar dispersion of the daily mean living room temperatures on days with a daily mean outdoor temperature of 11 $^0$C.

With regards to the daily mean bedroom temperatures, the low household size group shows a slightly higher interquartile range ($4^0$C) than the interquartile range of the non-low household size group ($3^0$C). However, the dispersion of bedroom temperature of the non-low household size group is far greater than those for homes in the low household size group. As shown in Figure 34, daily mean living room temperatures of low household size homes are right (positively) skewed than in non-low household size homes which indicates lower living room on 'typical' September day. Further, the daily mean bedroom temperatures of low household size homes are right skewed, and the daily mean bedroom temperatures of the non-low household size homes are left skewed.

**Figure 34 Box plot for mean indoor temperature on days with a daily mean outdoor temperature of 11 $^{0}$C**

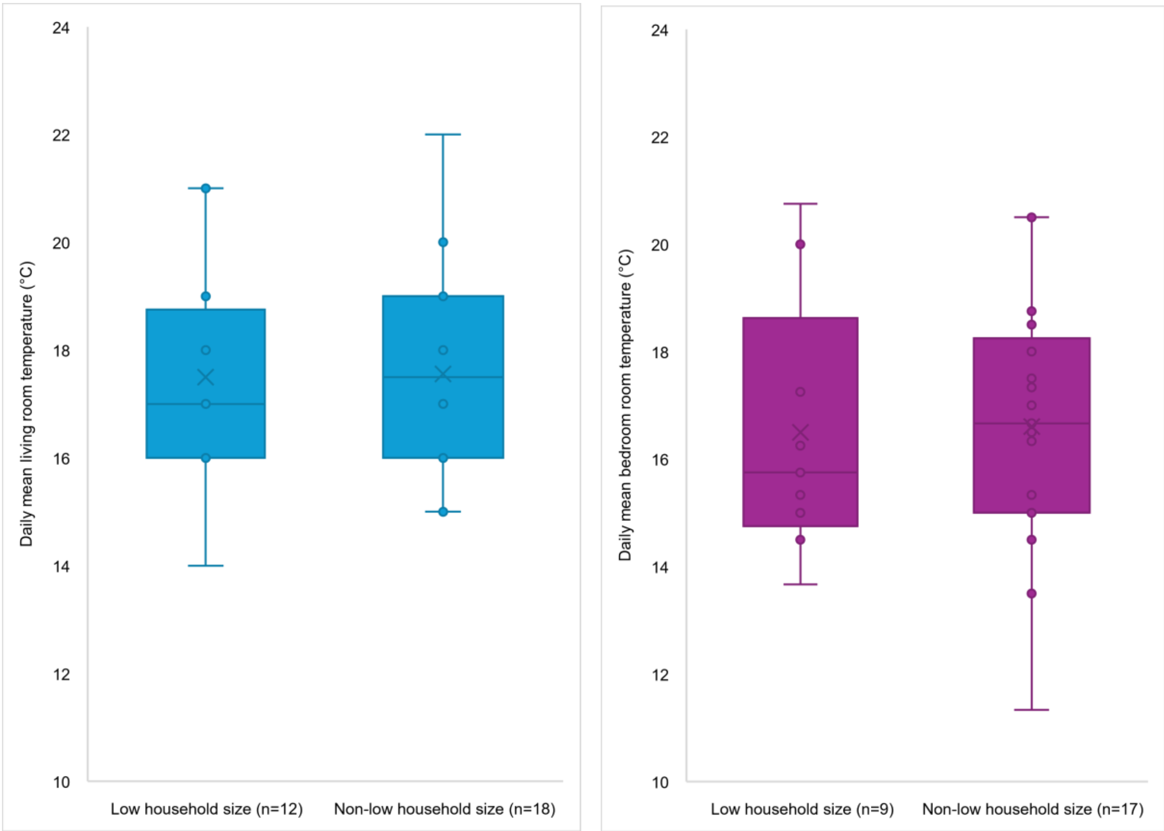



Figure 35 shows the comparison of the average daily mean living room temperatures and bedroom temperatures for the low and non-low household size groups in relation to the daily mean outdoor temperatures. On average, the mean daily living room temperatures and bedroom temperatures in both low and non-low household size groups presented a positive association with the daily mean outdoor temperatures. The visual analysis of the graph reveals that the mean indoor living room temperatures in the non-low household size appeared to be higher than those in low household size at all temperature levels except 9$^{0}$C, 12$^{0}$C, 18$^{0}$C and 22$^{0}$C. The mean indoor bedroom temperatures in the non-low household size appeared to be higher than those in low household size at colder outdoor temperatures (8-12$^{0}$C). Also, it can be noted that the bedroom temperatures in both groups are less than 18$^{0}$C at colder outdoor temperatures (8-12$^{0}$C). Further, not much difference was observed in the living and bedroom temperatures of both groups at warmer outdoor mean temperatures.

**Figure 35 Comparison of daily mean indoor temperature at daily mean outdoor temperatures - low/non-low household size**

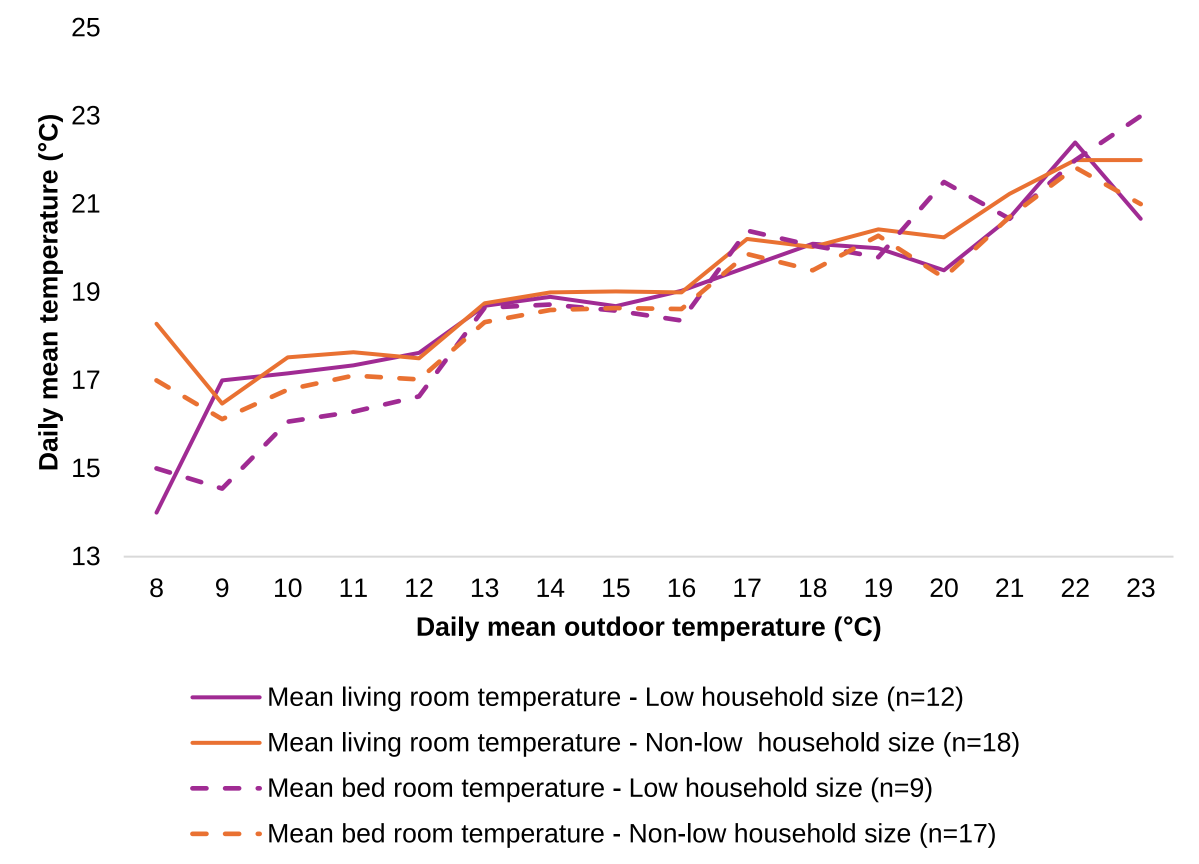
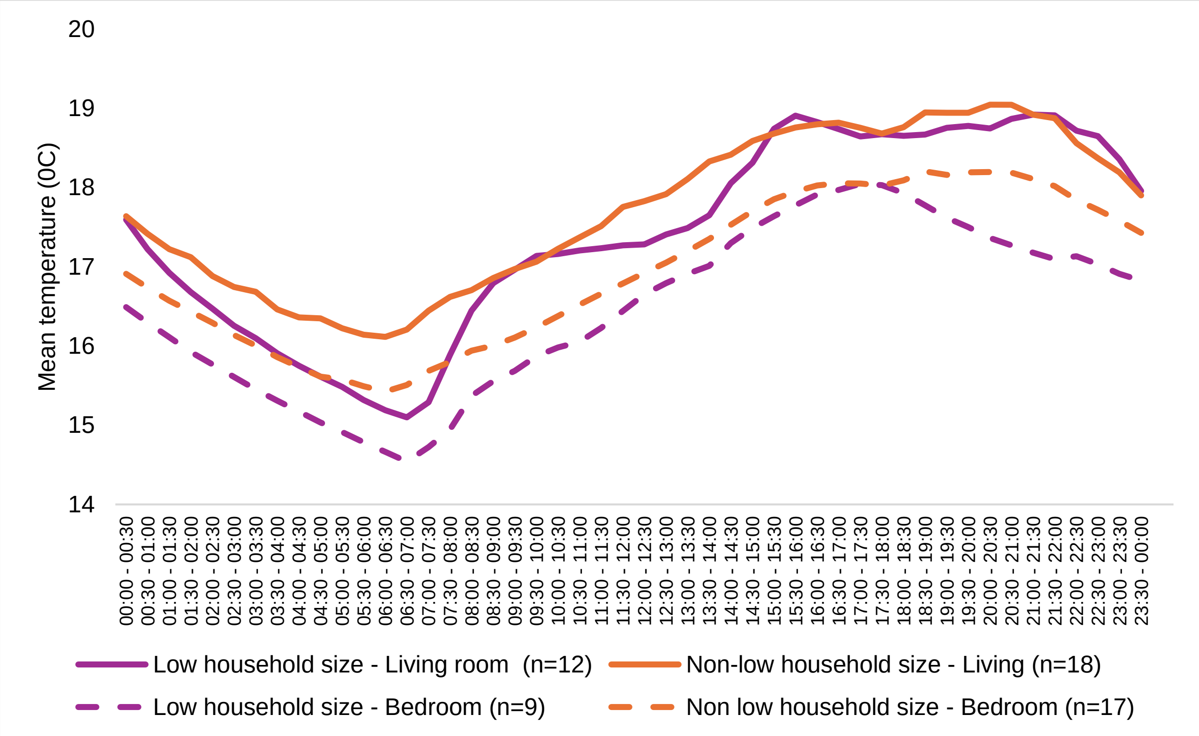



Figure 36 present the diurnal variations of mean living room and bedroom temperature on 'typical' September days with a daily mean outdoor temperature of 11°C in low and non-low household size groups respectively. The living room temperatures in both groups drop overnight until about 6.30 am. The kink in the graphs suggests that heating devices were switched on between 6.30 am and 7.30 am in both groups. The mean living room temperatures of both groups rise during the day and afternoon until they peak in the evening. A slight peak in the living room temperatures of the low household size can be observed at 3.30 pm. The mean bedroom in both groups drops overnight until about 7.00 am. The mean bedroom temperatures of non-low household size groups rise during the day and afternoon until they peak in the evening. However, mean bedroom temperatures of low household size groups rise during the day and afternoon until they peak in the late afternoon and start to drop after 6.00 pm. In both groups, the bedroom temperatures appear to be lower than the living room at all times. The non-low household size group appears to present a higher living room temperature throughout the day than the low household size group except at 9.00 am to 10.30 am, 3.00 pm to 4.30 pm and 9.30 to 11.30 pm. The non-low household size group appears to present a higher bedroom temperature throughout the day than the low household size group except from 5.30 pm to 6.00 pm where both lines intersect. Low household size homes such as INT6 presented higher living room temperatures on typical September days at all times. INT2 presented a spike in the living room temperatures from 8.00 am to 11.00 am and 5.30 pm to 7.00 pm. INT7 presented higher living room temperatures in the evening. These are all older householders. INT17 also showed a spike in the living room temperatures from 3.00 pm to 5.00 pm. Non-low household size homes such as HH40 presented higher living room temperatures on typical September days at all times. HH34 presented higher living room temperatures from 11.30 am to 8.00 pm. HH44 also presented higher living room temperatures after 1.00 pm. HH39 presented lower living room temperatures throughout the night till 11.30 am in the morning on typical September days.

Low household size homes such as INT1 and INT2 presented higher bedroom temperatures on 'typical' September days at all times. INT4 presented lower bedroom temperatures overnight till 11.30 am. Again, these are older householders. Non-low household size homes such as HH44 had higher bedroom temperatures from late afternoon till midnight. INT12 presents higher bedroom temperatures from early morning till afternoon. HH39 presented lower bedroom temperatures throughout the night till 1.30 pm and in the evenings on typical September days.

**Figure 36 Comparison of diurnal variations of mean half-hourly indoor temperature in low and non-low household size on days with a daily mean outdoor temperature of 11 $^{0}$C**




## 5.4 SUMMARY

While household size is a predictor of gas use on average i.e. households with fewer people use less gas on average, specific circumstances can have a significant impact. The highest gas use occurred in a household of low size which was non energy efficient and had a desire to keep the house warm overnight. As such, we see that behaviours regarding home heating vary enormously. There is a factor of 6.5 between the lowest users and the highest users in very cold weather, even though the lowest users are a non-low households, and the high users are in households of low size.

Both groups show a peak in gas use in the evenings when people tend to be relaxing at home and in need of ambient heating as the outside temperature falls. Non-low households also show a distinct morning peak. More of these households are working families with a distinct daily routine that the entire household prepares for in the early morning. They tend to heat the house during that period as they get ready to go to work and school. This is sometimes done by turning heating on and off manually and sometimes using a timer. Households with low size in our sample tend to be older people beyond working age who have a less standard morning routine and so there is no morning peak shown for this group. We see other households running their heating continually, sometimes with a different temperature set point at night. These are the households for which gas usage continues all night.

In contrast, overall electricity use is not a function of household size in our sample. Electricity use is dominated by other factors such as use of electric heating or a continuously running spa heater. Variation in electricity usage during the day follows a similar pattern to gas usage. Both groups show an evening peak and smaller morning peaks, with the peak for non-low households slightly earlier than the peak for households with fewer people, likely because of activity patterns.

Household size is not a good predictor of indoor temperature, although we do see some variation in morning temperatures consistent with the different behaviours of the groups as described above.

# 6 Annual income – Low, mid, and high

This section presents preliminary results for the gas consumption, electricity consumption and indoor temperatures disaggregated by the annual income of the household.

## 6.1 GAS USAGE

This section presents the gas consumption data with respect to low, mid, and high household income groups. Gas data was available for 32 homes (7 low income, 14 mid income and 11 high income) for September 2023. As shown in Table 12, the range of daily mean total gas consumption of low-income group is low in the coldest, 'typical' September day and the warmest temperatures. The range of daily mean total gas consumption is low on the coldest and 'typical' September days in the mid income group. The range is high on the warmest days in the high-income group. High income households present zero gas consumption as a minimum during 'typical' September days. Further, high-income households have a low minimum on the warmest days. The average gas consumption on the 'typical' September day was higher in the low-income group. However, the average gas consumption on the coldest days was considerably higher in the high-income group. The average gas consumption on the warmest days was high in the mid-income group.

**Table 12 Descriptive statistics of daily mean total gas consumption in relation to daily mean outdoor temperatures**

| Daily mean outdoor temperature (°C) | Daily mean total gas consumption (MJ/day) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Low income (n=7) | | | | Mid income (n=14) | | | | High income (n=11) | | | |
| | Min | Ave. | Max | Range | Min | Ave. | Max | Range | Min | Ave. | Max | Range |
| **8** | 7 | 150 | 293 | 286 | 5 | 169 | 404 | 399 | 137 | 316 | 649 | 512 |
| **11 ('typical' September day)** | 8 | 178 | 411 | 403 | 4 | 166 | 504 | 500 | 0 | 171 | 602 | 602 |
| **23** | 4* | 4 | 4 | 0 | 16 | 51 | 87` | 71 | 2 | 40 | 61 | 59 |

Note: The low-income group presented the same value for minimum, maximum, and average due to the outdoor mean temperature of 23 °C being present on 30.09.2023 at only HH29 in the low-income group.

Figure 37 presents box plots comparing the daily mean total gas consumption between the groups on days with a daily mean outdoor temperature of 11 $^{0}$C. Gas consumption data of 30 homes (7 low income, 13 mid income and 10 high income) for September 2023 was considered for the box plot. The interquartile range of the high income group (241MJ) is higher than the low income (224 MJ) and mid income group (207MJ). However, the mid income group showed a higher dispersion of mean gas consumption than those for homes in low income and high income groups. The data of all three groups appear to be right (positively) skewed. The box plot shows that on average low-income homes appeared to consume more gas than mid and high-income homes during a 'typical' September day. HH29 had the lowest daily mean gas consumption and INT5 had the highest daily mean gas consumption of the low-income homes on a 'typical' September day. HH45 had the lowest daily mean gas consumption and INT8 had the highest daily mean gas consumption of the mid income homes on a 'typical' September day. INT7 and INT18 had the lowest daily mean gas consumption and HH28 had the highest daily mean gas consumption of the high-income homes on a 'typical' September day. Details of these households have been described in Section 4.1. The high gas users (INT5, INT8 and HH28) all required warm houses for health reasons or as a general preference. The low gas users are efficient homes who keep their homes at a lower temperature (HH29 and HH45) or have electric heating (INT7 and INT18).

**Figure 37 Box plot for mean gas usage on days with a daily mean outdoor temperature of 11 $^{0}$C**

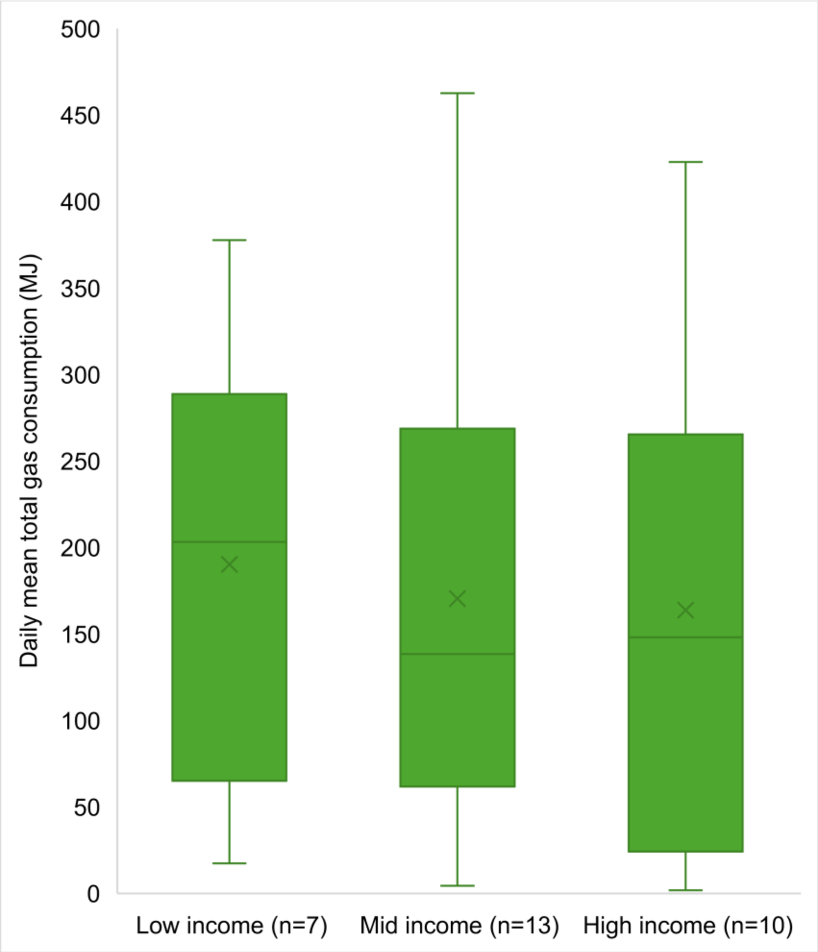



Figure 38 shows the comparison of the daily mean total gas consumption for the low, mid and high income groups in relation to the daily mean outdoor temperatures. On average, the daily mean total gas consumption in low, mid and high income groups presented a negative association with the mean outdoor temperatures. The visual analysis of the graph suggests that the daily mean total gas consumption in the high income homes was similar across all income groups.

**Figure 38 Comparison of daily mean total gas consumption at daily mean outdoor temperatures - low/mid/high annual income**

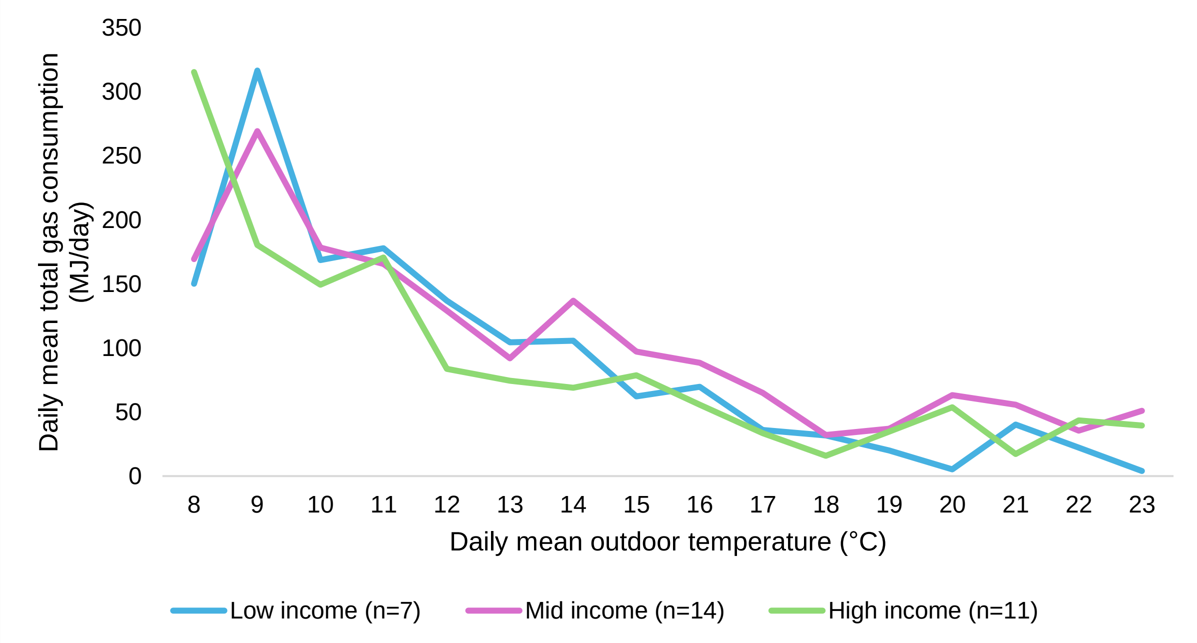
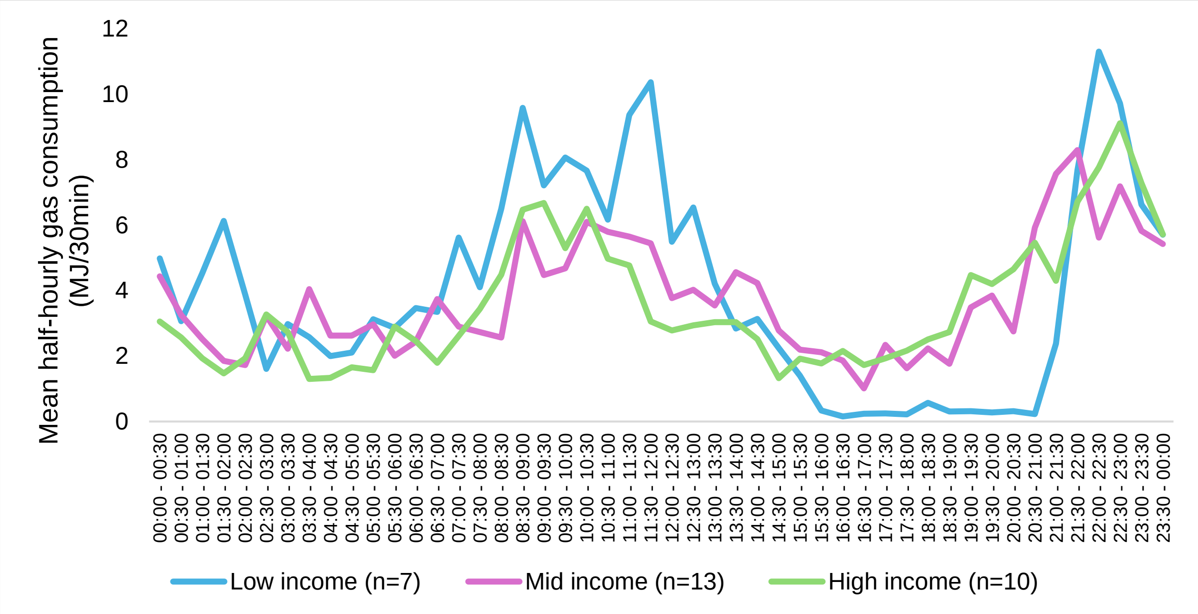



Figure 39 compares the diurnal variations in average half-hourly gas consumption on 'typical' September days of low, mid and high income homes. The distribution of half-hourly gas use in the three groups is bi-modal (one peak in the morning and one peak in the evening). The average half-hourly gas consumption of low and mid income groups rises in the morning from 7.00 am to 12.30 pm during the day and drops in the afternoon. However, the average half-hourly gas consumption of high income group rises in the morning from 7.00 am to 10.30 am during the day and drops in the afternoon. The evening peak in the three groups of homes is higher than its morning peak. The average gas consumption of the low income group rises from 8.30 pm until they peak at 10.30 pm in the evening and drops. The average gas consumption of the mid income group rises from 5.00 pm until they peak at 10.00 pm in the evening. The average gas consumption of the high income group rises from 3.00 pm until it peaks at 11.00 pm in the evening. The low income group shows more pronounced peaks in the morning and evening than the mid and high income groups. Further, the average gas consumption of the low income group becomes lower than mid and high income between 3.30 pm – 9.00 pm. The low income group also shows a peak in gas consumption at 2.00 am, likely caused by anti-legionella cycles in gas hot water systems as described in Section 4.1.

**Figure 39 Comparison of diurnal variations of mean half-hourly gas consumption in low, mid and high annual income groups on days with a daily mean outdoor temperature of 11 $^{0}$C**




## 6.2 ELECTRICITY USAGE

This section presents the electricity consumption data with respect to household income categories. Electricity data of 30 homes (7 low income, 13 mid income and 10 high income) was considered in this analysis. As shown in Table 13, The range of daily mean total electricity consumption on the coldest days were high in low income group. However, the range of daily mean total electricity consumption 'typical' September days and warmest days was higher in the mid income group. The minimum, average and maximum on daily mean total electricity consumption on the warmest days were the same in the low-income group. This is due to HH29 being the only home in the low income group with 23 °C mean outdoor temperature on 30.09.2023. There is not much difference between the average electricity consumption on the coldest days, 'typical' September days and warmest days in the mid income and high income groups.

**Table 13 Descriptive statistics of daily mean total electricity consumption in relation to daily mean outdoor temperatures**

| Daily mean outdoor temperature (°C) | Daily mean total electricity consumption (MJ/day) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Low income (n=7) | | | | Mid income (n=13) | | | | High income (n=10) | | | |
| | Min | Ave. | Max | Range | Min | Ave. | Max | Range | Min | Ave. | Max | Range |
| **8** | 12 | 48 | 85 | 73 | 20 | 30 | 45 | 25 | 8 | 20 | 34 | 26 |
| **11 ('typical' September day)** | 9 | 31 | 85 | 76 | 8 | 33 | 93 | 85 | 6 | 21 | 88 | 82 |
| **23** | 10 | 10 | 10 | 0 | 16 | 34 | 55 | 39 | 15 | 21 | 29 | 14 |

Figure 40 presents a box plot comparing the daily mean total electricity consumption between the low, mid and high income groups on days with a daily mean outdoor temperature of 11 $^{0}$C. The interquartile range of the low income group is lower (11 MJ/day) than the mid income group (25 MJ/day) and high income group (19 MJ/day). Further, the upper limit value of the low income group appears to be the same as the upper boundary of the interquartile range (32 MJ/day). Therefore, low income group appear to have a lower spread of mean electricity consumption than those for homes in the mid and high income group. This could be due to lower number of homes (7) in the low income group. An outlier can be noted in the low income group: HH34[21] (77 MJ/day). The mid income group shows a higher dispersion of mean electricity consumption than those for homes in the high income group. INT20 had the lowest daily mean electricity consumption and INT6 had the highest daily mean electricity consumption of the mid income group of homes on a 'typical' September day. HH32 and HH28 had the lowest daily mean electricity consumption and HH22 had the highest daily mean electricity consumption of the high income group of homes on a 'typical' September days. The daily mean electricity consumption of low, mid and high income homes appears to be right skewed.

**Figure 40 Box plot for mean electricity usage on days with a daily mean outdoor temperature of 11 $^0$C**

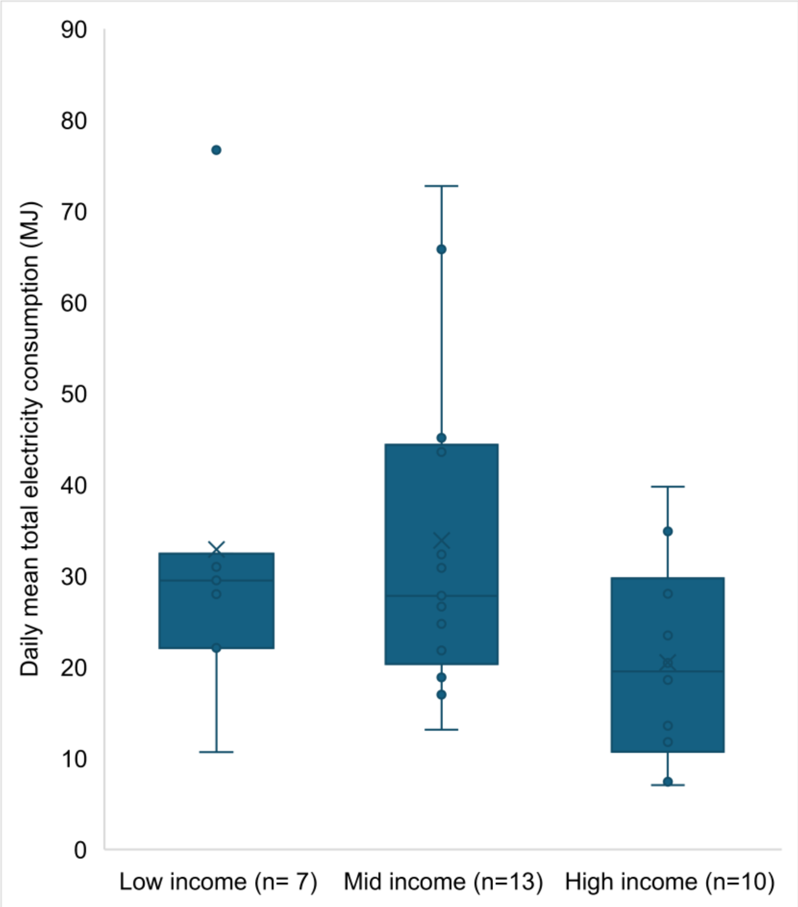



Figure 41 compares the daily mean total electricity consumption for the low, mid and high income groups in relation to the daily mean outdoor temperatures. On average, the daily mean total electricity consumption in low, mid and high income groups presented a negative association with the mean outdoor temperatures. The visual analysis of the graph reveals that the daily mean total electricity consumption in the high income group appeared to have been lower than those in the low and mid income groups at all mean outdoor temperatures except 19$^0$C and 21$^0$C - 23$^0$C. The difference in daily mean total electricity consumption of the three groups is high on the colder days and warmer days. However, not much difference in daily mean total electricity consumption of the low income and mid income homes can be observed 11$^0$C -19$^0$C. There is a pronounce peak of the low income group's daily mean total electricity consumption at 8$^0$C mean outdoor temperature. This is because only two locations

[21] As noted in Section 4.1, this is likely due to a continually operating spa heater.

of the low income group (HH29 and HH34) had a mean outdoor temperature of 8⁰C. The daily mean total electricity consumption of the high and low income slightly increases at 19⁰C.

**Figure 41 Comparison of daily mean total electricity consumption at daily mean outdoor temperatures – low/mid/high income**

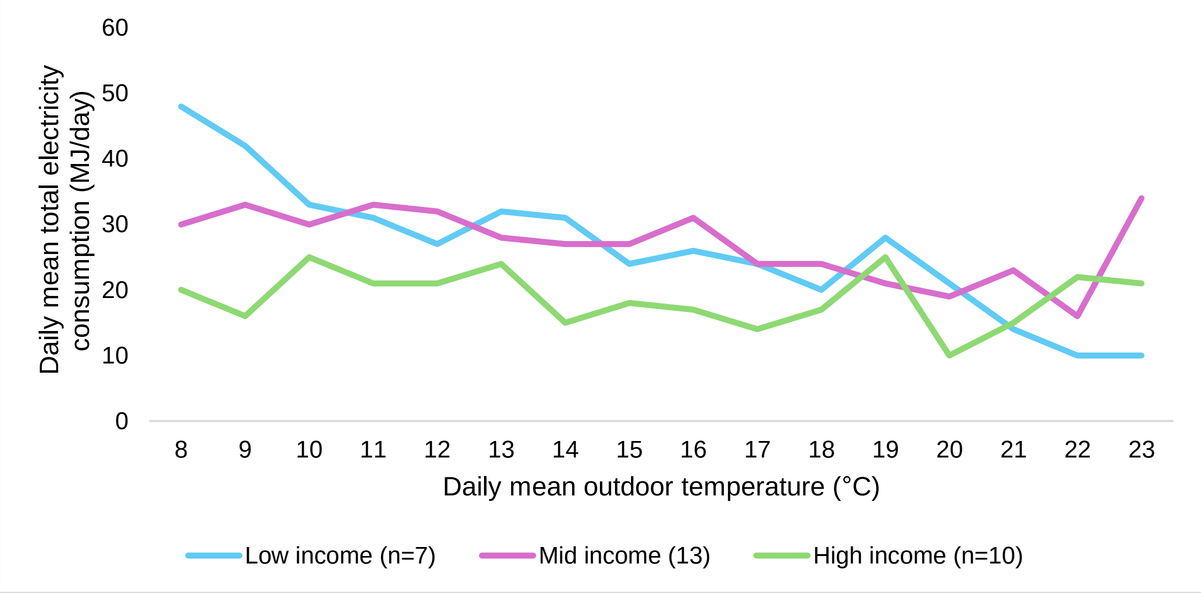
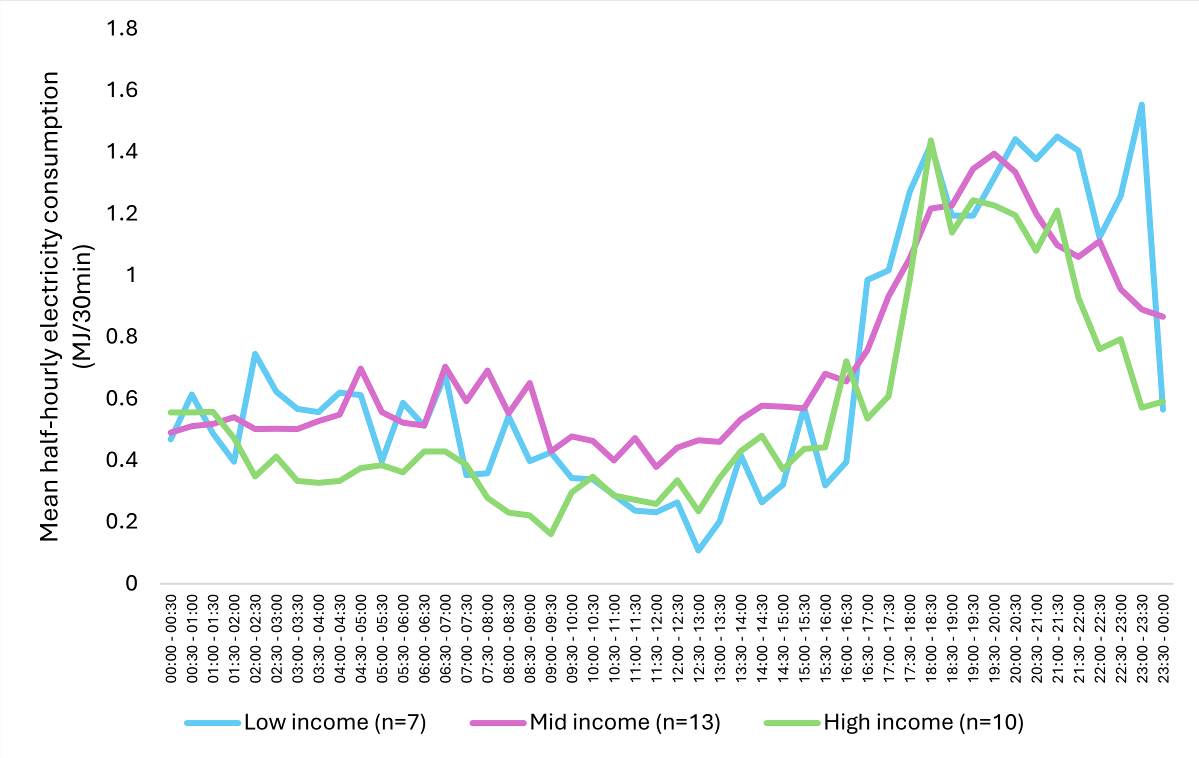



Figure 42 compares the diurnal variations in average half-hourly electricity consumption on 'typical' September day of the low, mid and high income groups. The distribution of electricity use in the three groups is bi-modal with the second, higher peak in the afternoon. All three groups have smaller average electricity consumption peaks in the morning (low income - 5.30 am to 7.00 am, mid income - 6.00 am to 9.00 am, high income – 6.00 am to 7.30 am). The higher evening peak is visible from 6.00 pm to 11.30 pm in low income groups, 6.00 pm to 9.30 pm in high income groups and 6.30 pm to 8.30 pm in mid income groups. The average electricity consumption appears to be higher in the low income group than in the mid and high income group from 1.30 am to 5.00 am, 4.30 pm-6.30 pm,and 7.30 pm-11.30 pm. However, the average electricity consumption appears to be higher in the mid income group than the low and high income group from 1.30 am-2.00 am, 4.30 am-5.00 pm, 6.30 am-4.00 pm and 6.30 pm-8.00 pm. The high income group's average electricity consumption appears to be lower than the low and mid income groups 1.30 am to 10.30 am. 4.30 pm to 6.30 pm, 7.30 pm-9.00 pm and 9.30 pm to midnight.

**Figure 42 Comparison of diurnal variations of mean half-hourly electricity consumption in low, mid and high income homes on days with a daily mean outdoor temperature of 11 $^{0}$C**




## 6.3 INDOOR TEMPERATURES

This section presents the indoor temperature data with respect to low, mid and high income homes. Living room temperature data was available for seven low income, 13 mid income and 10 high income homes. The range of daily mean living room temperatures on the coldest days, 'typical' September days and warmest days were bigger in the mid income group than in the low income and high income group (Table 14). The range of daily mean living room temperature of the low income group was same as the high income group on the 'typical' September days. The low income and mid income groups had the same minimum daily mean living room temperatures on the coldest days and 'typical' September days. Further, the low income group presented the same maximum daily mean living room temperatures on the coldest days and 'typical' September days. On the warmest days, the range of the low income group is zero where the minimum and maximum daily mean living room temperatures are the same. This is due to the outdoor mean temperature of 23 °C being present on 30.09.2023 at only HH29 in the low-income group. The difference between the minimum and maximum daily mean living room temperatures with the daily mean outdoor temperature on the warmest days of all three income groups is 1°C -2°C.

**Table 14 Descriptive statistics of daily mean living room temperatures in relation to daily mean outdoor temperatures**

| Daily mean outdoor temperature (°C) | Daily mean living room temperatures | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Low income (n=7) | | | Mid income (n=13) | | | High income (n=10) | | |
| | Min (°C) | Max (°C) | Range (°C) | Min (°C) | Max (°C) | Range (°C) | Min (°C) | Max (°C) | Range (°C) |
| **8** | 15 | 21 | 6 | 13 | 22 | 9 | 15 | 20 | 5 |
| **11('typical' September day)** | 15 | 21 | 6 | 13 | 24 | 11 | 14 | 20 | 6 |
| **23** | 21 | 21 | 0 | 20 | 25 | 5 | 21 | 22 | 1 |

As shown in Table 15, the bedroom temperature data was available for six low income homes, 10 mid income and 10 high income homes. The daily mean bedroom temperature range on the coldest days was the same in both low income and mid income homes. However, the range of daily mean bedroom temperatures of the high income group was higher than the low and mid income groups on the coldest days. The daily mean bedroom temperature range on the 'typical' September days was the same in the mid income and high income groups; the low-income group was lower. The daily mean bedroom temperature range on the warmest days was zero in the low income and the mid income and the high income group was higher by 1°C and 2°C respectively. On the warmest days, the range of the low income group is zero where the minimum and maximum daily mean bedroom temperatures are the same. This is due to the outdoor mean temperature of 23 °C being present on 30.09.2023 at only HH29 in the low-income group. The difference between the minimum and maximum daily mean bedroom temperatures with the daily mean outdoor temperature on the warmest days of low and mid income groups is 1°C -2°C.

**Table 15 Descriptive statistics of daily mean bedroom temperatures in relation to daily mean outdoor temperatures**

| Daily mean outdoor temperature (°C) | Daily mean bedroom temperatures | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Low income (n=6) | | | Mid income (n=10) | | | High income (n=10) | | |
| | Min (°C) | Max (°C) | Range (°C) | Min (°C) | Max (°C) | Range (°C) | Min (°C) | Max (°C) | Range (°C) |
| **8** | 16 | 18 | 2 | 12 | 14 | 2 | 14 | 21 | 7 |
| **11('typical' September day)** | 14 | 21 | 7 | 13 | 21 | 8 | 13 | 21 | 8 |
| **23** | 24 | 24 | 0 | 21 | 22 | 1 | 20 | 22 | 2 |

Figure 433 presents the box plots comparing the daily mean living room and bedroom temperatures between the low, mid, high income groups on days with a daily mean outdoor temperature of 11 $^0$C. The interquartile range of the mid income group is higher by 1$^0$C than the low income and high income groups. Both low and high income groups have the same interquartile range (3$^0$C) Further, the dispersion of the daily mean living room temperatures on days with a daily mean outdoor temperature of 11 $^0$C is higher in the mid income group than the low and high income groups. The daily mean living room temperatures of high income group of homes appear to be symmetrically distributed. However, daily mean living room temperatures of low income and mid income group of homes are right (positively) skewed and the high income groups. Three homes in the low income group (HH29, INT9 and INT16) had the lowest daily mean living room temperature (16$^0$C) and INT2 had the highest daily mean living room temperature (21$^0$C) on a 'typical' September day. HH45 had the lowest daily mean living room temperature (14$^0$C) and HH40 had the highest (22$^0$C) daily mean living room temperature on a 'typical' September day in the mid income group. HH43 had the lowest daily mean living room temperature (15$^0$C) and INT12 had the highest (20$^0$C) daily mean living room temperature on a 'typical' September day in the high-income group. With regards to the daily mean bedroom temperatures, both low income and high income groups have the same interquartile range (4$^0$C) and higher than the interquartile range of the mid income group (3$^0$C). However, the dispersion of bedroom temperature of the mid income group is far greater than those for homes in the low and high income groups. The daily mean bedroom temperatures of low, mid and high income homes appear to be right (positively) skewed. HH16 had the lowest daily mean bedroom temperature (15$^0$C) and INT2 had the highest daily mean bedroom temperature (21$^0$C) on a 'typical' September day in the low income group. INT4 had the lowest daily mean bedroom temperature (14$^0$C) and HH44 had the highest (21$^0$C) daily mean bedroom temperature on a 'typical' September day in the mid income group. Four homes (HH32, INT13, INT18 and HH43) had the lowest daily mean bedroom temperature (15$^0$C) and INT12 had the highest (21$^0$C) daily mean bedroom temperature on a 'typical' September day in the high income group.

**Figure 43 Box plot for mean indoor temperature on days with a daily mean outdoor temperature of 11 $^{0}$C**

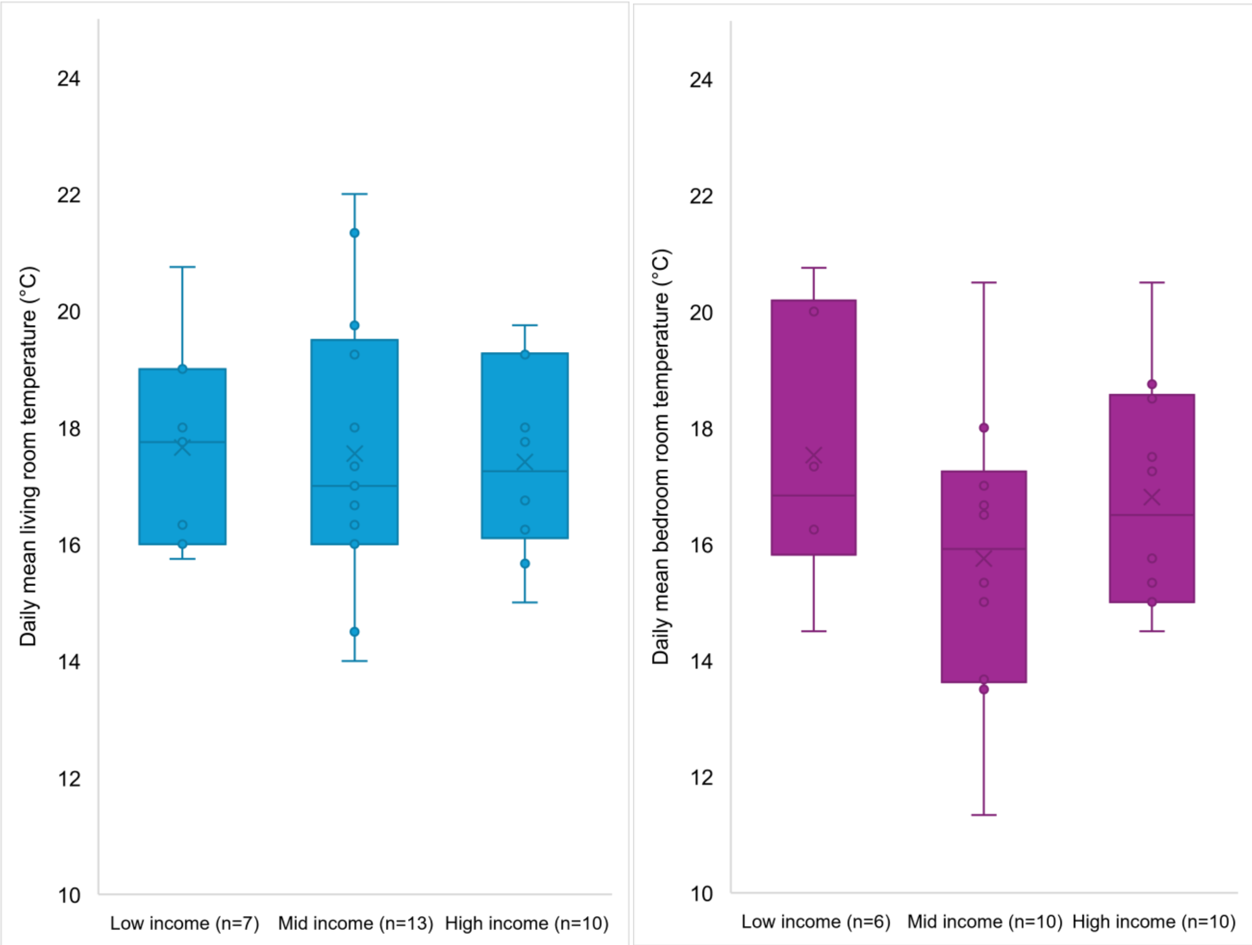



Figure 44 shows the comparison of the average daily mean living room temperatures and bedroom temperatures for the low, mid, and high income groups in relation to the daily mean outdoor temperatures. On average, the mean daily living room temperatures and bedroom temperatures in both low, mid and high income groups presented a positive association with the daily mean outdoor temperatures. The visual analysis of the graph reveals that the difference in the mean indoor living room temperatures of the low and high income groups is less on colder days than the warmer days. Further, the difference in the mean indoor living room temperatures of the low and mid income groups is less on warmer days than the colder days. There is little difference in the mean indoor bedroom temperatures of the low, mid and high income groups at all temperatures except at the coldest (8$^{0}$C -9$^{0}$C), and the warmer temperatures (20$^{0}$C, 22$^{0}$C and 23$^{0}$C). At 21$^{0}$C mean outdoor temperature, the three groups have the same mean bedroom temperature (20.6$^{0}$C). Also, it can be noted that both living room and bedroom temperatures in both groups are 18$^{0}$C or less at colder outdoor temperatures (8-12$^{0}$C). Further, it can be noted that the mean bedroom temperatures of mid and high income homes are slightly below their mean living room temperatures. However, in the low income group, the bedroom temperatures appear to be higher than the living room temperatures on warmer days.

**Figure 44 Comparison of daily mean indoor temperature at daily mean outdoor temperatures - low/mid/high income groups**

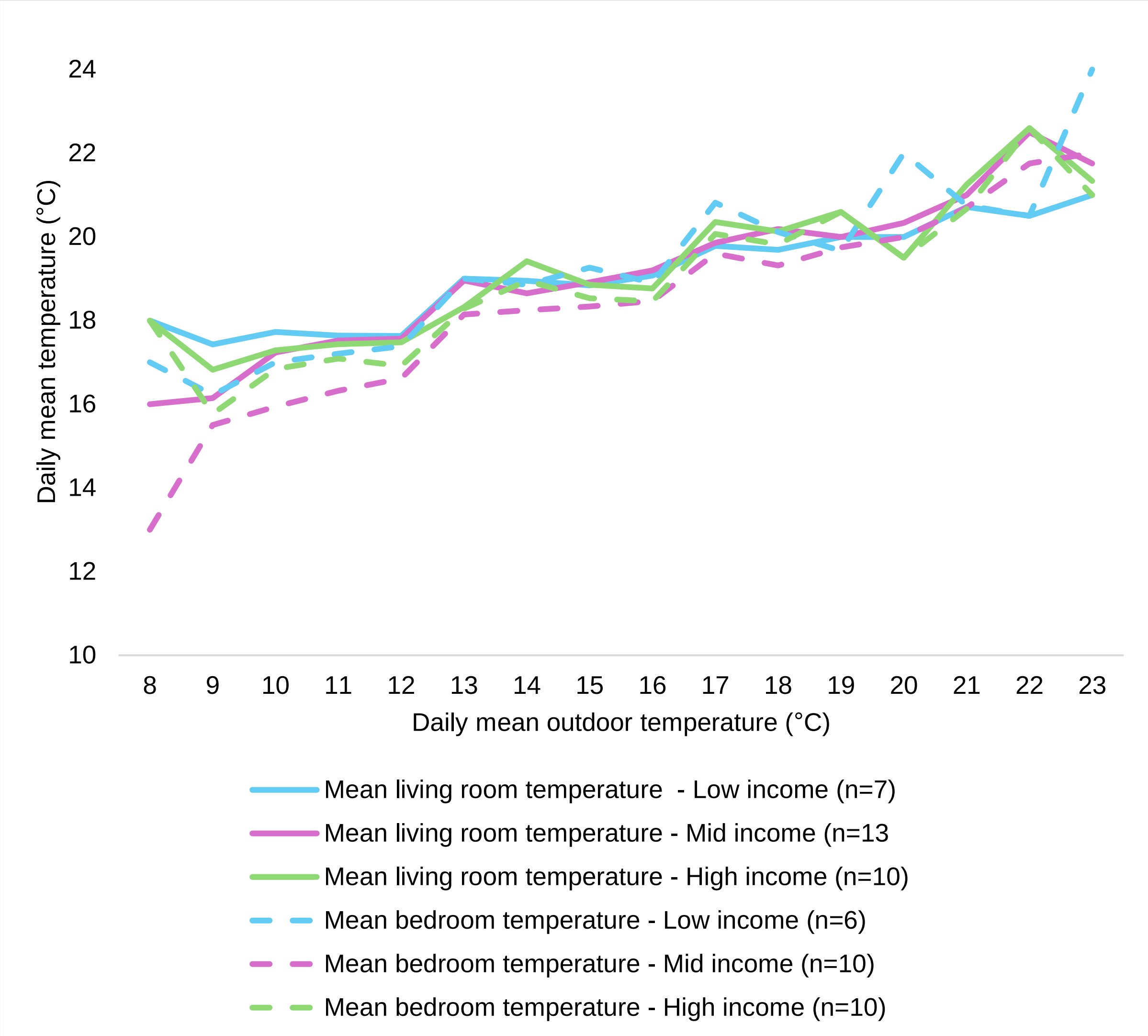
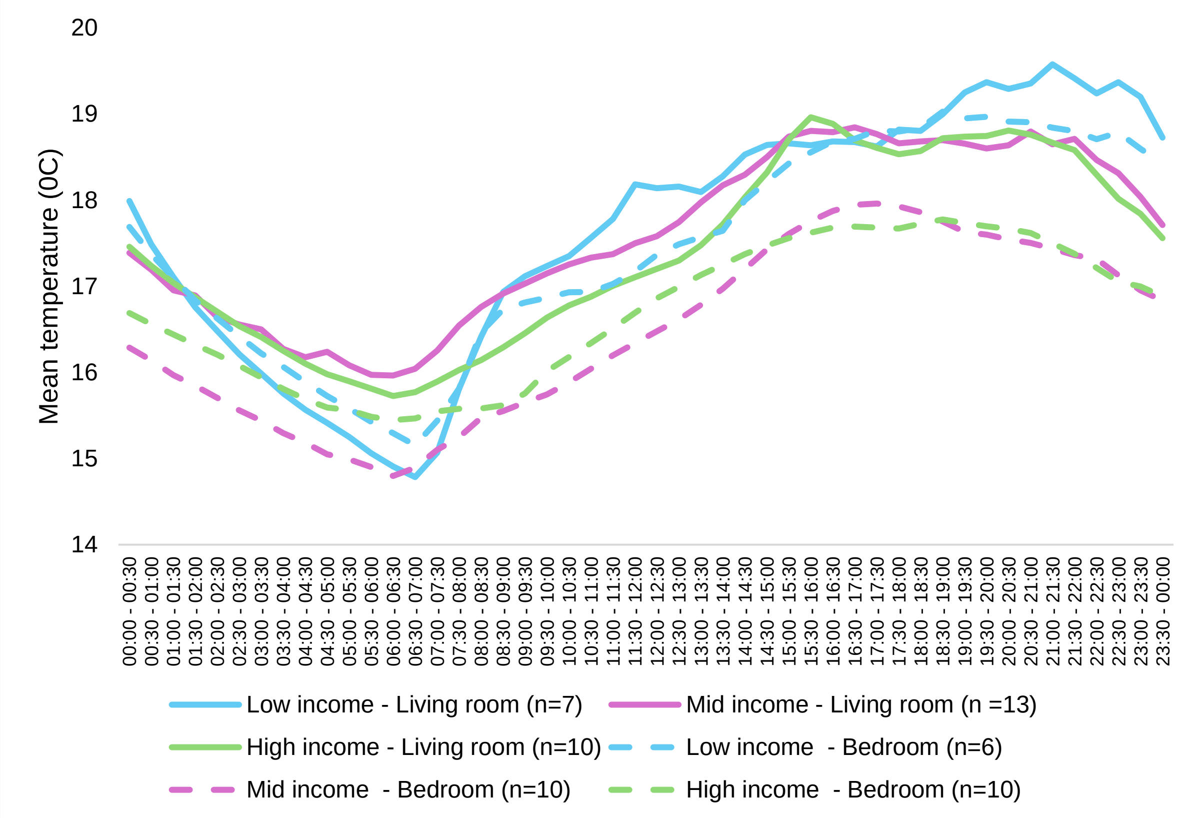



Figure 45 present the diurnal variations of mean living room and bedroom temperature on 'typical' September days with a daily mean outdoor temperature of 11°C in low, mid and high income groups respectively. The living room temperatures in the three groups drop overnight until about 6.30 am. However, there's a steep drop in the living room temperatures in the low income group than the mid and high income groups. The kink in the graphs suggests that heating devices were switched on between 6.30 am and 7.30 am in the three groups. The mean living room temperatures of low, mid and high income groups rise during the day and afternoon until they peak in the evening. The graph shows a pronounced spike in the mean living room temperatures of the low income group from 7.00 am-9.30 am than the mid and high income groups. The mean living room temperatures of the low income groups become higher than the mid and low income groups 9.30 am -3.00 pm. A peak in the living room temperatures of the low income group which is higher than the mid and high income groups can be observed from 6.30 pm to 11.30 pm. The mid and high income groups show a similar mean living room temperature from midnight to 4.30 am and 4.30 pm to midnight.

The mean bedroom temperatures in the three groups drop overnight until about 7.00 am in low income group, 6.30 am in mid income homes and 8.30 am in the high income homes. The mean bedroom temperatures of the three groups rise during the day and afternoon until they peak in the evening. There's a pronounced spike in the mean bedroom temperatures of the low income group from 6.30 am to 9.00am. The mean bedroom temperatures of the low income group are higher than the mid and high income group at all times except from 5.00 am -8.00 am. There is not much difference in the bedroom temperatures of mid and high income groups from 8.30 am to midnight. However, the mean bedroom temperatures of mid income homes are lower than the low and high income homes from midnight to 8.30 am. In mid and high income groups, the bedroom temperatures appear to be lower than the living room at all times. However, in the lower income group, the bedroom temperature exceeded the living room temperature from 1.30 am to 8.00 am and 4.30 pm to 6.00 pm. The low income group homes such as INT2 and HH34 presented higher living room temperatures from 7.30 am to midnight on days with a daily mean outdoor temperature of 11 $^{0}$C. INT 5 also showed higher living room temperatures from 9.00 am to 6.00 pm and 10.00 pm to midnight on days with a daily mean outdoor temperature of 11 $^{0}$C.INT9 and INT16 had lower living room temperatures in the low income group from 1.30 am to 10.00 am and HH29 and INT16 had lower living room temperatures throughout the day till the evening. Mid income homes such as HH40 INT6, INT15 and HH44 always presented higher living room temperatures on 'typical' September days. Mid income homes HH39 and HH45 presented lower living room temperatures throughout the day on 'typical' September days. INT12 presents living room temperatures 19-20 °C throughout the day in the high income group. INT7 presented higher living room temperatures in the evening. INT17 also showed a spike in the living room temperatures from 3.00 pm to 5.00 pm. HH43 presented lower living room temperatures throughout the day on typical September days in the high income group. Low income group homes INT2 and INT1 presented higher bedroom temperatures on typical September days at all times. INT16 presented lower bedroom temperatures throughout the day on 'typical' September days in the low income group. Mid income homes HH44 always presented higher bedroom temperatures on 'typical' September days. The bedrooms of INT8 and HH35 were also warmer (less than HH44 but warmer than the other homes) from 7.30 am to midnight. HH39 and INT4 present lower bedroom temperatures throughout the day on typical September days in the mid income group. INT12 in the high income group present higher bedroom temperatures throughout the day. Further, INT10 present an increase in the bedroom temperature from 5.00 am to midnight. The mean bedroom temperature of HH28 is high from 6.00 am to 9.00 am and 6.00 pm to 9.30 pm. INT18 and HH43 presented lower bedroom temperatures throughout the day on 'typical' September days in the high income group.

**Figure 45 Comparison of diurnal variations of mean half-hourly indoor temperature in low, mid and high income groups on days with a daily mean outdoor temperature of 11 $^{0}$C**




## 6.4 SUMMARY

Income is not a simple determinant of household gas use but there are some discernible differences between income groups. High income households use much more gas on very cold days than low or mid income households with average consumption increasing by 85% when the outdoor temperature drops from 11 to 8 whereas gas consumption in the other income groups changes little with outdoor temperature. On a 'typical' September day, gas consumption does not vary widely between income groups, although all income groups have a wide range within them.

As might be expected considering the common practice of switching the heating off overnight and the general pattern of homes being too cold for comfort in the early morning, all income categories showed morning and evening gas usage peaks. While patterns are generally similar, the low income group shows a more pronounced dip between these two peaks indicating little or no gas use in most low income households during the day. There is also a pronounced 2.00 am gas use peak for the low income household group, perhaps indicating they are most likely to have hot water services with an anti-legionella cycle running late at night.

On average, the largest users of electricity were the middle income group. The lower average use of electricity by low and high income groups appears to have subtly different drivers. Low income households are concerned about cost and tend to try to use less electricity due to concerns about bills. On the other hand, high income households have more discretionary spending power and have chosen to invest in energy efficient options (more energy efficient houses, more comprehensive solar power systems) and so have lower mains electricity usage. While all income groups use less electricity as outdoor temperature increases, this relationship is strongest for low income households and weakest for high income households. This again shows the effect that higher income households tend to live in newer and more energy efficient houses.

Household income was not a good predictor of indoor temperature, with living room temperatures being similar across the different income categories and bedroom temperature being lowest for the middle income category.

# 7 Cultural and linguistic diversity – CALD and non-CALD

This section presents preliminary results for the gas consumption, electricity consumption and indoor temperatures disaggregated by the cultural and linguistic diversity of the household.

## 7.1 GAS USAGE

This section presents the gas consumption data with respect to CALD and non-CALD household gas data was available for 32 homes (13 CALD and 19 non-CALD household) for September 2023. As shown in Table 16, the range of daily mean total gas consumption of non-CALD homes is much higher than the CALD homes on the coldest days and 'typical' September days. However, the range of daily mean total gas consumption of the CALD homes is higher than the non-CALD homes on the warmest days. The group of CALD homes presented a lower minimum, average and maximum consumption value during the coldest days and warmest days. However, the minimum consumption on 'typical' September day of both CALD and non-CALD groups was zero consumption. The average and the maximum consumption on the 'typical' September day were higher in the non-CALD group than the CALD group.

**Table 16 Descriptive statistics of daily mean total gas consumption in relation to daily mean outdoor temperatures**

| Daily mean outdoor temperature (°C) | Daily mean total gas consumption (MJ/day) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | CALD (n=13) | | | | Non-CALD (n=19) | | | |
| | Min | Ave. | Max | Range | Min | Ave. | Max | Range |
| **8** | 5 | 178 | 404 | 399 | 100 | 295 | 649 | 549 |
| **11 ('typical' September day)** | 0 | 145 | 504 | 504 | 0 | 189 | 602 | 602 |
| **23** | 2 | 31 | 61 | 59 | 52 | 69 | 87 | 35 |

Figure 46 presents box plots comparing the daily mean total gas consumption between the groups on days with a daily mean outdoor temperature of 11 $^0$C. Gas consumption data of 30 homes (12 CALD and 18 non-CALD) for September 2023 was considered for the box plot. The interquartile range of the CALD group (269 MJ) is higher than the non-CALD group (175 MJ). The non-CALD group showed a higher dispersion of mean gas consumption than those for homes in the CALD group. Both groups of data appear to be right skewed. The box plot shows CALD homes appeared to consume less gas than the non-CALD homes during 'typical' September day. INT18 had the lowest daily mean gas consumption and INT12 had the highest daily mean gas consumption of the CALD homes on a 'typical' September day. INT7 had the lowest daily mean gas consumption and INT8 had the highest daily mean gas consumption of the non-CALD homes on a 'typical' September day. Details of these households have been described in Section 4.1. The high gas users (INT12 and INT8) prefer warm houses for health reasons or as a general preference. The low gas users (INT7 and INT18) have electric heating. Detailed explanations at a household level are given in previous sections.

**Figure 46 Box plot for mean gas usage on days with a daily mean outdoor temperature of 11 $^0$C**

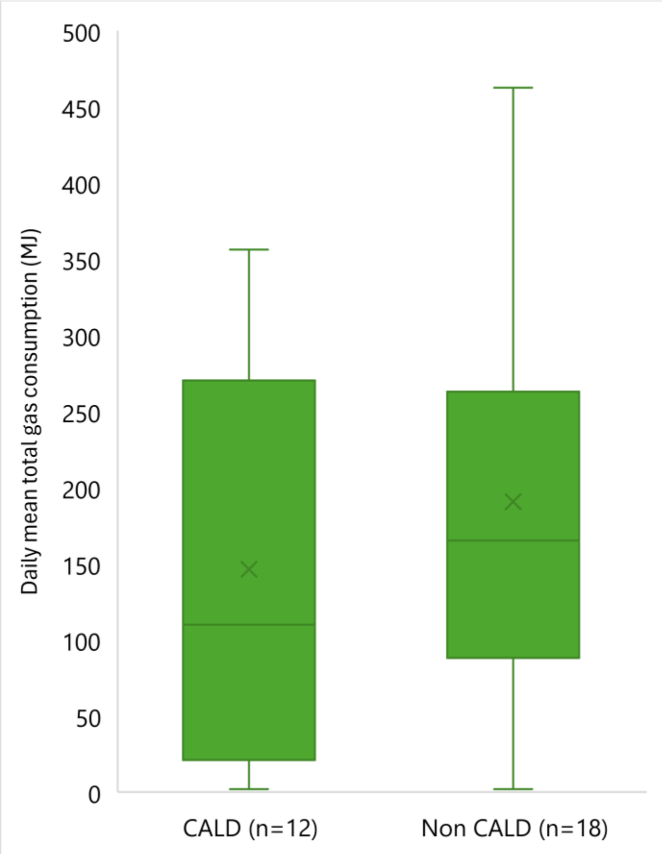



Figure 47 shows the comparison of the daily mean total gas consumption for the CALD and non-CALD groups in relation to the daily mean outdoor temperatures. On average, the daily mean total gas consumption in both CALD and non-CALD groups presented a negative association with the mean outdoor temperatures. The visual analysis of the graph reveals that the daily mean total gas consumption in the CALD homes appeared to have been lower than those in non-CALD homes across all outdoor temperature levels. The difference in daily mean total gas consumption between the two groups appeared to be higher during colder days than the warmer days in September. Non-CALD homes HH39 presented the lowest mean gas consumption of 100 MJ/day and HH28 presented the highest mean gas consumption of 649 MJ/day when the outdoor temperature was 8$^0$C. CALD homes HH45 had the lowest mean gas consumption of 5 MJ/day and HH40 presented the highest mean gas consumption of 404 MJ/day when the outdoor temperature was 8$^0$C. As such, gas use on cold days in non-CALD households varied by a factor of 6.5, whereas gas use in CALD households varied by a factor of 80 with a significantly higher average.

**Figure 47 Comparison of daily mean total gas consumption at daily mean outdoor temperatures - CALD/non-CALD**

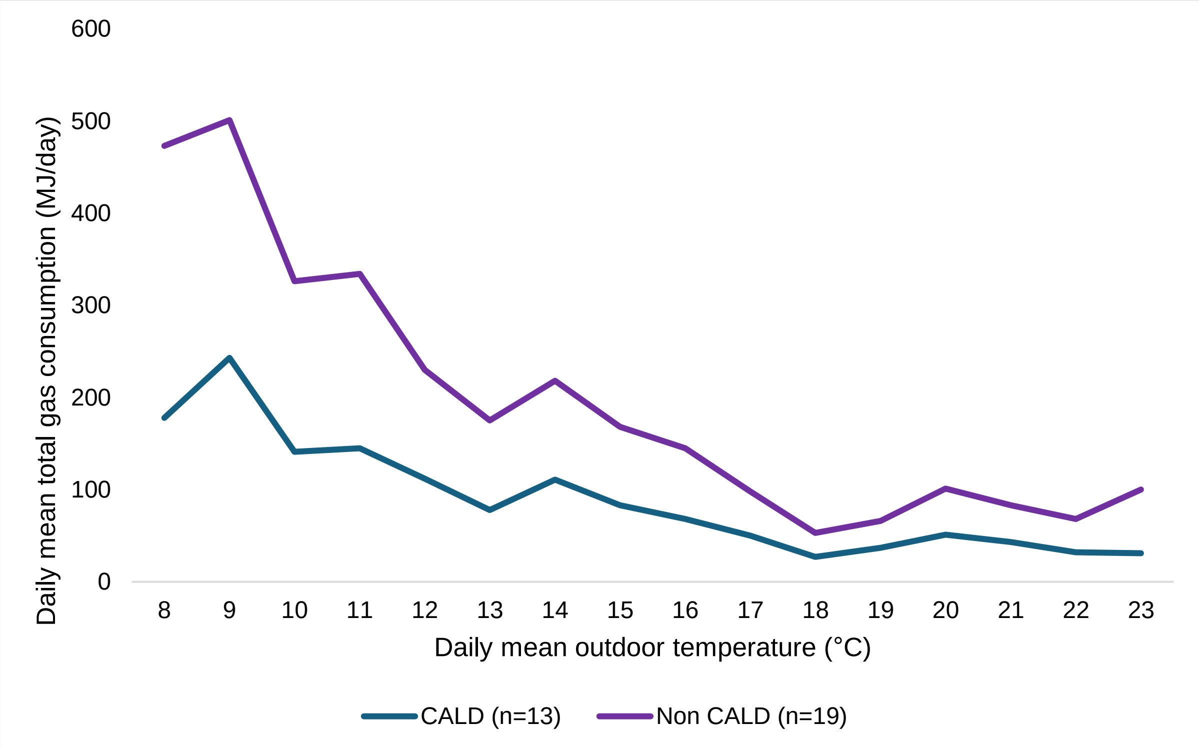
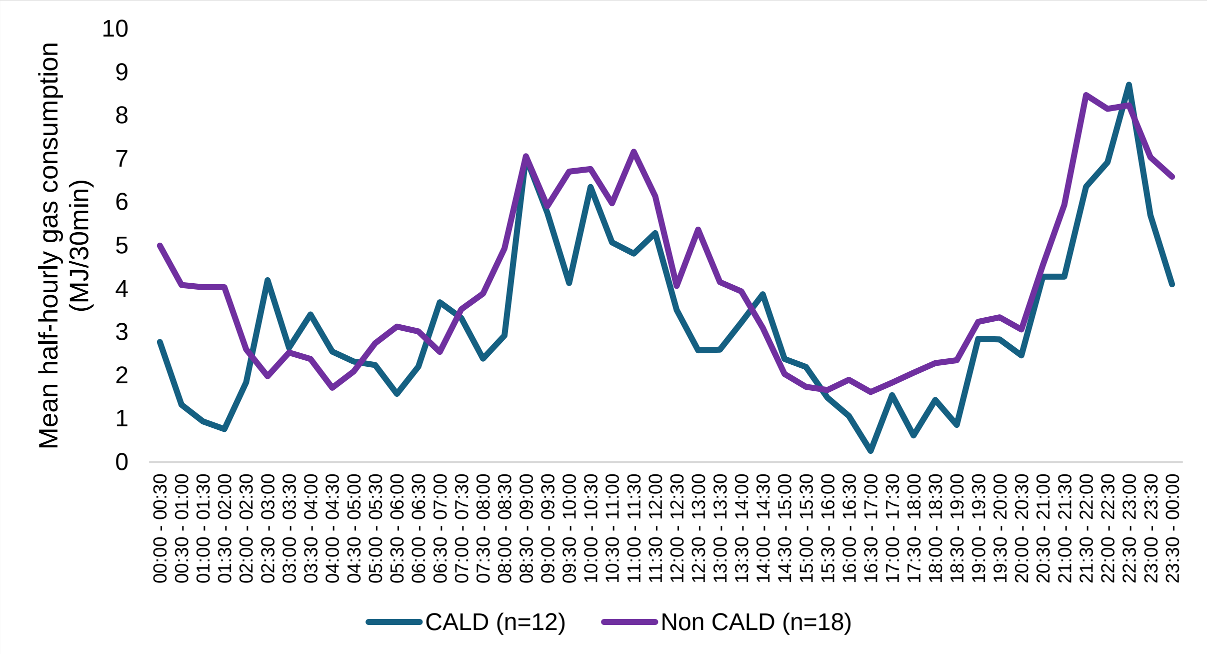



Figure 48 compares the diurnal variations in average half-hourly gas consumption on 'typical' September days of CALD and non-CALD homes. The distribution of half-hourly gas use in both groups is bi-modal. The average half-hourly gas consumption of both groups rises in the morning from 7.00 am to 12.30 pm during the day and drops in the afternoon. The average gas consumption of the CALD homes gradually rises from 4.30 pm until it peaks at 11.00 pm in the evening. The average gas consumption of the non- CALD homes gradually rises from 4.30 pm until it peaks at 10.00 pm in the evening. The evening peak in both CALD and non-CALD groups of homes is higher than its morning peak. The non-CALD group of homes exhibit a higher peak in the morning (starting from 7.30 am to 11.30 am) However, the CALD group shows pronounced peak in the evening 10.30 pm to 11.00 pm. Further, there's an increase in gas consumption between 2.00 am to 4.00 am in the CALD group of homes. The average half-hourly gas consumption appears to be higher in the non-CALD group than the CALD group on days with a daily mean outdoor temperature of 11 $^{0}$C. Non-CALD homes such as INT9 presented pronounced peak of gas use in the morning. INT8 showed high use of gas in the evening 9.00 pm -10.30 pm. INT10 showed high use of gas in the evening 7.00 pm -7.30 pm and 10.00 pm -11.00 pm. INT5 in the non-CALD group presented a pronounced use of gas use in the early morning at 1.30 am – 2.00 am. Non-CALD homes INT7 and INT20 presented lower gas consumption throughout the day on days with a daily mean outdoor temperature of 11 $^{0}$C. CALD homes such as HH41 presented pronounced peaks several times throughout the day (2.30 am – 3.00 am, 6.30 am – 7.00 am, 1.30 am- 2.30 am). This could indicate the times the gas heating automatically turned on. INT12 presented a pronounced use of gas use in the morning and evening. HH42 also presented pronounced peak in the morning and evening. INT1 (10.00 pm - 10.30 pm) and HH44 (9.30 pm -10.30 pm) in the CALD group had a higher use of gas use in the late evening. HH40 presented a higher use of gas from 8.00 am - 11.30 pm. Detailed explanations at a household level are given in previous sections.

**Figure 48 Comparison of diurnal variations of mean half-hourly gas consumption in CALD and non-CALD household size on days with a daily mean outdoor temperature of 11 $^0$C**




## 7.2 ELECTRICITY USAGE

This section presents the electricity consumption data with respect to CALD and non-CALD household sizes. Electricity data of 30 homes (12 CALD and 18 non-CALD) was considered in this analysis.

As shown in Table 17, The range of daily mean total electricity consumption on the coldest days and 'typical' September days was higher in the non-CALD group. However, the range of daily mean total electricity consumption on the warmest days was higher in the CALD group. The group of non-CALD homes presented a lower minimum on the coldest days. Both CALD and non-CALD had the same minimum mean total electricity consumption on the 'typical' September days when the temperature was 11 °C. Further, the group presented a lower maximum on the 'typical' September days and the warmest days. The CALD group had lower average and maximum daily mean total electricity consumption on the coldest days and the 'typical' September days.

**Table 17 Descriptive statistics of daily mean total electricity consumption in relation to daily mean outdoor temperatures**

| Daily mean outdoor temperature (°C) | Daily mean total electricity consumption (MJ/day) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | CALD (n=12) | | | | Non-CALD (n=18) | | | |
| | Min | Ave. | Max | Range | Min | Ave. | Max | Range |
| **8** | 12 | 26 | 45 | 33 | 8 | 39 | 85 | 77 |
| **11 ('typical' September day)** | 6 | 23 | 50 | 44 | 6 | 32 | 93 | 87 |
| **23** | 10 | 18 | 29 | 19 | 49 | 52 | 55 | 6 |

Figure 49 presents a box plot comparing the daily mean total electricity consumption between the groups on days with a daily mean outdoor temperature of 11$^0$C. The interquartile range of the CALD group is slightly lower (19 MJ/day) than the non-CALD group (20 MJ/day). However, the non-CALD group shows a higher dispersion of mean electricity consumption than those for homes in the CALD group. HH32 had the lowest daily mean electricity consumption and HH44 had the highest daily mean electricity consumption of the CALD group of homes on a 'typical' September day. HH28 had the lowest daily mean electricity consumption and INT8 had the highest daily mean electricity consumption of the non-CALD group of homes on a 'typical' September day. The daily mean electricity consumption of CALD and non-CALD homes is right skewed. However, the non-CALD homes appear to have higher daily mean electricity consumption on days with a daily mean outdoor temperature of 11$^0$C. Two outliers are presented above the whiskers of the box plot of the non-CALD group: INT6 (73 MJ/day) and HH34 (77 MJ/day). Detailed explanations at a household level are given in previous sections.

**Figure 49 Box plot for mean electricity usage on days with a daily mean outdoor temperature of 11 $^0$C**

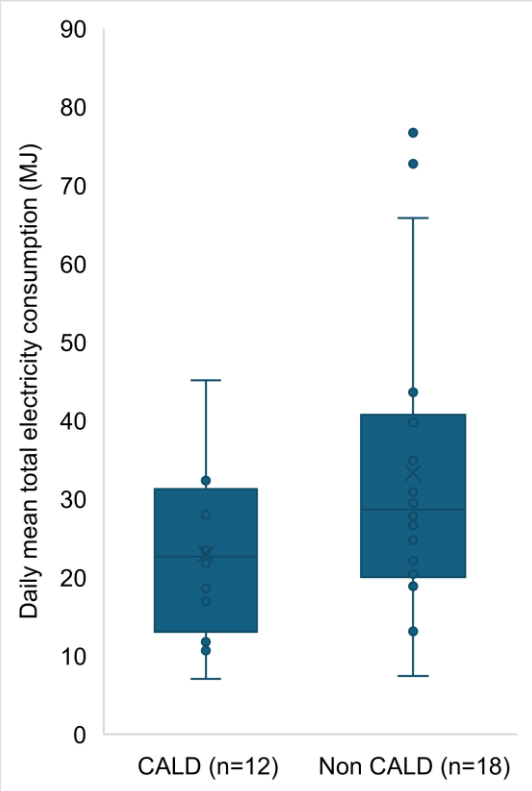



Figure 50 compares the daily mean total electricity consumption for the CALD and non-CALD groups in relation to the daily mean outdoor temperatures. On average, the daily mean total electricity consumption in both CALD and non-CALD groups presented a negative association with the mean outdoor temperatures. The visual analysis of the graph reveals that the daily mean total electricity consumption in the CALD group appeared to have been lower than those in the non-CALD group at all mean outdoor temperatures. A slight high peak in the CALD group's daily mean total electricity consumption is shown when the daily mean outdoor temperature is 10$^0$C and 19$^0$C. There is no significant difference in daily mean total electricity consumption between the two groups across all outdoor temperature levels except at the coldest temperatures (8$^0$C, 9$^0$C), and the warmest temperature (23$^0$C). There is a pronounced peak of the non-CALD group's daily mean total electricity consumption at 23$^0$C mean outdoor temperature. This is because only two locations of the non-CALD group (INT6 and HH39) had a mean outdoor temperature of 30.09.2023.

**Figure 50 Comparison of daily mean total electricity consumption at daily mean outdoor temperatures - CALD/non-CALD**

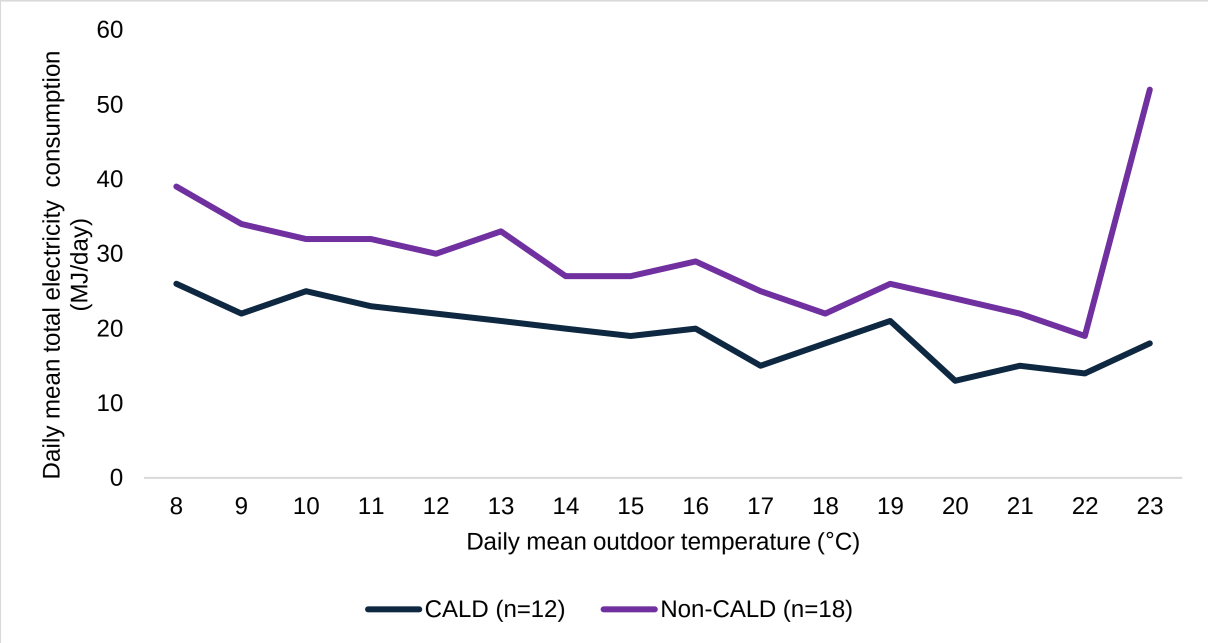
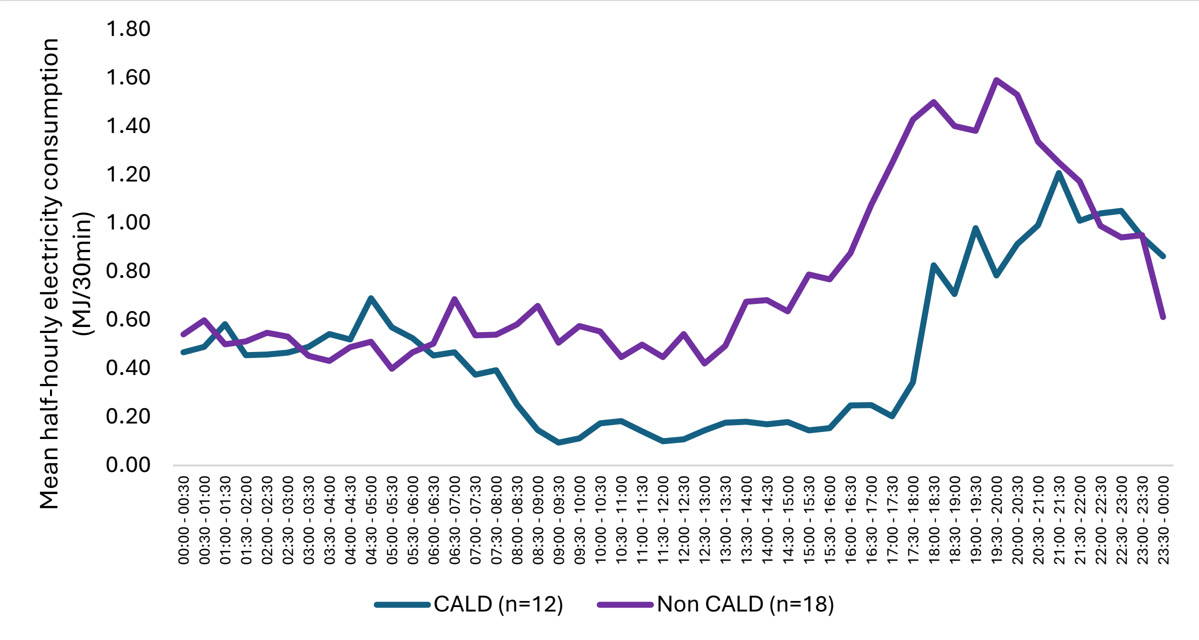



Figure 51 compares the diurnal variations in average half-hourly electricity consumption on 'typical' September day of the CALD and non-CALD groups. The distribution of electricity use in both groups is bi-modal in both groups with the second, higher peak in the afternoon. The average electricity consumption appears to be higher in the non-CALD group from 6.30 am to 10.30 pm. However, the average electricity consumption appears to be higher in the CALD group from 10.00 pm to midnight, and 1.00 am to 2.00 am. The average electricity consumption peaks are more pronounced in the non-CALD group from 7.00 pm to 8.30 pm in the evening. Whereas in the CALD group, the peaks are more pronounced from 8.30 pm to 10.00 pm in the evening. There is a dip in the electricity consumption of the CALD households from 8.00 am to 5.30 pm. HH41 in the CALD group presented pronounced peak of electricity use from 4.30 am to 5.30 am and 7.00 pm to 8.00 pm. HH44 in the CALD group presented pronounced peak of electricity use from 2.30 am to 8.30 am and 1.00 pm to 6.00 pm. INT16 presented a spike in electricity consumption 8.30 pm to 10.30 pm and INT18 presented a spike in electricity consumption from 9.00-9.30 pm. INT7 in the non-CALD group presented pronounced peak of electricity use in the afternoon till 9.30 pm in the evening. HH34 in the non-CALD group presented high electricity use from 4.30 pm to 11.30 pm (4.30 pm-6.00 pm, 7.00 pm-9.30 pm, 10.30 pm-11.30 pm). Further, HH34 also presented spikes in electricity use from 2.00 am to 7.00 am. INT17 showed a spike in electricity consumption from midnight to 2.00 am. Explanations are similar to those already provided in section 4.1. Detailed explanations at a household level are given in previous sections.

**Figure 51 Comparison of diurnal variations of mean half-hourly electricity consumption in CALD and non-CALD household size on days with a daily mean outdoor temperature of 11 $^0$C**




## 7.3 INDOOR TEMPERATURES

This section presents the indoor temperature data with respect to CALD and non-CALD homes. Living room temperature data was available for 12 CALD homes and 18 non-CALD homes. The range of daily mean living room temperatures on the coldest days, 'typical' September days and warmest days were bigger in the CALD group than in the non-CALD group (Table 18). However, the minimum temperature of the CALD group was same as the non-CALD group on the coldest days. The maximum living room temperature of the CALD group was higher than the non-CALD group on the coldest, warmest and 'typical' September days. Non-CALD group presented zero range during the warmest days (However, only one day at HH39 in the non-CALD group had a mean outdoor temperature of 23°C).

**Table 18 Descriptive statistics of daily mean living room temperatures in relation to daily mean outdoor temperatures**

| Daily mean outdoor temperature (°C) | Daily mean living room temperatures | | | | | |
|---|---|---|---|---|---|---|
| | CALD (n=12) | | | Non-CALD (n=18) | | |
| | Min (°C) | Max (°C) | Range (°C) | Min (°C) | Max (°C) | Range (°C) |
| **8** | 13 | 22 | 9 | 13 | 21 | 8 |
| **11('typical' September day)** | 13 | 24 | 11 | 14 | 22 | 8 |
| **23** | 20 | 25 | 5 | 21 | 21 | 0 |

As shown in Table 19, the bedroom temperature data was available for 12 CALD homes and 14 non-CALD. The daily mean bedroom temperature range on the coldest days was the same in both CALD and non-CALD homes. However, the range of daily mean bedroom temperatures on the 'typical' September days was high by 1°C in the CALD group. The non-CALD group has zero range on and warmest days. (However, only one day at HH39 in the non-CALD group had a mean outdoor temperature of 23°C). CALD groups had the same minimum temperatures on the coldest days and 'typical' September days.

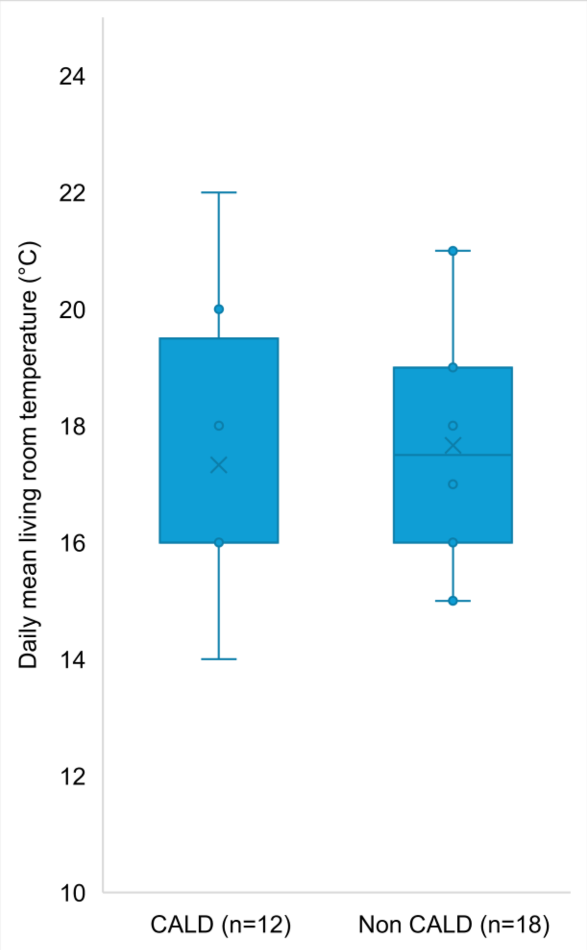
**Table 19 Descriptive statistics of daily mean bedroom temperatures in relation to daily mean outdoor temperatures**

| Daily mean outdoor temperature (°C) | Daily mean bedroom temperatures | | | | | |
|---|---|---|---|---|---|---|
| | CALD (n=12) | | | Non-CALD (n=14) | | |
| | Min (°C) | Max (°C) | Range (°C) | Min (°C) | Max (°C) | Range (°C) |
| **8** | 14 | 21 | 7 | 12 | 19 | 7 |
| **11 ('typical' September day)** | 14 | 21 | 7 | 13 | 21 | 8 |
| **23** | 20 | 24 | 4 | 21 | 21 | 0 |

Figure 52 presents the box plots comparing the daily mean living room and bedroom temperatures between the CALD and non-CALD groups. The interquartile range of the CALD group is higher by 1$^0$C than the non-CALD group. Further, the dispersion of the daily mean living room temperatures on days with a daily mean outdoor temperature of 11 $^0$C is higher in the CALD group than the non-CALD group. The daily mean living room temperatures of CALD and non-CALD homes appeared to be right skewed. HH45 had the lowest daily mean living room temperature (14$^0$C) and HH40 had the highest daily mean living room temperature (22$^0$C) on a 'typical' September day in the CALD group. HH39 and HH43 had the lowest daily mean living room temperature (15$^0$C) and INT2 and INT6 had the highest (21$^0$C) daily mean living room temperature on a 'typical' September day in the non-CALD group. Detailed explanations at a household level are given in previous sections.

With regard to the daily mean bedroom temperatures, both CALD and non-CALD groups have the same interquartile range (4$^0$C). However, the dispersion of bedroom temperature of the non-CALD group is far greater than those for homes in the CALD group. The daily mean bedroom temperatures of CALD homes are right skewed and the non-CALD homes appear to be slightly left (negatively) skewed. Several CALD homes presented the lowest daily mean bedroom temperature (15$^0$C) (HH32, HH45, INT13, INT16 and INT18), and HH44 and INT12 had the highest daily mean bedroom temperature (21$^0$C) on a 'typical' September day in the CALD group. INT14 presented the lowest daily mean bedroom temperature in the non-CALD homes (11$^0$C which is same as the outdoor mean temperature). INT2 had the highest daily mean bedroom temperature (21$^0$C) on a 'typical' September day in the non-CALD group. Detailed explanations at a household level are given in previous sections.

**Figure 52 Box plot for mean indoor temperature on days with a daily mean outdoor temperature of 11 $^0$C**



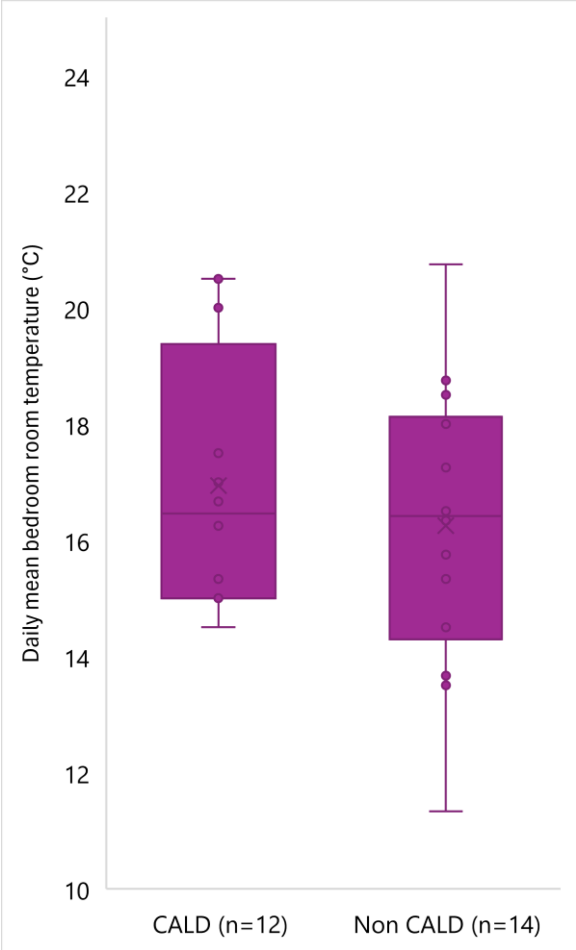




Figure 53 shows the comparison of the average daily mean living room temperatures and bedroom temperatures for the CALD and non-CALD groups in relation to the daily mean outdoor temperatures. On average, the mean daily living room temperatures and bedroom temperatures in both CALD and non-CALD household size groups presented a positive association with the daily mean outdoor temperatures. The visual analysis of the graph reveals that the mean indoor living room temperatures in the non-CALD homes appeared to be higher than those in CALD at all temperature levels except 8$^0$C, 9$^0$C,14$^0$C, 15$^0$C, 17$^0$C, 21$^0$C, and 22$^0$C. There is little difference in the mean indoor bedroom temperatures of the non-CALD and CALD at all temperatures except at the coldest and the warmer temperatures such as 20$^0$C and 22$^0$C. Also, it can be noted that both living room and bedroom temperatures in both groups are less than 18$^0$C at colder outdoor temperatures (8-12$^0$C).

**Figure 53 Comparison of daily mean indoor temperature at daily mean outdoor temperatures - CALD/non-CALD household size**

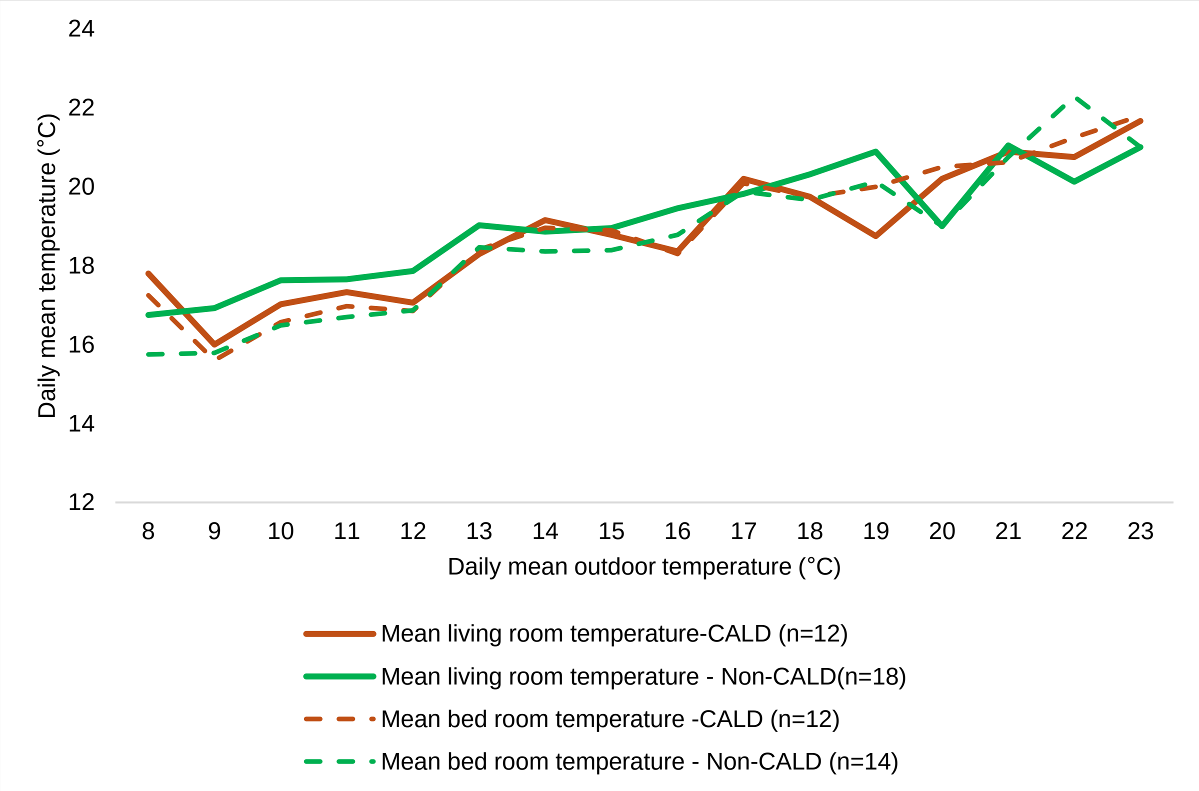
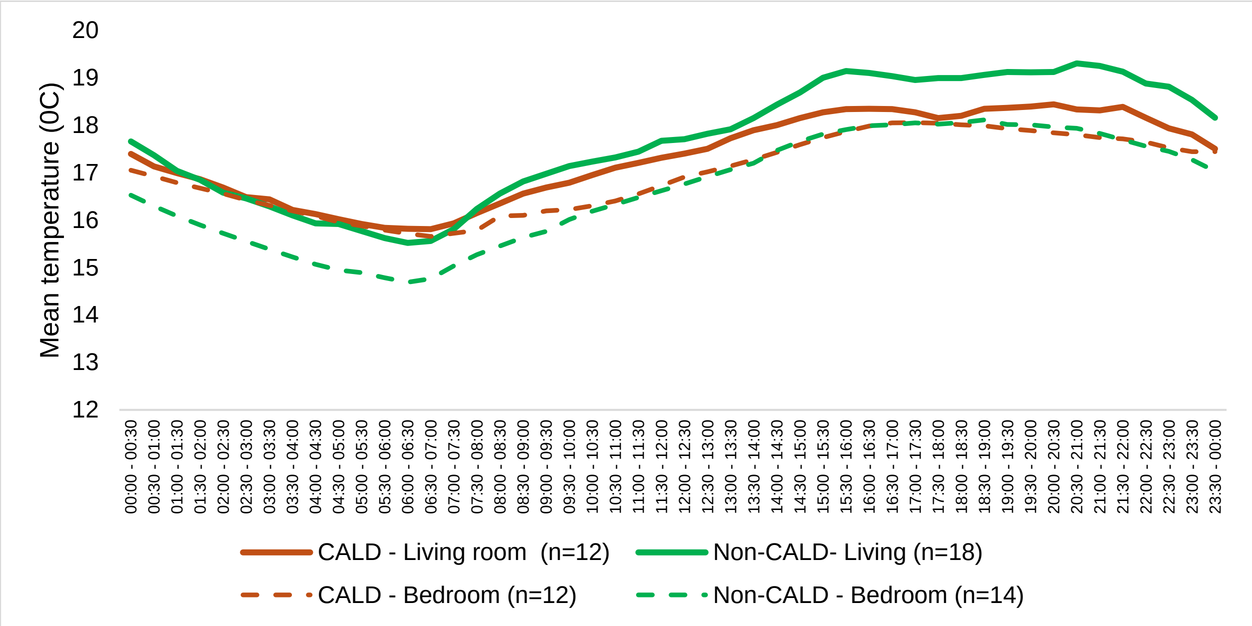



Figure 54 present the diurnal variations of mean living room and bedroom temperature on 'typical' September days with a daily mean outdoor temperature of 11°C in CALD and non-CALD groups respectively. The living room temperatures in both groups drop overnight until about 6.30 am. The kink in the graphs suggests that heating devices were switched on between 6.30 am and 7.30 am in both groups. The mean living room temperatures of both groups rise during the day and afternoon until they peak in the evening. A peak in the living room temperatures of the non-CALD can be observed at 3.30 pm and 10.30 pm. The living room temperatures of the CALD group are lower than the non-CALD group from midnight to 1.30 am and 7.30 am to midnight. The mean bedroom in both groups drop overnight until about 7.00 am in CALD and 6.30 am in non-CALD homes. The mean bedroom temperatures of both groups rise during the day and afternoon until they peak in the evening. Not much difference in the bedroom temperatures of both groups 10.00 am to 11.30 pm. However, the mean bedroom temperatures of CALD homes are higher than the non-CALD homes from 11.30 pm to 10.00 am. In both groups, the bedroom temperatures appear to be lower than the living room at all times. CALD homes such as HH40 always presented higher living room temperatures on typical September days. HH44 presented higher living room temperatures after 1.00 pm. INT12 presents living room temperatures 19-20°C throughout the day. HH42 presented increase in the living room temperature from 7.00 pm to 11.00 pm. HH45 presented lower living room temperature from midnight to 1.00 pm and 6.30 pm to midnight. Non-CALD homes such as INT2 presented a spike in the living room temperatures from 8.00 am to 11.00 am and 5.30 pm to 7.00 pm. HH34 presented higher living room temperatures from 11.30 am to 8.00 pm. INT7 presented higher living room temperatures in the evening. INT17 also showed a spike in the living room temperatures 3.00 pm to 5.00 pm. INT6 always maintained living room temperatures 20-21°C on typical September days. INT17 also showed a spike in the living room temperatures 3.00 pm to 5.00 pm. INT15 showed an increase in the living room temperature from midnight to 9.00 am. HH39 and HH43 presented lower living room temperatures throughout the day on 'typical' September days. Detailed explanations at a household level are given in previous sections.

CALD homes such as INT1, INT12 and HH44 present higher bedroom temperatures throughout the day. HH35 shows a gradual increase in the bedroom temperatures from 6.30 am which peaks around

3.00 pm and maintains till midnight. INT18 and INT16 have lower bedroom temperatures 12.00 pm to 10.00 pm. HH32 presents lower bedroom temperatures from midnight to 6.30 am and HH45 presents lower bedroom temperatures from midnight to 11.00 am. Non-CALD home INT2 presented higher bedroom temperatures on typical September days at all times. INT10 shows higher bedroom temperature from 6.00 am to 8.00 pm. INT8 shows higher bedroom temperatures from 8.00 am to 6.30 pm. INT4 and HH39 presented lower bedroom temperatures at all times in the non-CALD group. Detailed explanations at a household level are given in previous sections.

**Figure 54 Comparison of diurnal variations of mean half-hourly indoor temperature in CALD and non-CALD household size on days with a daily mean outdoor temperature of 11 $^0$C**




## 7.4 SUMMARY

The CALD status of households is not a strong determinant of their gas consumption but there are some interesting differences between CALD and non-CALD groups. While the variation is significant, CALD households tend to use more gas than non-CALD households as the outdoor temperature drops. Some CALD households who come from warmer places find Melbourne winters hard and so use high levels of home space heating.

Both CALD and non-CALD households show morning and evening gas usage peaks with no major differences.

When it comes to electricity use, non-CALD households show higher use but also more variation in use. For both groups, electricity consumption falls with increasing outdoor temperature. On average non-CALD households use more electricity across all outdoor temperatures. When it comes to diurnal variation in electricity use, the CALD households are younger on average and so are more likely to be away from their home during the working day. The non-CALD group includes more older and retired people who are at home all day.

CALD status is not a good predictor of living room temperature however it appears that CALD households might be somewhat more likely than non-CALD households to heat their bedrooms. The coldest bedrooms are those in non-CALD households.

# 8 Householder Archetypes

In this section, we present four vignettes that illustrate the four householder archetypes that represent the varied householder attitudes to the use of natural gas in the home. Archetyping involves the clustering of individual units of analysis by common traits to reduce complexity and facilitate predictions. Archetyping as a tool to upscale the low carbon housing transition often involves the presentation of dwelling typologies, for example by construction date, thermal performance and appliances, and housing stock models, (e.g. Clean air partnership, 2022 and Climateworks Centre 2023). When the unit of analysis is the dwelling, predictions centre on carbon emission or energy reductions due to the technological opportunities of material retrofits.

Other studies have used archetypes to explore the feasibility of electrification, focusing on fuel choice, appliances and dwelling type (size and energy efficiency of home, (e.g. ACIL Allen Consulting, 2020)) However, archetyping may also focus on people and seek to characterise households to explore the possible effect of technical or other interventions on householder vulnerabilities (e.g. Centre for Sustainable Energy 2020). Income, digital literacy, health and other attributes are combined to describe archetypes and their distribution across populations to reflect on the possible impacts of interventions on households. These exercises are characterised by a segmentation approach, subdividing large data sets of housing stock or energy consumers into subsets with common attributes. These categorisations of dwellings and /or households lend themselves to identifying target groups and developing interventions that align with key characteristics for effectiveness.

By contrast, in this section, we present vignettes that illustrate four householder archetypes that exemplify the variety of householder attitudes to the use of natural gas in the home. These vignettes describe the situations in real households and explore householder energy practices and attitudes within their specific housing contexts. The vignettes aim to highlight the complexities of energy use in homes and the entanglement of dwelling characteristics with householders, practices and values that shape energy outcomes, such as warmth, coolness and affordability, and energy-related home improvements. The vignettes provide information on the demographic situation of householders and material characteristics of their dwellings. The descriptions focus on the householders' practices of heating, cooling and cooking and capture their perceptions on efforts to regulate gas out of new housing. The choice of vignettes aligns with the archetypes and does not favour any particular viewpoint. The vignettes may help facilitate discussions and consider different perspectives on the low carbon transition of fuel in housing.

## 8.1 VIGNETTES

**Entrenched in gas archetype: INT 6 - non energy efficient, low household size, middle income, non-CALD**

Bob is close to 70. He is a retired telecommunications technician, and he owns the house where he lives with his partner and their cat. It's a weatherboard house in the inner western suburbs of Melbourne and Bob has been there for over 20 years. Bob says they are home bodies meaning that the house is almost continuously occupied. They speak English at home and have a combined annual income of about $120,000.

The house has two bedrooms with an open plan kitchen, living and dining space. The house has insulation in some of the walls and in the ceiling, a cement tile roof and single glazed windows. There are external canvas blinds on north- and west-facing windows and large trees also provide some shade. There are draft excluders on all external doors and Bob has also stuck bubble wrap over some glass sliding doors that connect the main living area to an uninsulated sleepout at the back of the house.

Six years ago, Bob chose to install a split air conditioning system in the main living area to replace the window mounted refrigerated units that were there when he bought the house. He thought the old units were inefficient and noisy, so he decided to upgrade. He considered putting in a ducted system but decided it wasn't really necessary. He did the electrical side of the installation himself and so saved some money. In the hot weather, he turns the unit on when the thermometer in the kitchen gets to 24 degrees and then leaves it running all day. On particularly hot nights, they will run the unit all night and it effectively cools the bedroom too. He uses a portable electric fan to push the air into the bedroom. There's also a ceiling fan in the bedroom that is used when it's not so hot.

For heating, there is a freestanding artificial log gas heater in the lounge room in addition to the split system. Bob maintains the heater himself including checking its performance using a CO monitor. In the past, the gas heater was the primary heat source in the winter but since gas prices have increased, they use the split system as the primary method of heating and the gas heater is turned on for aesthetics. Typical set points for the split system in winter are 17 degrees at night and 21 degrees during the day.

Comfort is Bob's primary consideration in using heating and cooling. Bob tells us that in his younger days he used to 'just tough it out' in the summer. Now as an older person 'it's great to have the modern comforts.' While aiming for comfort, he tries not to waste electricity and so turns the unit off if he's comfortable or if he goes out. This is driven by cost considerations but also because he's aware that the grid is under pressure at the moment and so he tries to do his bit to keep electricity usage under control. His actions are not driven by concerns for climate change, telling us: 'This environmental thing, I think it's overrated to be honest. I can see the commercial aspects and just everyone's jumping on the bandwagon, "We're gonna make a lot of money out of this." I'm no scientist, but all the environmental things, really, we're only measuring 200 years, I'm sorry. This might be just a normal cycle in the world.'

He services the air conditioning unit himself by cleaning the filters and blades. He tells us when he stays in a motel he often takes the filters out of air conditioners and cleans them as they are usually almost blocked. He doesn't like breathing other people's dust and such inefficient use of power annoys him.

When it comes to cooking, Bob has a fan forced electric oven and gas hotplates. They were both new when he bought the house. Although he says they are 'a bit tired', they are still working and so he has no plans to replace them. He likes the gas hotplates because of the immediate heat available and controllability. He has installed an exhaust fan ducted externally that he uses whenever he's cooking. Bob also has an old LPG BBQ which gets used a bit during summer.

This household has a gas storage hot water service that's about fifteen years old. Bob recently replaced a faulty thermostat because it was cheaper rather than paying someone else to do it. When the tank fails, he plans to change to an instantaneous flow through gas hot water system because he thinks this will be more efficient.

Bob can afford to pay his energy bills but he has shopped around to find the best deal. Buying his energy from an Australian-owned company is important to him. He thinks energy prices are 'out of control'. Everyone is 'pushing their own agenda'. He doesn't trust the environmental movement saying 'this green agenda – I'm sorry, it's gone too far' and he thinks the gas companies can 'probably see the end is nigh for gas so they're making the most out of it, perhaps in Australia. The greed factor – they're selling it overseas and getting great prices. Good luck to them, but they're not looking after us here at home are they?' Overall, he likes gas and has no plans to change fuels. 'It's very efficient. They used to say gas was the clean fuel. I don't know where it's got dirty.'

Bob thinks that the Victorian government's plan to restrict the extension of the domestic gas network and not connect new houses is ridiculous. In his view, gas is an efficient way to cook and heat. Further, he is concerned about society's overreliance on electricity. Coal is too polluting to burn for power generation but wind and solar are not able to provide base load power – in his view, gas is the best fuel for base load power generation, too.

**Moving to all electric – multiple benefits archetype: INT 5 - non energy efficient, low household size, low income, non-CALD**

Kathy lives with her adult daughter and their cats in a 30 year old brick veneer home in the western suburbs. She has lived there for 20 years. Kathy completed a trades qualification but she has not worked in that capacity recently – she is now a full time carer for her daughter who is severely disabled. They speak English at home. Household income comes from their government pensions.

The house has four bedrooms but two of them are rarely used. Similarly for the formal living room. Kathy and her daughter live mainly in the open plan kitchen/dining/lounge area and their two bedrooms. The home is occupied almost continuously as they don't go out much.

Kathy sees herself as a bit of a science geek and takes a keen interest in nature documentaries 'watching the poor old polar bears lose sea ice and watching Greenland become green rather than white and the same with down south at the other pole'. She links these global trends to her own life, saying 'I went to the big climate marches and do everything we can to reduce our carbon footprint and whatever we can'.

Kathy is a keen gardener and has planted trees to protect the house from the afternoon sun and to create a cool, sheltered area around the main entrance. There are also canvas blinds and/or heavy curtains on most windows. In the summer, Kathy manages to keep the house cool mainly by managing solar radiation and ventilation through the house describing her regime of opening and closing windows, blinds and shutters over the course of the day. There is a fixed ceiling fan in the main living area and portable fans in the bedrooms. The single evaporative air conditioner unit is about 40 years old (she got it second hand) and is rarely turned on. Her only plans to improve cooling are to plant more garden. Information about her summer indoor temperature was not yet available at the time of writing.

When it comes to heating, the wood slow combustion heater in the main living space runs continuously in the colder months. Kathy also manages ventilation to keep the heat in. The wood heater is supplemented by gas ducted heating. Kathy recently installed new gas ducted heating replacing an old system. At the time (before gas prices went up) she simply replaced like with like. If she were buying a new system now, she would look at electric options. The gas heating is mainly used in autumn and spring (when the wood heater is not running). When it's running, Kathy keeps it set at 20 degrees but turns it off at night. Kathy aims to minimise energy use wherever she can saying 'it's a new ducted heating system that we have, and so, that's really energy efficient, but again, as much as we can we'll put more jumpers on before we turn the heating on'. As a consequence, on 'typical September ' days, Kathy's living room presented temperatures above the minimum threshold of 18°C from 10.00 am onwards even though her gas usage was low.

The house has rooftop solar panels installed as a result of the government rebate scheme. Kathy has the app on her phone and she told us 'I love watching when I'm putting more energy into the system than I'm using'. As pension holders, Kathy and her daughter have access to the associated energy concessions. She has looked at deals to optimise retail rates and payment options and has changed energy retailers where she thinks she can get a better deal. Kathy's high electricity use was relatively high compared to the other non-efficient dwelling households: her daily electricity consumption was in the third quartile.

When it comes to cooking, Kathy tries to be time and cost efficient. She tends to cook in bulk using various benchtop electric appliances (pressure cooker, air fryer etc). She does this during the day to make the best use of her solar panels. She also uses the washing machine during the day for the same reason and line dries all washing (she has no dryer or dishwasher). She has a gas cooktop but doesn't use it much describing cooking on it as 'splurging with gas'. In her view, the war in Ukraine gave the gas companies an excuse to 'make mega bucks out of us'. Kathy's gas use was very high compared to the other non-efficient dwelling households: her daily gas consumption was in the top quartile.

Between our visits, Kathy made plans to change her hot water service from a gas storage system to an electric heat pump. This decision was driven by the old system starting to fail and the recently announced heat pump government subsidies. She is now saving up to buy an induction cooktop. She is also hoping that in the future there might be government rebate systems linked to replacing gas heating with electric that she would try to take up.

Kathy is very concerned about the future of the plant: 'I'm terrified of climate change. I've been watching the weather, what's been going on in the north – the hemisphere, what's going on with Antarctica and the Arctic, the fires, the droughts, the floods, just the devastation of people. It's terrible, just shocking. Yeah. Just a little bit, everyone does their little bit. I'm so sick of these people who say, "Oh, but Australia, if we do this", well, everyone has to do something. But anyway, I believe the scientists. I don't care what the Murdoch readers think.'

Despite these concerns, overall, Kathy is an optimist. As she says, 'I can make the best lemonade out of whatever lemons you give me'. She is aware of government announcements on energy and moves to transition to low carbon homes. She thinks 'it's the best idea ever and I really do… Australia should be able to go fully renewable. There's so many countries that have already done that. And we don't need new nuclear. That's the dumbest idea ever … I just think we've got the smarts and we've got the space to really create our own energy without having to dig up coal and without having to use gas. I think we can do it. And technology is just going to keep improving, isn't it? Improving, improving, improving.'

**Energy agnostic archetype: INT12, a non-energy efficient, non-low household, high income, CALD**

Lily lives with her husband, 2 young sons and their dogs in a three bedroom, 20 year old brick veneer home in the western suburbs. The family has lived here for 15 months. The family speaks Vietnamese and English at home. Lily has a university degree and works full time, mostly from home, so the house is almost continuously occupied. The combined household income is over $250,000.

During hot weather if the whole family is home, they run the ducted refrigerated cooling. Windows are single glazed with external roller shutters and no internal blinds or curtains. During the hot weather they close all the roller shutters. If Lily is working at home alone, she likely just uses a pedestal fan to keep cool. Lily sees the current ducted system as ineffective, taking more than 30 minutes to make much difference to the indoor temperature and expensive to run because it is not zoned. They don't usually run the air conditioner at night, but the previous summer they had a new baby and so used to leave the unit running on hot nights. They really noticed the high energy bills as a result and are now actively using the air conditioning less frequently. When the unit is running, the thermostat is set to 23 degrees. The family would like to install a split air conditioning system in each room so they have better cooling and more control over which areas are cooled but they cannot afford this as yet.

The house is also centrally heated with a gas furnace which is on most of the time in winter, even when Lily is home alone. They set it at 22 degrees. Lily likes to be warm in winter and she thinks it is important for the health of the family, particularly her toddler. She also thinks that keeping the set point constant and the heating running saves energy although she is not sure of the mechanism for this. The system is not zoned so when it is running, it heats the entire house. Lily is aware of the potential for what she calls 'monoxide issues' with gas and reports that they had a compliance check/service on the gas furnace when they moved in and intend to repeat that every two years. In addition to the central heating, the family have portable heaters in bedrooms and electric blankets on all the beds. They tend to run these all night in winter and turn the central heating off. She tells us that the driver for this is 'not being wasteful. And also cost. Our bills have been going up a lot as well, but also, it's not really needed because we're not really out here. It doesn't make sense to turn on and keep the heater on all night for the whole house.'

Since moving in, the family has done major renovations to the living area of the house, knocking out several walls to make it open plan and remodelling the kitchen. As Lily tells us, 'I wanted open living and I just wanted to open the space and the flow of how everything is. That was my main thing.' The family kitchen is not used on a day to day basis for major cooking. Lily's extended family lives nearby and they often eat together and otherwise they eat a lot of takeaway due to pressure of work. When she does cook for her immediate family, Lily tends to use the air fryer because it is quick, easy and energy efficient. She also sometimes hosts events for her extended family and the renovation is partly to create a large entertaining space and kitchen for those occasions. As for her new kitchen appliances, Lily bought a top of the range gas cooktop as recommended by the appliance showroom to replace the old gas stove. She later found out from friends that the government is phasing out gas. The previous appliances were 20 years old and she didn't like them so both stove top and oven were replaced. In choosing new appliances, Lily chose ones with a high energy rating as they cost less to run. She uses the exhaust system whenever she is cooking on the stove top largely to contain cooking smells. She has no concerns for the children linked to use of gas for cooking. The family has an outdoor BBQ that she says uses coal (she likely means charcoal).

Hot water is supplied by a 20-year-old gas fired storage tank system. Lily pays no attention to it as it works with no problems. If it were to fail, she would take the plumber's advice on what kind of unit to replace it with.

Overall, when it comes to energy use in her home, Lily is mostly concerned about the comfort and amenity of her home for her family including a young child and sometimes hosting large family groups. Her secondary concern is cost. When it comes to finances, Lily tells us: 'we're quite stretched, to be honest. Childcare fees full-time is a lot of money, same as my other boy's school fees, so I think in general living costs for us, everything has increased quite significantly.' She looks carefully at when bills are due and pays at the last moment 'just because we're trying to hold onto our money, and our mortgage has increased like crazy'. As a result, Lily has looked into changing energy retailers – she checks every 3 months or so that they are getting the best deal. She has the PowerPal app on her phone and checks energy usage there.

Energy efficiency was not an issue in deciding to purchase the house. As Lily explains: 'I didn't care about any of that because I just wanted to be across from my mum's house, so it's about location rather than the actual build because with the build we can always renovate and make changes and all those things, but geographically I didn't want to be far from my mum.' When doing their renovations, they thought about changing some of the windows to double glazed or even installing solar panels but in the end decided against making any changes of this kind. This decision was influenced by friends and neighbours who have solar panels and reported that the saving on electricity costs was not as much as they expected. They were also warned that maintenance costs of solar panels are significant.

Lily has little interest in or knowledge of low carbon or energy efficient homes generally. She has never heard of star ratings for homes. She doesn't have a strong understanding of, or interest in, energy sources in her home. For example, she insists that their refrigerated air conditioning system is powered by natural gas. She initially told us her stove top was electric but it's gas. As such, her family has no plans to phase out their gas use.

She is vaguely aware of government policy on energy transition away from gas, but she is concerned that the electricity system may not be reliable.

*'I'm actually really curious to know, in terms of electricity, how is that getting manufactured at the moment too, and if there's anything around that. This is what I've heard anyway - don't know if it's true - but there's already been warnings about electricity power cuts in summer coming up because there's not enough electricity. So, if you remove gas and then you've got no electricity, what are we left with?*

*For someone who has a young family, I need to know. If you're going to be cutting off power, are we going to be stinking hot and then I've got nothing for the kids to cool down? In my mind, it's like you're limiting people's options. If you're going to be getting rid of gas for whatever the reason is, then you need to make sure that you've got enough electricity to supply that. That's, in my mind, already not-so-great thing. It'll be interesting to see, this summer, if that happens, because I think getting rid of gas completely and then not having electricity either and not having enough supply, I don't understand why you'd get rid of something.'*

**Moving to all electric - cost archetype: INT 20 - non energy efficient, low household size, medium income, non-CALD**

Kylie is in her late thirties. She and her cat live in her double brick unit which is one of six in a block built in the 1960s. She has a busy lifestyle with a range of professional jobs (she has a Master's degree), some done from home and others outside the home. She is often out with friends at the weekends so overall her home is intermittently occupied. Kylie's annual income is around $100,000. The unit has two bedrooms with a kitchen and separate living/dining space. Kylie had ceiling insulation installed when she bought the property 18 months ago. Windows are single glazed. The configuration of the block is such that her unit is upstairs and has windows on all sides with large ones facing east and west. Kylie likes that this makes the space light-filled all day, but she says it's also energy inefficient. She has installed new honeycomb insulating internal blinds on some of the windows that seems to help.

When Kylie bought the property, the main means of heating was an old gas wall furnace. It was effective at heating the space but it made her nervous to use – she doesn't think they are safe 'you know, carbon monoxide poisoning, setting the house on fire '– and she intends to remove it. When we first visited, she had recently installed a new reverse cycle system in the living room and now uses that for heating, but she tries to limit how much she uses it, preferring to put on an extra jumper first. She has installed draft seals around the doors (as well as the new blinds) to try to hold on to solar warmth. She also uses an electric throw rug when sitting on the couch watching TV or when sitting working at home, rather than turning the heating on. Between our visits, she also replaced the portable oil heaters that she was using in her bedroom with another new split air conditioning system.

In summer, she tries to keep cool by creating a draft through the unit and also keeping blinds closed. She also uses a portable fan in the bedroom in preference to turning on the air conditioning unless it's really hot. The new reverse cycle system in the lounge room also replaces an old evaporative cooler that had been retrofitted to her unit many years ago. It was noisy, ugly and didn't effectively cool. In contrast, the split system cools the living space very effectively at a set point of 24 degrees.
When it comes to cooking, Kylie's kitchen has a gas stove and oven which she uses most days. They were there when she bought the unit and are decades old. Ultimately, she would like to replace them with new electric appliances including an induction cooktop, but this is not a high priority. She likes cooking with gas but is a little concerned about having an open flame in the kitchen.
This household has an instantaneous gas hot water service that's not original but looks like it has been in service for some time. It sits on the back balcony of the unit. Kylie is happy with the system and has no plans to replace it.

Now that she does not need to use the wall furnace for heating, comfort and cost are Kylie's primary concerns when it comes to managing the temperature of her living space. Kylie can afford to pay her energy bills but she has noticed them going up. She has an electricity usage monitoring app on her phone so she knows which appliances cost her most money to run. She has experimented with the best way to run her heating to balance comfort and running cost which was a big factor in replacing the portable heater in her bedroom with a second split system. Apart from her comfort a third factor was considering resale value of her unit which she thinks is improved by having the unit in the bedroom as well as the lounge. She also runs her washing machine using cold water because the app tells her it uses less energy. As she explains, 'it's a direct correlation for me between – well, I've used more energy, therefore it will cost me more and it'll tell me exactly it's cost you $2.82 for your electricity today versus $1.72 when you didn't use the heater, as an example, right. So, there's a literal direct correlation between the energy and the cost.' In addition, she uses Powershop to buy energy in advance that suits her needs and saves money.

Climate considerations do not really figure in her decision making. 'There's also an argument to be made for obviously things like climate change and all of that sort of stuff … if the app told me that as well, I'd probably start focusing on that too. I'd be like, oh well, that's one polar bear or whatever. As an example. I guess it's much easier to make the connection between the energy usage and the cash though.'

Overall, Kylie would like to make further energy-related changes to her home. She would love to replace the windows with double glazing but her expected price of over $20,000 is too high for now. In the medium term, she would like to phase out gas from her property (which means replacing the gas cooking and the hot water service) but these are not high priorities as they are not big energy users and so don't cost much to run. Nevertheless, 'if there were government incentives to get rid of my gas appliances, I would be very happy to take them up on that.'

Kylie is only vaguely aware of state government announcements about gas policy and has no strong views about it. She is in favour of government policies that promote low energy, low carbon homes design to use 'energy sources … that are as climate conscious as possible. Whether that's solar or hydro or whatever it happens to be.'

## 8.2 SUMMARY

This section presents four vignettes that illustrate the four householder archetypes (entrenched in gas, energy agnostic, moving to all electric – cost, moving to all electric – multiple benefits) that represent the varied attitudes of householders to the use of natural gas in the home. The next section presents the Discussion of the research findings.

# 9 Discussion

This project aimed to provide a better understanding of

- how householders balance electricity and gas services, and
- how householder energy practices shape, or are shaped, by vulnerabilities and affordability.

Vulnerabilities in this framework are causal conditions and outcomes. Vulnerabilities that were given prominence in this study were low income, low household size, CALD and living in an energy inefficient home. Vulnerability as the outcome describes situations in which members of the households are not achieving essential energy outcomes that are essential to sustain health and wellbeing (Day et al. 2016). For this winter analysis, the key energy outcome was indoor warmth.

Energy efficiency of the home did not automatically translate into less energy use and more comfortable or healthy indoor temperatures because householder energy use practices and values did not align with the assumptions embedded in the NatHERS tool that calculates the energy efficiency of homes.

The assumption that more energy efficient homes are warmer in winter and use less energy is based on the assumption in the NatHERS rating tool that key factors, such as the thermostat settings, are the same in each dwelling. The thermostat settings are defined as follows:

- For living spaces (including kitchens and other spaces typically used during waking hours): a heating thermostat setting of 20° Celsius (C).
- For bedroom spaces (including bathrooms and dressing rooms, or other spaces closely associated with bedrooms): a heating thermostat setting of 18°C from 7.00 am to 9.00 am and from 4.00 pm to 12.00 am; and a heating thermostat setting of 15°C from 12.00am to 7.00 am.(NatHERS National Administrator 2012).

The NatHERS administrator explains the strategy behind the tool:

“The loads, hours of operation and thermostat settings in AccuRate are a conservative representation of dwelling occupancy for comparative testing only. The actual use of any particular dwelling will vary from hour to hour, day to day, and year to year according to many factors such as occupant number and behaviour (influenced by age, lifestyle, occupation, wealth, and health). The dwelling operational details are not designed to reflect a particular household, but instead are designed to allow a consistent and reasonable comparison between buildings on the basis of the potential to be comfortable in each space according to its designed function and Climate Zone.” (NatHERS National Administrator 2012:23)

In addition, the NatHERS star rating is only based on heating and cooling loads and does not take into consideration the efficiency of the heating and cooling system. The star rating also assumes a standard occupancy, ignores other domestic energy uses such as hot water use, lighting and other domestic appliances, as well as the benefits of solar microgeneration. Hence, the NatHERS star ratings are a poor predictor of actual energy consumption even in the comparison of dwellings with identical building envelopes in the same climate zone.

The investigation of householder practices and energy outcomes here not only revealed that householder energy routines deviated from NatHERS assumptions but that values beyond affordability and health shaped energy routines.

Key values beyond the affordability of energy and health were resource conservation and the desire for spatial control of warmth. Efficient homes were characterised by large size and open plan design of new houses. Gas heating in these new homes was linked to central heating with very limited opportunities for zoning. In addition, homes were often underoccupied during the day, that is some rooms were not used. These material and social conditions counteracted householders’ desire to restrict heating to areas that were actually occupied and triggered a switch to individual room heating afforded by electric heaters. Solar panel microgeneration, where available, reinforced the switch to electric heating, because it was perceived as being “free” or at least to be saving money. As a result, even many efficient homes were too cold for health for much of the day and rarely reached the assumed target temperature of 20°C. The study also confirmed other conditions, such as embracing frugality, considering cold homes as normal, and lacking awareness of the health implications, that have been related to cooler living conditions in the literature (Willand et al. 2021).

By contrast, homes were warmer when heating was used continuously and not switched off overnight, either for comfort or under the perception that lowering the temperature rather than switching the system off completely ensure optimum performance. Warmth for health was evident in homes of older and frail people and those with young families. This agrees with the literature that older people, those leading a more sedentary and home-centred lifestyle and person on certain medications are likely to live in warmer homes (Willand et al. 2021). The study also highlighted that there was much uncertainty of adequate thermostat settings with outcomes in indoor temperature and energy usage that may be considered excessive. This supports previous research that there is a general lack of knowledge and understanding of energy in the home in Australian households (Willand et al. 2021). Importantly, most homes were underheated which may be interpreted as a health risk.

The relationship between household size and energy use was only partly explained by shared practices of hot water and appliances. Larger households presented gas morning and evening peaks when several household members were assumingly showering and electricity peaks when several household members were assumingly using communication devices and solar PV yield was low. These findings concur with the literature that parents are critical of their teenage children’s hot water during showering or bathing (Gram-Hanssen, 2007). We found, though, that most people used showers and that the continual readiness of a hot spa in one home offset the benefits of solar PVs.. We also found that a high number of adolescents could increase electricity use. Interestingly, there was little critical reflection on children’s electricity use by parents (Wallis, Nachreiner and Matthies, 2016).

In our small sample, household income did not present a simple linear relationship with gas and electricity use nor with indoor temperatures. The highest gas use on very cold days in the high-income group concurs with assumption that these households will not compromise on having at least some level of comfort. By contrast, low-income households tried to avoid gas use during the day. Interestingly, the middle-income household group emerged as the group with the highest electricity use which may reflect their access to energy saving appliances.

With regards to CALD, the findings suggest more gas use, presumable for heating, gas cooking and hot showers, in CALD homes on very cold days and a general preference for warmer bedrooms, which concurs with the limited research into CALD energy practices (Maller, 2012).

# 10 Conclusions

This report has detailed the gas and electricity use and indoor temperatures in 32 households in September 2023, compared outcomes in energy use and warmth between four categories of vulnerability, and explained outcomes in individual homes through energy practices. The findings shine a light on the relationship between outdoor temperatures and energy outcomes and patterns in daily fluctuations. Specifically, the study found that, on average, homes did not provide a stable, warm indoor environment as indoor temperatures were related to outdoor temperatures and most homes were underheated even when people were home. Daily gas usage patterns were characterised by a morning and an evening peak, whereas electricity use peaked at night. Most householders had a rough awareness of their energy use patterns; many householders who engaged with their solar PV system's monitoring application managed their electric usage to avoid the purchase of grid electricity. Householder perceptions of efforts to move to all-electric homes were varied and ranged from welcoming the changes to mistrust and resistance.

# 11 Implications and recommendations for industry

As a 'consumer first' approach is required to transition effectively and equitably to a lower carbon housing future, it is important to understand how the socio-technical system of energy in the home affects energy outcomes. By juxtaposing monitored energy use and indoor temperatures with householder energy routine and rationales, this study has established that common categories of energy vulnerability, such as energy efficiency ratings of homes, income, CALD status and household size, offer incomplete explanations of gas and electricity use and indoor temperatures. This suggests that any assessment of vulnerability in household in the low carbon transition should consider a more comprehensive and nuanced approach to vulnerability.

While affordability of fuel played a role in householder practices, and energy price increases had signalling effects, values such as duty of care for older or disabled people and very young children were more important than economic priorities and manifested in warmer homes. Considering that Australia has an ageing population, and that the Ageing in Place policy is favoured by older people and policy makers, keeping people warm in their homes will require more energy in the future unless there are interventions that improve the energy efficiency of dwellings and appliances.

Interestingly, heating in all areas and overnight was seldom considered essential. This perception contradicts regulatory assumptions (NatHERS) and the WHO's public health recommendations, Consequently, cold homes were a common phenomenon. This means that, in general, householders were under consuming energy and that achieving adequate or healthy temperatures, even in energy efficient dwellings, requires more energy use or the improvement of the thermal performance of building envelopes and appliances.

Another important finding was the bi-modal shape of daily gas use, with peaks in the mornings and nights and a through during the day. This pattern may have implications for considering equity in a possible time of day gas tariff. Demand-side tariffs, for example offering cheap unit prices during times of low demand, are common in the electricity sector but not in Victoria's gas distribution areas. Should the gas sector introduce such nuanced pricing policies, then expensive gas prices in the morning and night may lead to higher overall heating expenses. Gas prices during the night should be low for two reasons. Firstly, low nighttime gas tariffs may encourage householders to keep their homes warm during the night to avoid the morning peaks. Heating overnight may also improve the adequacy of warmth. Secondly, low night tariffs would prevent the high costs of the anti-legionella hot water cycles that were evident around the early hours of the morning.

The study also provided insights into how householders were actively managing their thermal environment and solar microgeneration. Most householders used a manual, rather than automatic, control of space conditioning systems, and there was little evidence of a 'set and forget' mentality. The predominance of manual thermostat or room heating control expressed the underlying dissatisfaction of householders with the efficiencies of, and ability to control, their heating systems. This suggests that the heating systems were not effectively communicating with householders which may have hindered achieving the balance of adequate warmth and energy saving. By contrast, solar panels influenced time of day usage of appliances, because the real time monitoring applications made the energy generation and usage visible. Currently, householders cannot monitor their natural gas usage. The findings suggest, though, that real time gas monitoring may also influence gas usage patterns. Real time gas monitoring should be a requirement should demand-side tariffs ever be employed for gas usage to allow householders control over the costs of running their home.

A key observation is that many householders were actively engaged in home energy improvements ranging from simple draft proofing and garden design to provide shading, through to technology improvements. In the selection of appliances, environmental outputs or greenhouse gas emissions were seldom front of mind and also not visible. Instead, perceptions of efficiency, safety, energy security, and sensory stimuli such as noise of appliances, smell of cooking, feeling of radiant warmth and the sight of flames shaped the householders' choices. In general, householders operated a combination of appliances be it for heating, cooling and cooking. Only hot water provision relied on a single system. This is an important finding for policy makers and the industry as a pure focus on quantitative, environmental or economic benefits of home energy intervention schemes may be less effective than appeals to people's ethical values.

Further, we emphasise that considerations in decision making on energy carriers, e.g. gas, electricity and wood, extended beyond the individual household to wider societal outcomes, such as resource conservation or waste avoidance and resilience of the electricity grid. Resource conservation included admiration for the longevity of appliances and the desire to extend their life cycle through regular maintenance and repairs. Replacements were generally linked to the breaking down of appliances rather than being proactive. While there was strong evidence of optimism in technology and that government incentives precipitates appliance upgrades and the installation of solar panels, the distrust and suspicion among a few householders that the push towards technological changes included a certain level of commercial avarice should not be dismissed. Policy makers and the industry may consider building trust in the technological and regulatory processes that are part of the transition to low carbon housing. This final point echoes a similar finding from previous research regarding built environment policy under RP2.2-03. That work highlighted the extent to which built environment policy and energy policy were often disconnected, leading to confusion and a lack of trust on the part of some stakeholders.

# 12 Next steps and future works

The next step of this study is to explore the summer household interviews and quantitative data findings. A similar analysis of indoor temperatures, gas, and electricity uses in summer months with regard to four demographic categories: dwelling efficiency, household size, income level, and CALD status will be done. Further, the quantitative data collection is scheduled to be finished by August 31, 2024. A similar analysis for the winter 2024 quantitative data will be done under four demographic categories. The results of this analysis will be used to validate the conclusions drawn from the indoor temperatures, gas, and electricity usage data collected between June-August 2023 and September 2023. The final report of the study would incorporate the findings from the summer quantitative and qualitative data analysis. Further, we might look at another quantitative analysis utilizing the four archetypes. The analysis would explore how the four archetypes correspond to the findings from the four demographic categories.

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# 14 Appendices

## Appendix 1: Household characteristics

| Household | Number of occupants | Household composition | | | Annual income | Cultural background | Languages spoken at home | Home occupancy pattern | | Home ownership |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Adults | Children | Pets | | | | Weekdays | Weekends | |
| INT1 | 2 | 2 | 0 | 1 | < $50,000 | Chinese/Singapore and Australian | English | Someone is home all day | Someone is home all day | Owned outright |
| INT2 | 1 | 1 | 0 | 0 | < $50,000 | Maltese | English | Someone is home all day | Someone is home all day | Owned outright |
| INT3 | 3 | 3 | 0 | 2 | $50,000 - $150,000 | Australian | English | Nobody home between about 9:00 am and 5:00 pm, Monday to Thursday | In and out | Owned outright |
| INT4 | 2 | 2 | 0 | 1 | $50,000 - $150,000 | Italian | English | Someone is home all day | Someone is home all day | Owned outright |
| INT5 | 2 | 1 | 1 | 3 | < $50,000 | Australian | English | Someone is home all day | Someone is home all day | Mortgage |
| INT6 | 2 | 2 | 0 | 1 | >$150,000 | Australian | English | Someone is home all day | Someone is home all day | Owned outright |
| INT7 | 1 | 1 | 0 | 0 | >$150,000 | Australian | English | Someone is home all day | Someone is home all day | Owned outright |
| INT8 | 3 | 3 | 0 | 3 | $50,000 - $150,000 | Australian | English | Someone is home all day | Someone is home all day | Mortgage |
| INT9 | 3 | 3 | 0 | 1 | < $50,000 | English - UK | English | Nobody at home in the morning | Someone is home all day | Owned outright |
| INT10 | 4 | 2 | 2 | 1 | >$150,000 | Italian-Australian | English | Nobody at home till 4.00 pm, three days a week | Someone is home all day | Mortgage |
| INT12 | 4 | 2 | 2 | 2 | >$150,000 | Vietnamese | English, Vietnamese | Someone is home all day | Someone is home all day | Mortgage |
| INT13 | 3 | 2 | 1 | 0 | >$150,000 | Indian | English, Hindi | Someone is home all day | Someone is home all day | Mortgage |
| INT14 | 6 | 2 | 4 | 4 | $50,000 - $150,000 | Anglo-Saxon | English | Nobody at home till the evening | In and out | Mortgage |
| INT15 | 3 | 1 | 2 | 1 | $50,000 - $150,000 | Australian | English | Nobody at home till the evening | Someone is home all day | Mortgage |
| INT16 | 2 | 2 | 0 | 1 | < $50,000 | Maltese | English, Maltese | Someone is home all day | Someone is home all day | Owned outright |
| INT17 | 2 | 2 | 0 | 0 | >$150,000 | Irish heritage and Anglo-Indian | English | Someone is home all day | Someone is home all day | Mortgage |
| INT18 | 4 | 3 | 1 | 1 | >$150,000 | Chinese | English, Mandarin | Someone is home all day | Someone is home all day | Mortgage |
| INT19 | 3 | 3 | 0 | 2 | $50,000 - $150,000 | Scottish | English | Someone is home all day | Someone is home all day | Owned outright |
| INT20 | 1 | 1 | 0 | 1 | $50,000 - $150,000 | Caucasian | English | Occupancy varies based on work timing | Out in the day, home at night | Mortgage |
| HH22 | 2 | 2 | 0 | 0 | >$150,000 | English - UK | English | Someone is home all day | Sometimes someone is at home | Mortgage |
| HH28 | 4 | 2 | 2 | 1 | >$150,000 | Australian | English | Sometimes someone is at home | Someone is home all day | Mortgage |
| HH29 | 2 | 2 | 0 | 0 | < $50,000 | Chinese | Chinese, English | Someone is home all day | Someone is home all day | Owned outright |
| HH32 | 4 | 2 | 2 | 0 | >$150,000 | Indian | Punjabi, English | Someone is home all day | Depends on the activities | Mortgage |

| Household | Number of occupants | Household composition | | | Annual income | Cultural background | Languages spoken at home | Home occupancy pattern | | Home ownership |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Adults | Children | Pets | | | | Weekdays | Weekends | |
| **HH34** | 7 | 6 | 1 | 1 | < $50,000 | Australian | English | Someone is home all day | Someone is home all day | Owned outright |
| **HH35** | 3 | 1 | 2 | 0 | $50,000 - $150,000 | Indonesian. | English | Sometimes someone is at home | 50% someone is there | Mortgage |
| **HH39** | 4 | 4 | 0 | 2 | $50,000 - $150,000 | Australian | English | Someone is home all day | Someone is home all day | Owned outright |
| **HH40** | 3 | 2 | 1 | 0 | $50,000 - $150,000 | Indian | Telugu, English | Someone is home all day | Someone is home all day | Mortgage |
| **HH41** | 3 | 2 | 1 | 1 | $50,000 - $150,000 | Indian | Hindi, English | Someone is home all day | Someone is home all day | Mortgage |
| **HH42** | 3 | 2 | 1 | 0 | >$150,000 | Slovenia | English, Slovenian | Someone is home once a week | Someone is home all day | Owned outright |
| **HH43** | 3 | 2 | 1 | 1 | >$150,000 | Australian | English | Someone is home all day | Someone is home all day | Owned outright |
| **HH44** | 4 | 2 | 2 | 0 | $50,000 - $150,000 | Indian | Bengali, English | Someone is home all day | Someone is home all day | Mortgage |
| **HH45** | 2 | 2 | 0 | 0 | $50,000 - $150,000 | Indian | English, Hindi | Someone is home all day | Out of home every alternate weekend | Mortgage |

## Appendix 2: Dwelling characteristics

| House hold | Efficient vs Non efficient | Dwelling structure | Date of construction | Energy efficiency rating | Area ($m^2$) | Length of residence (years) | No. Baths | No. Bedrooms | No. Living areas | Wall materials | Wall Insulation | Roof/ceiling insulation | Floor insulation | Windows | Windows cannot be closed | Outside shutters | External Shading type | Indoor heavy curtains with pelmets | Energy efficient light bulbs | Solar panels | Solar battery |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INT1 | Efficient | Detached house | 2015 | 6 stars | 412 | 6 | 2 | 4 | 2 | Brick veneer | Yes | Yes | No | Double glazed | No | Yes | Roller shutter | Indoor heavy curtains with pelmets | LED | Yes | No |
| INT2 | Non-efficient | Detached house | 1986 | Not rated | Don't know | 37 | 1 | 2 | 1 | Brick veneer | Not sure | Yes | No | Single glazed | No | No | None | Indoor heavy curtains with pelmets | Led | Yes | No |
| INT3 | Non-efficient | Detached house | 1995 | Not rated | 149 | 28 | 2 | 3 | 2 | Brick | No | Yes | No | Single glazed | No | No | None | Vertical/venetian/holland blinds | LED | Yes | No |
| INT4 | Efficient | Townhouse | 2015 | 5 stars | 270 | 8 | 2 | 3 | 2 | Brick | No | Yes | No | Single glazed | No | Yes | Roller shutter | Indoor heavy curtains with pelmets | LED | Yes | No |
| INT5 | Non-efficient | Detached house | 2000 | Not rated | Not sure | 23 | 2 | 4 | 2 | Brick veneer | No | Yes | No | Single glazed | No | No | None | Indoor heavy curtains with pelmets | LED | Yes | No |
| INT6 | Non-efficient | Detached house | 2000 | Not rated | Not sure | 23 | 1 | 2 | 1 | Weatherboard | Yes | Yes | No | Single glazed | No | Yes | Roller shutter | Indoor heavy curtains with pelmets | LED | No | No |
| INT7 | Efficient | Detached house | 2018 | 5 stars | Not sure | 4.5 | 2 | 3 | 1 | Brick veneer | No | Yes | No | Double glazed | No | No | None | Indoor heavy curtains with pelmets | LED | Yes | No |
| INT8 | Non-efficient | Detached house | 1978 | Not rated | Not sure | 45 | 2 | 4 | 2 | Brick veneer | No | Yes | No | Single glazed | No | No | None | Indoor heavy curtains with pelmets and Venetian blind | LED | Yes | No |
| INT9 | Non-efficient | Detached house | 2002 | Not rated | Not sure | 9 | 2 | 3 | 2 | Sandstone | Not sure | Yes | No | Single glazed | No | Yes | Roller shutter | Indoor heavy curtains with pelmets and Venetian blind | LED | Yes | No |
| INT10 | Non-efficient | Detached house | 1998 | Not rated | 664 | 2 | 1 | 3 | 2 | Brick | Not sure | Yes | No | Single glazed | No | No | None | Indoor light curtains and Venetian blind | LED | Yes | No |
| INT12 | Non-efficient | Detached house | 2003 | Not rated | 300 | 2 | 2 | 3 | 2 | Brick veneer | Yes | Yes | No | Single glazed | No | Yes | Roller shutter | Vertical/venetian/holland blinds | LED | No | No |
| INT13 | Non-efficient | Detached house | 2000 | Not rated | Not sure | 3 | 2 | 4 | 2 | Brick | Yes | Yes | No | Single glazed | No | Yes | Roller shutter | Vertical/venetian/holland blinds and light curtains | LED | Yes | No |
| INT14 | Efficient | Detached house | 2008 | 5 stars | Not sure | 14 | 2 | 5 | 1 | Brick veneer | Not sure | Yes | No | Single glazed | No | No | None | Vertical/venetian/holland blinds and light curtains | LED | Yes | No |
| INT15 | Non-efficient | Detached house | 1998 | Not rated | Not sure | 4 | 1 | 2 | 1 | Brick veneer | No | Yes | No | Single glazed | No | No | None | Vertical/venetian/holland blinds | No | No | No |
| INT16 | Non-efficient | Detached house | 1973, extended 1990 | Not rated | 316 | 50 | 2 | 5 | 2 | Cedar | Yes | Yes | No | Single glazed | No | No | None | Vertical/venetian/holland blinds and light curtains | LED | No | No |
| INT17 | Non-efficient | Detached house | 1970 | Not rated | 170 | 1 | 1 | 2 | 1 | Double brick | No | No | No | Single glazed | Yes | Yes, Canvas awning | Canvas awning | Vertical/venetian/holland blinds | LED | No | No |
| INT18 | Non-efficient | Detached house | 2000 | Not rated | 180 | 3 | 1 | 3 | 1 | Weatherboard | Yes | Yes | No | Single glazed | No | No | None | Vertical/venetian/holland blinds | LED | Yes | No |
| INT19 | Non-efficient | Detached house | 1970 | Not rated | Not sure | 28 | 1 | 3 | 1 | Double brick | Yes | Yes | No | Single glazed | No | No, Roll up blinds | None | Vertical/venetian/holland blinds and light curtains | LED | Yes | No |
| INT20 | Non-efficient | Detached house | 1960 | Not rated | 90 | 2 | 1 | 2 | 1 | Double brick | No | Yes | No | Single glazed | No | No | None | Vertical/venetian/holland blinds | Led 50% | No | No |
| **HH22** | Non-efficient | Detached house | 1960 | Not rated | Not sure | 3 | 2 | 3 | 1 | Half weatherboard, half brick | Yes | Yes | No | Single glazed | No | No | None | Vertical/venetian/holland blinds | LED | No | No |
| **HH28** | Efficient | Detached house | 2020 | 6 stars | 334 | 3 | 2 | 5 | 1 | Brick veneer | Yes | Yes | No | Double glazed | No | No | None | Vertical/venetian/holland blinds | LED | No | No |
| **HH29** | Efficient | Detached house | 2014 | 6 stars | 446 | 9 | 3 | 5 | 2 | Brick veneer | Yes | Yes | Maybe | Double glazed | No | Yes | Roller shutter | Indoor light curtains | LED | Yes | No |
| **HH32** | Efficient | Detached house | 2010 | 6 stars | 214 | 13 | 2 | 4 | 1 | Brick veneer | Yes | Yes | No | Double glazed | No | No | None | Indoor heavy curtains with pelmets | LED in some parts of the house | Yes | No |
| **HH34** | Non-efficient | Detached house | 1994 | No rated | 186 | 29 | 2 | 4 | 1 | Brick veneer | Yes | Yes | No | Single glazed | No | No | None | Indoor heavy curtains with pelmets | LED | Yes | No |
| **HH35** | Non-efficient | Detached house | 2006 | Not rated | 200 | 10 | 2 | 4 | 2 | Brick veneer | No | No | No | Single glazed | No | Yes | Roller shutter | Vertical/venetian/holland blinds | LED | Yes | No |
| **HH39** | Non-efficient | Detached house | 2002 | Not rated | Not sure | 21 | 2 | 4 | 2 | Brick | Yes | Yes | No | Single glazed | No | No | None | Indoor heavy curtains with pelmets | LED | No | No |
| **HH40** | Efficient | Detached house | 2016 | 5 stars | 230 | 7.5 | 2 | 4 | 1 | Brick veneer | No | Yes | No | Single glazed | No | No | None | Indoor light curtains and Venetian blind | LED | Yes | No |

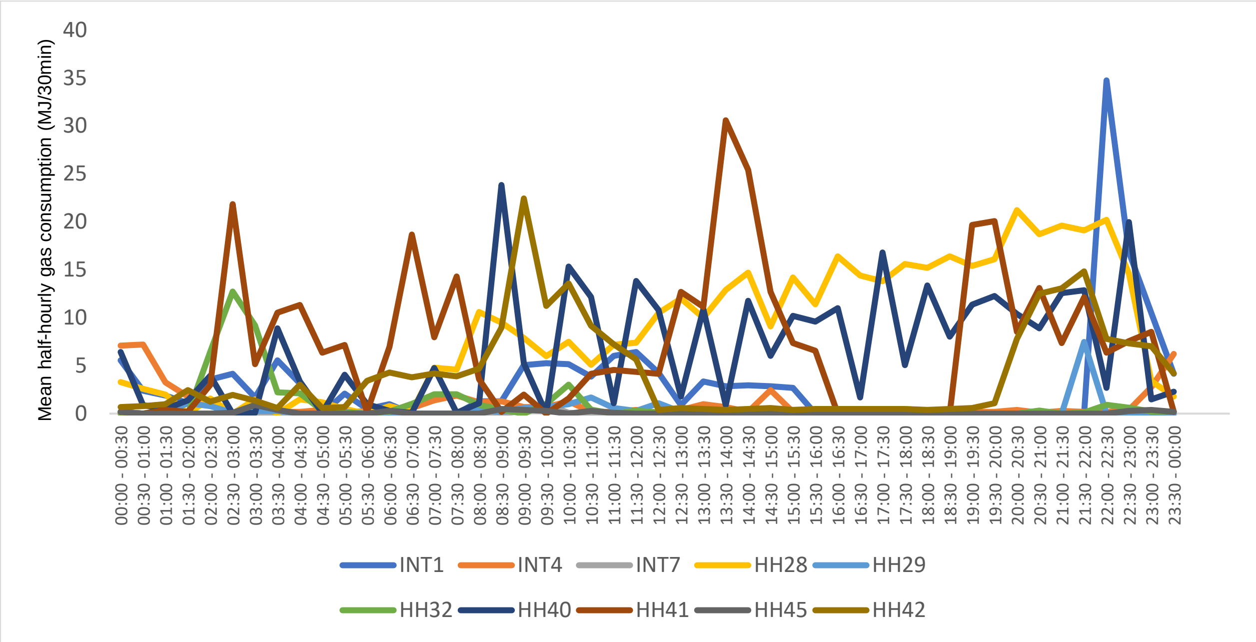
| House hold | Efficient vs Non efficient | Dwelling structure | Date of construction | Energy efficiency rating | Area (m²) | Length of residence (years) | No. Baths | No. Bedrooms | No. Living areas | Wall materials | Wall Insulation | Roof/ceiling insulation | Floor insulation | Windows | Windows cannot be closed | Outside shutters | External Shading type | Indoor heavy curtains with pelmets | Energy efficient light bulbs | Solar panels | Solar battery |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **HH41** | Efficient | Detached house | 2010 | 6 stars | 279 | 13 | 2 | 4 | 2 | Brick veneer | Yes | Yes | No | Single glazed | No | No | None | Indoor light curtains and Venetian blind | LED | Yes | No |
| **HH42** | Efficient | Detached house | Built 1980, renovated 2015 | Not rated | Not sure | 4 | 2 | 3 | 1 | Brick veneer | Not sure | Yes | No | Single glazed | No | No | None | Vertical/venetian/holland blinds | LED | No | No |
| **HH43** | Non-efficient | Detached house | 1960 | Not rated | 680 | 4 | 1 | 3 | 2 | Brick veneer | No | Yes | No | Single glazed | Yes | No | None | Vertical/venetian/holland blinds | Led | No | No |
| **HH44** | Non-efficient | Detached house | 1998 | Not rated | Not sure | 0.25 | 1 | 2 | 1 | Brick | No | Yes | No | Single glazed | No | No | None | Indoor heavy curtains with pelmets | LED -Only several lights | No | No |
| **HH45** | Efficient | Detached house | 2010 | 5 stars | 254 | 3 | 2 | 4 | 4 | Brick veneer | Yes | Yes | No | Single glazed | No | No | None | Vertical/venetian/holland blinds | LED | Yes | No |

Appendix 3: Additional graphs on gas and electricity usage and indoor temperature of the 32 homes

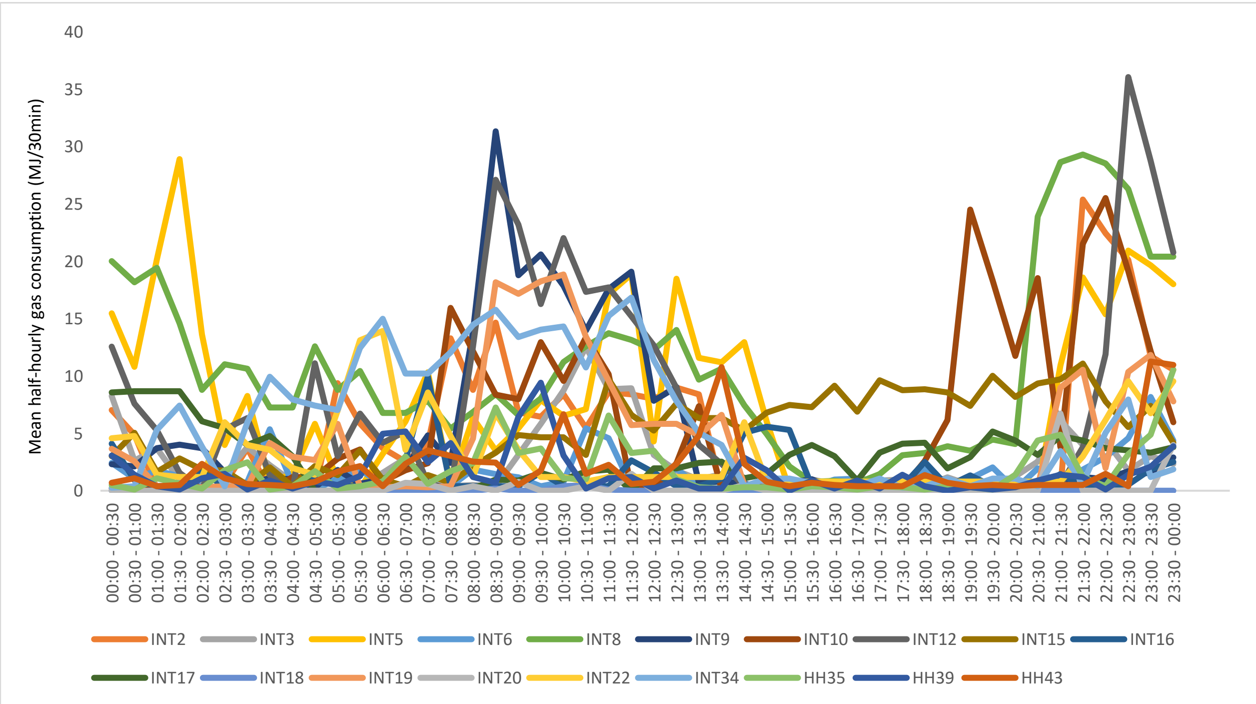
# 1. Dwelling efficiency

## 1.1 Gas usage

**Efficient homes**

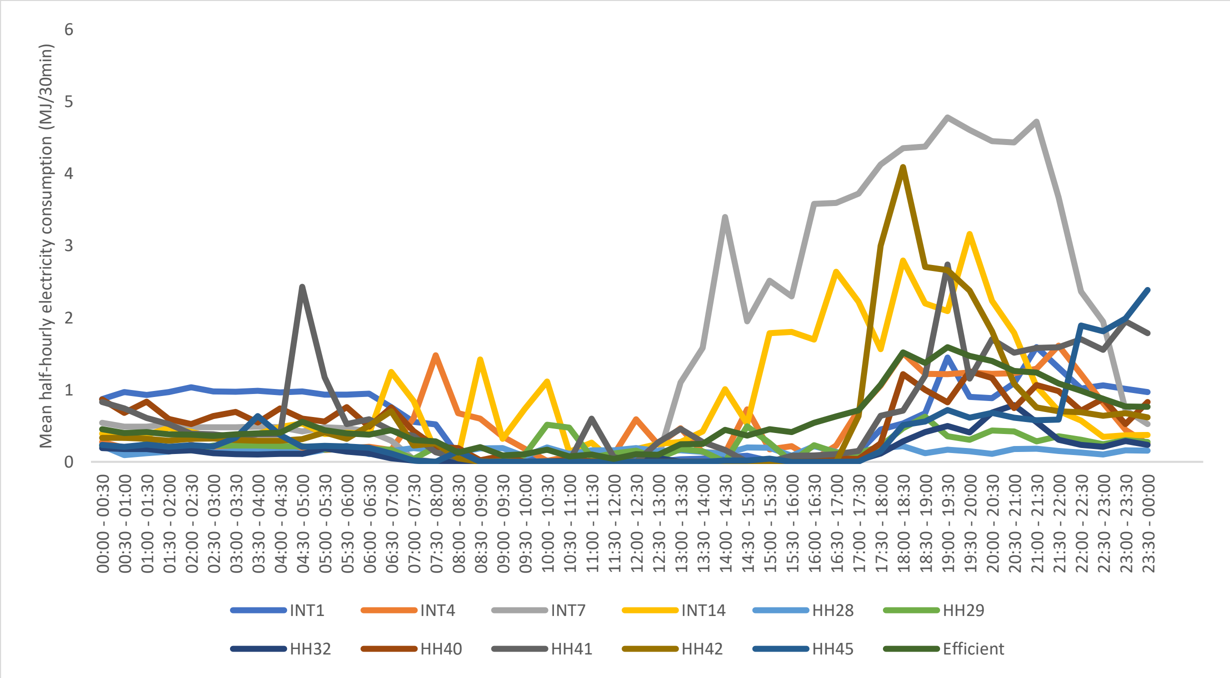



**Non-efficient homes**

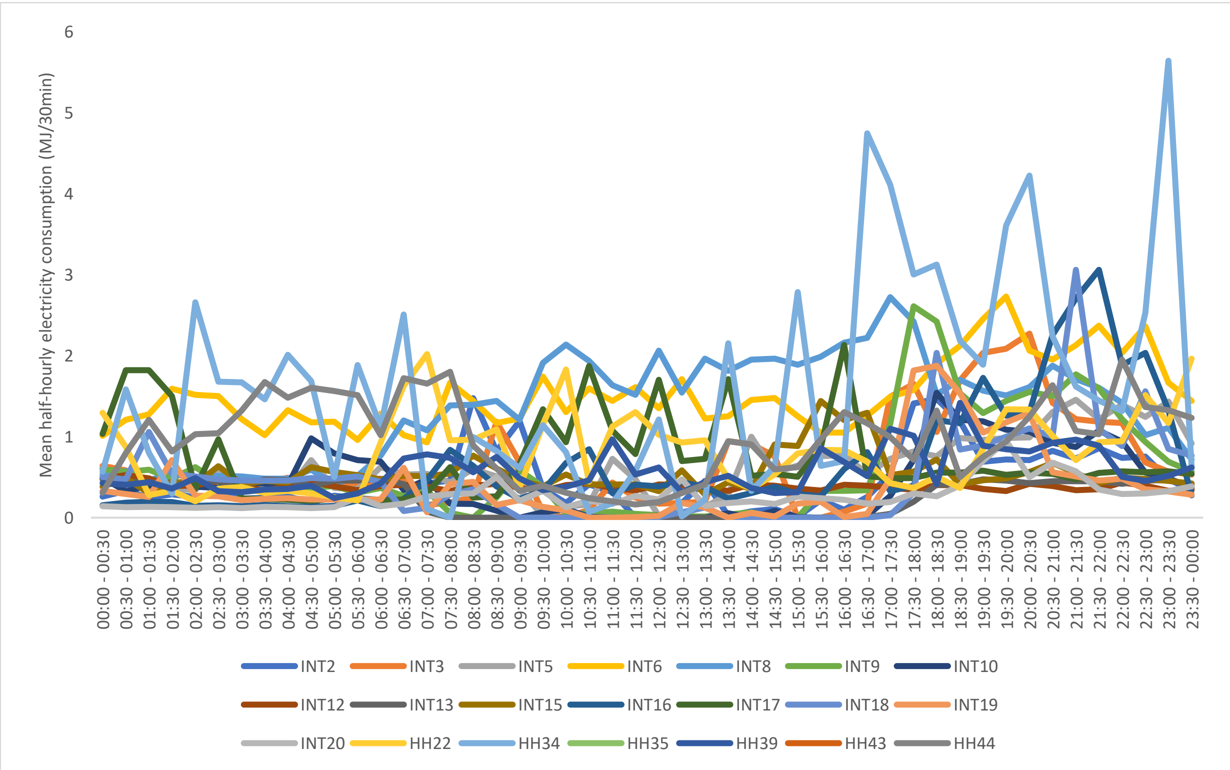


## 1.2 Electricity

### Efficient homes

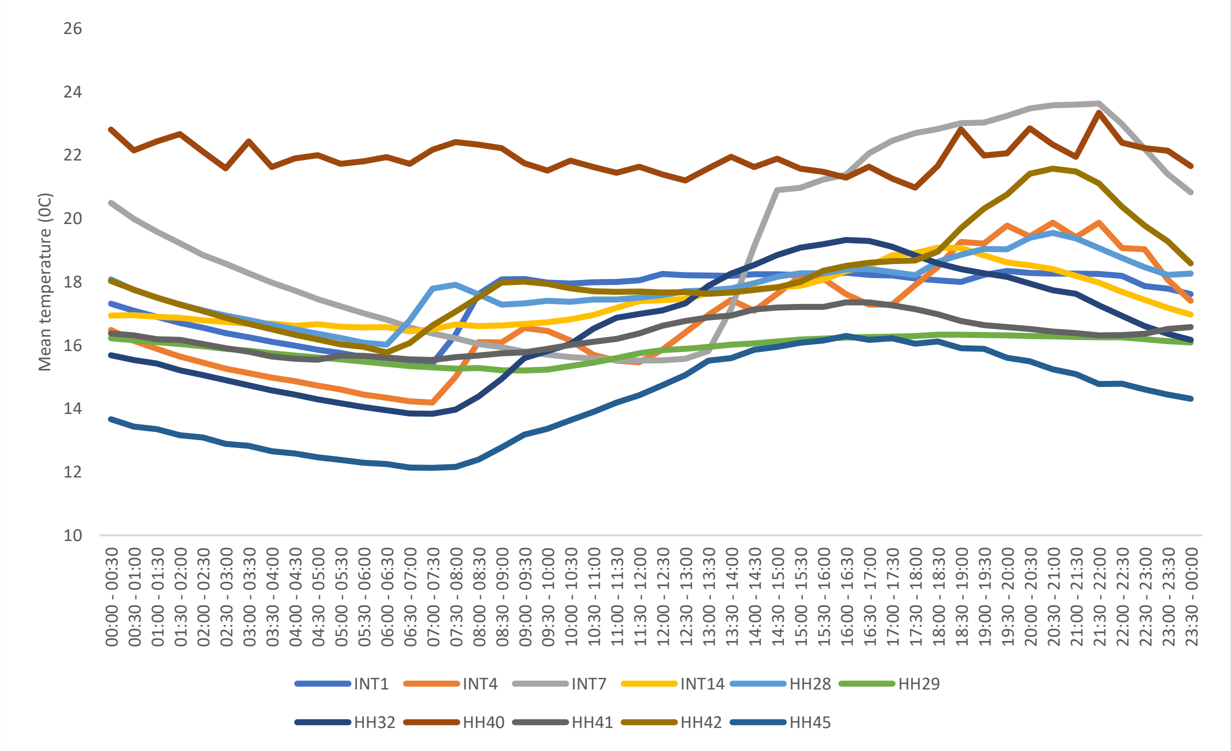



### Non-efficient homes

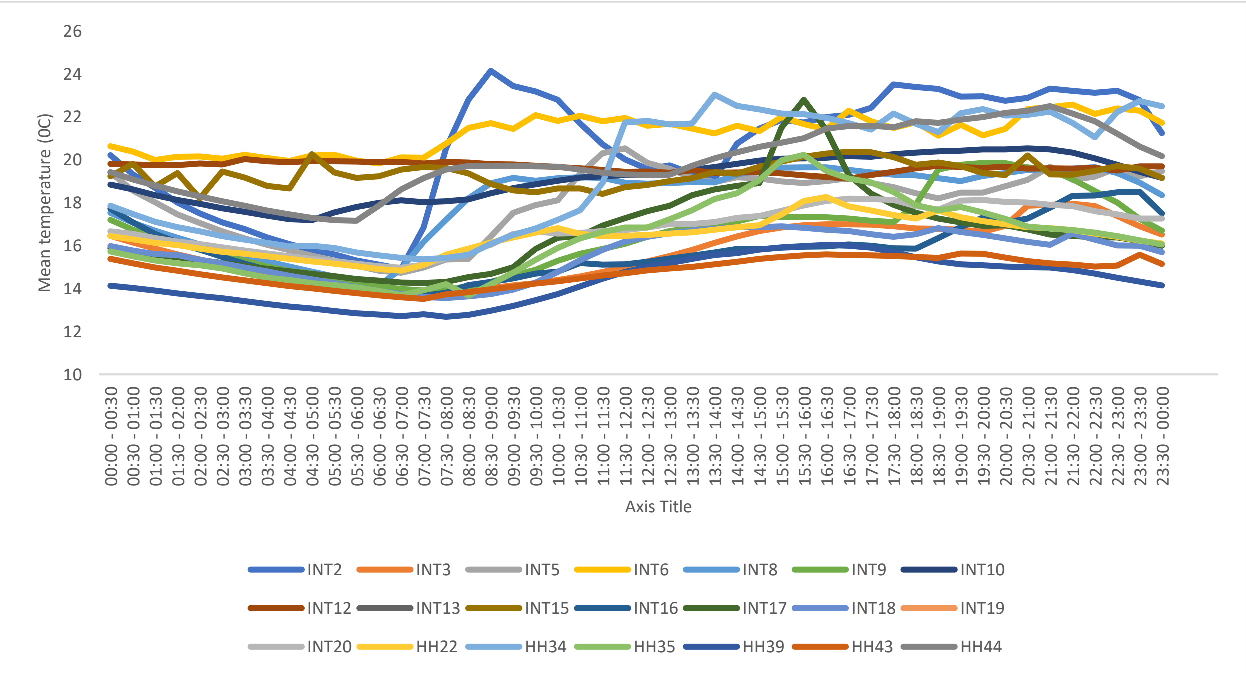


## 1.3 Living room temperature

### Efficient homes

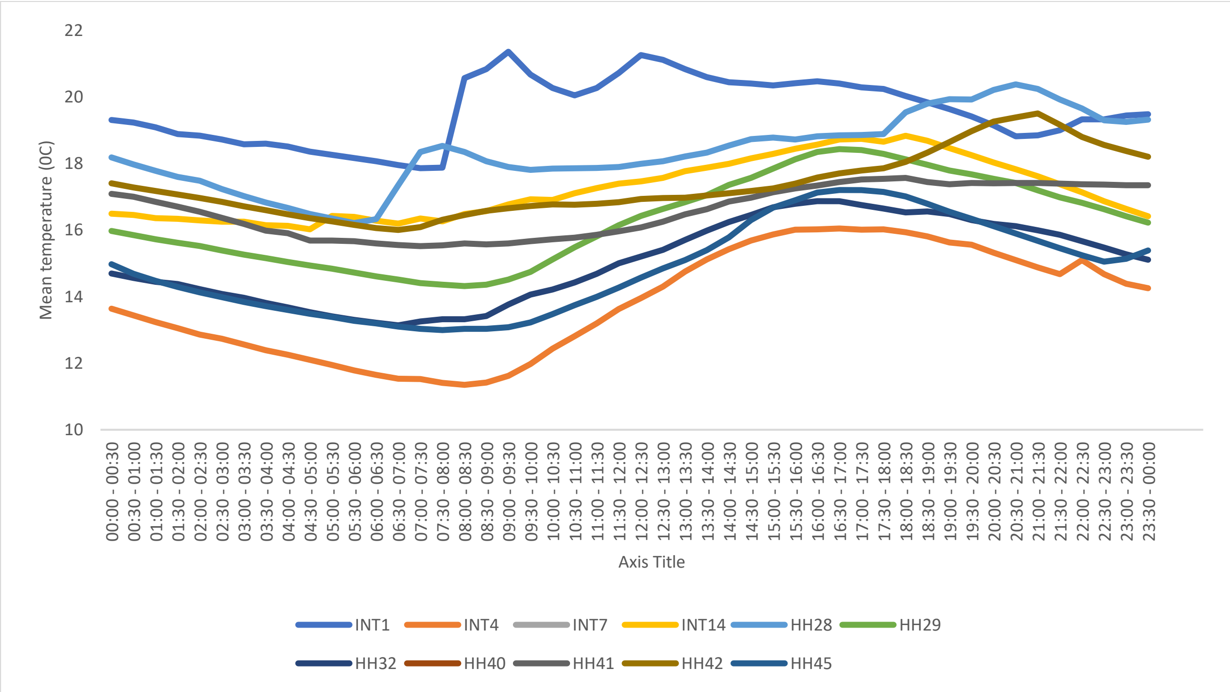



### Non-efficient homes

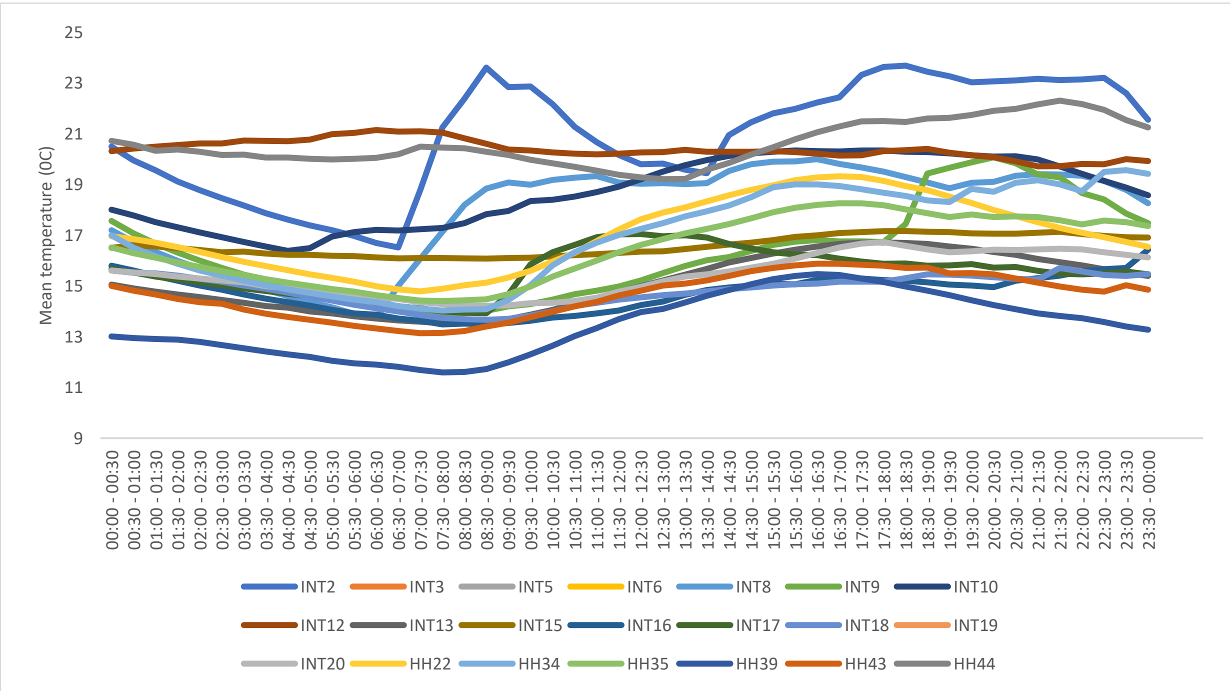


## 1.4 Bedroom temperature

### Efficient homes



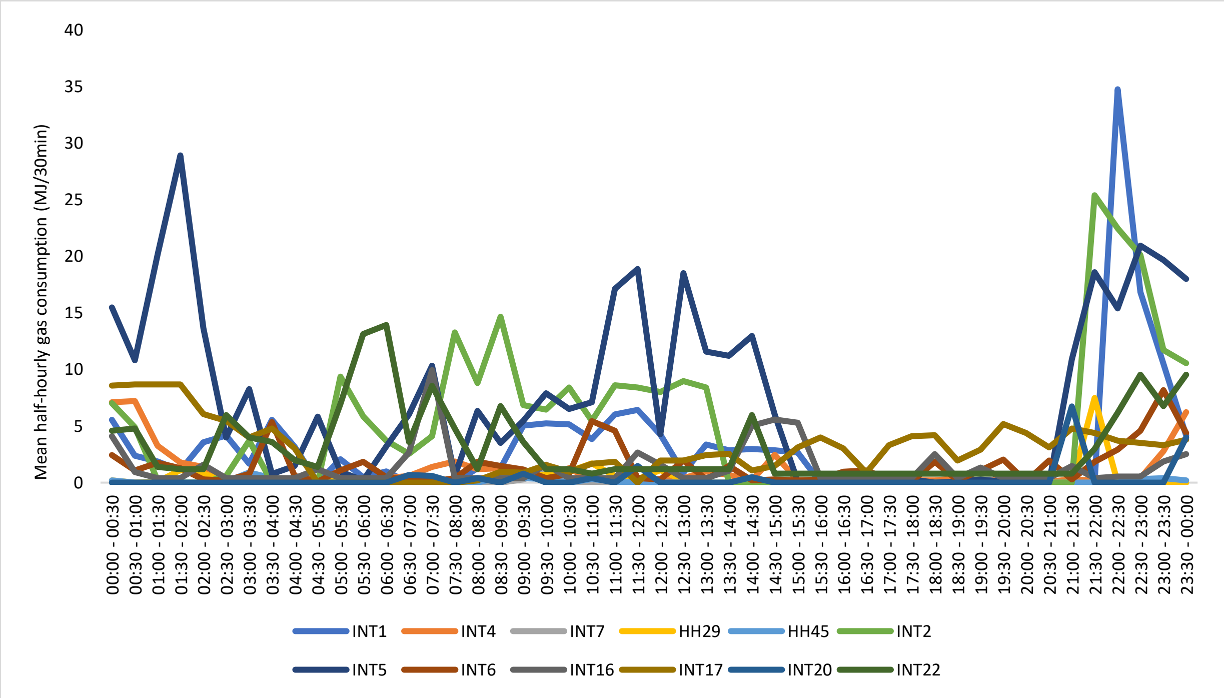

### Non-efficient homes



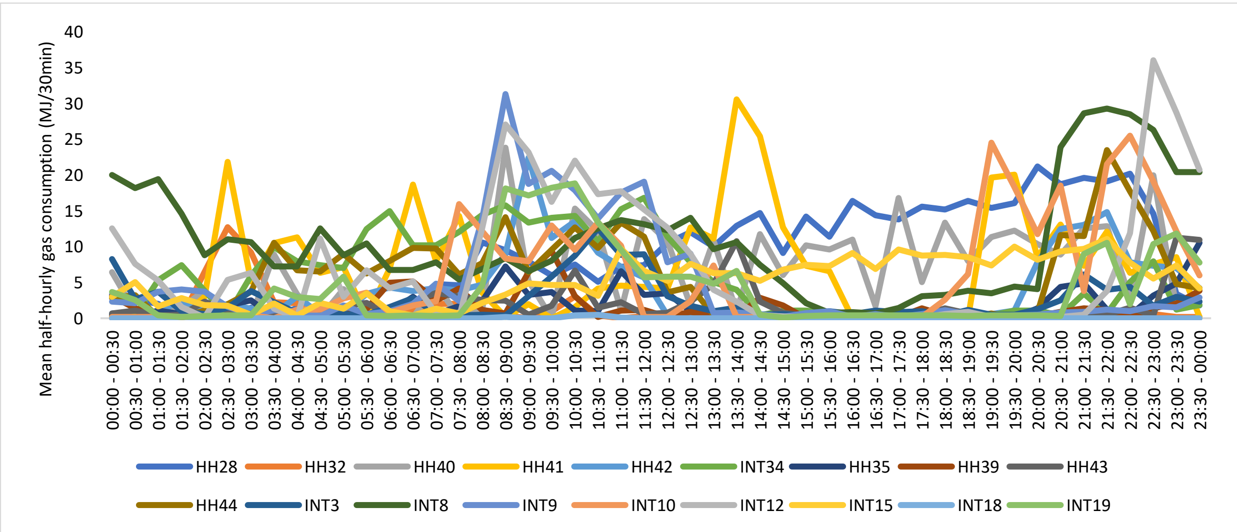
## 2. Household size

### 2.1 Gas

#### Low household size

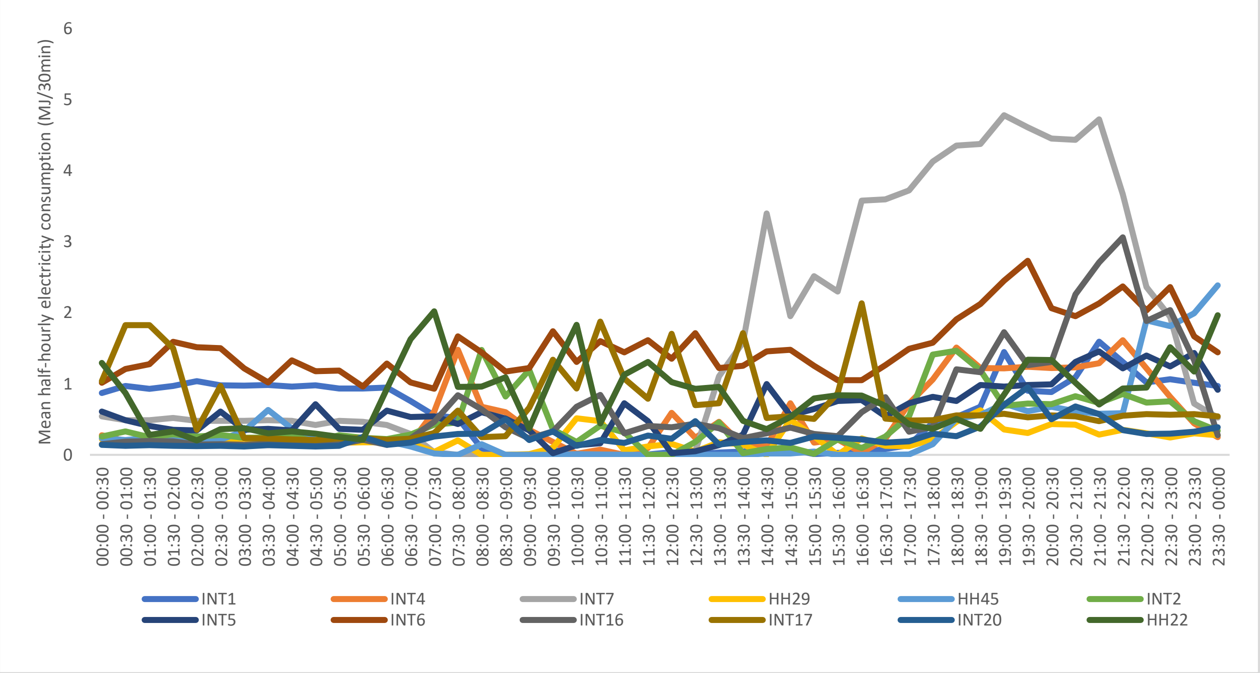



#### Non- low household size

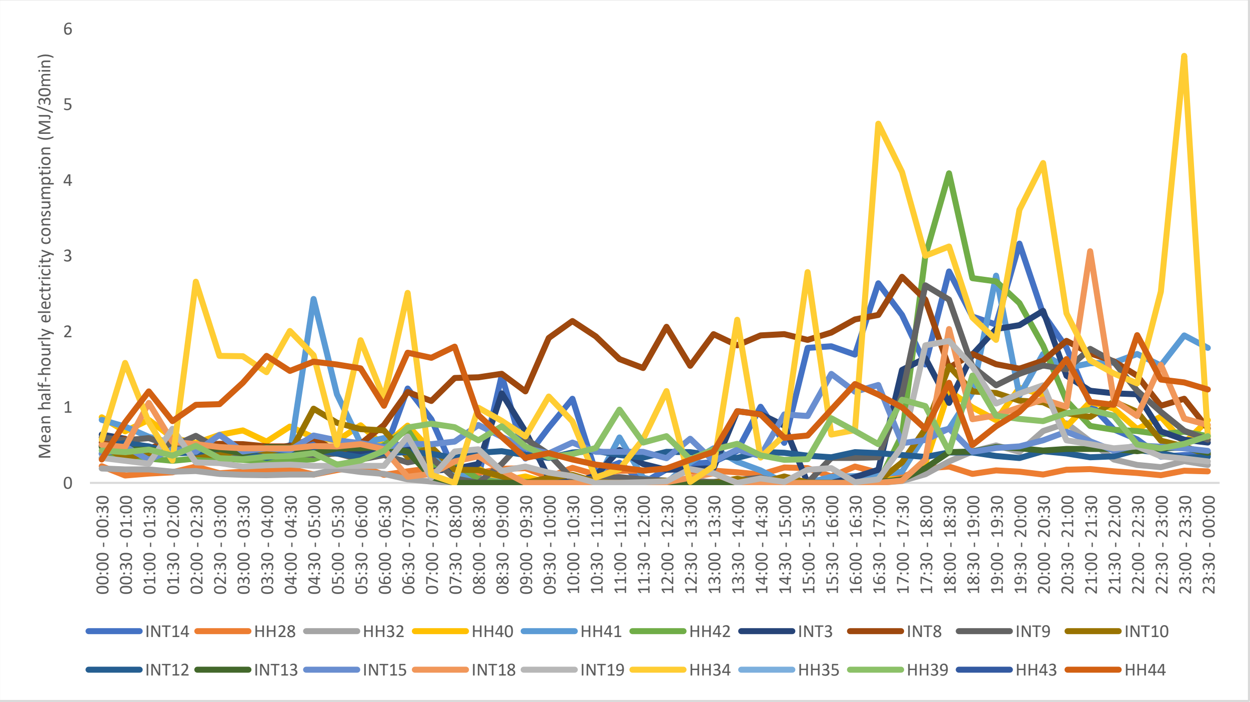


### 2.2 Electricity

#### Low household size

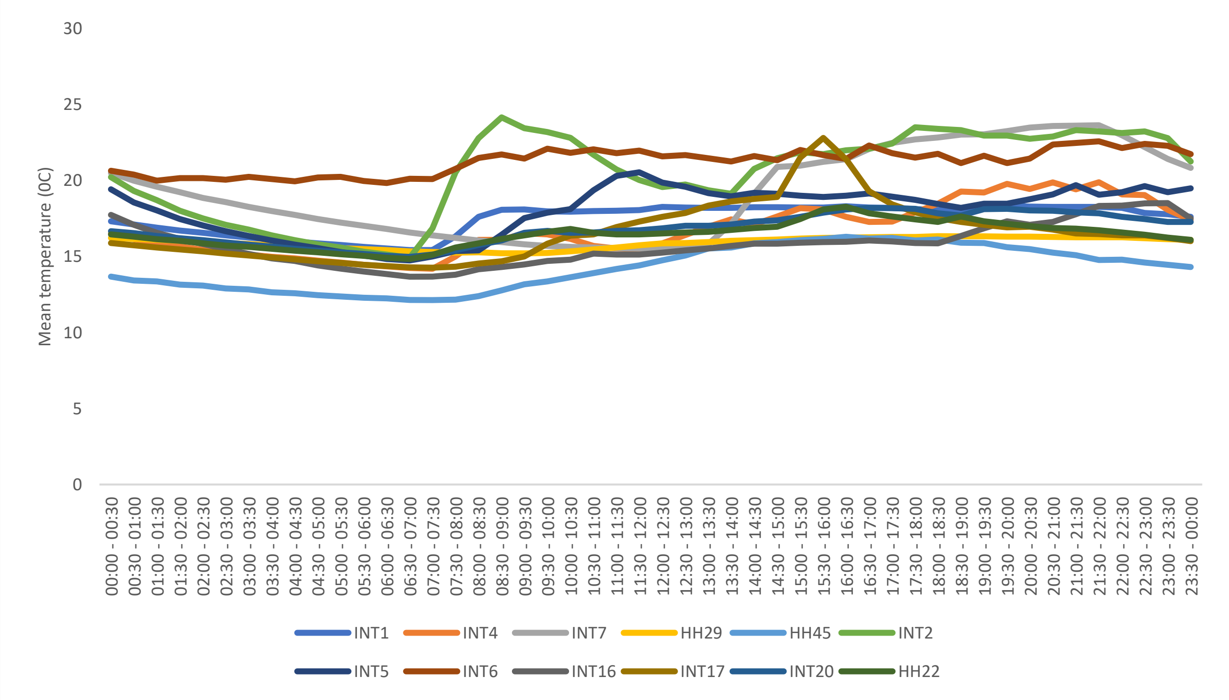



#### Non- low household size

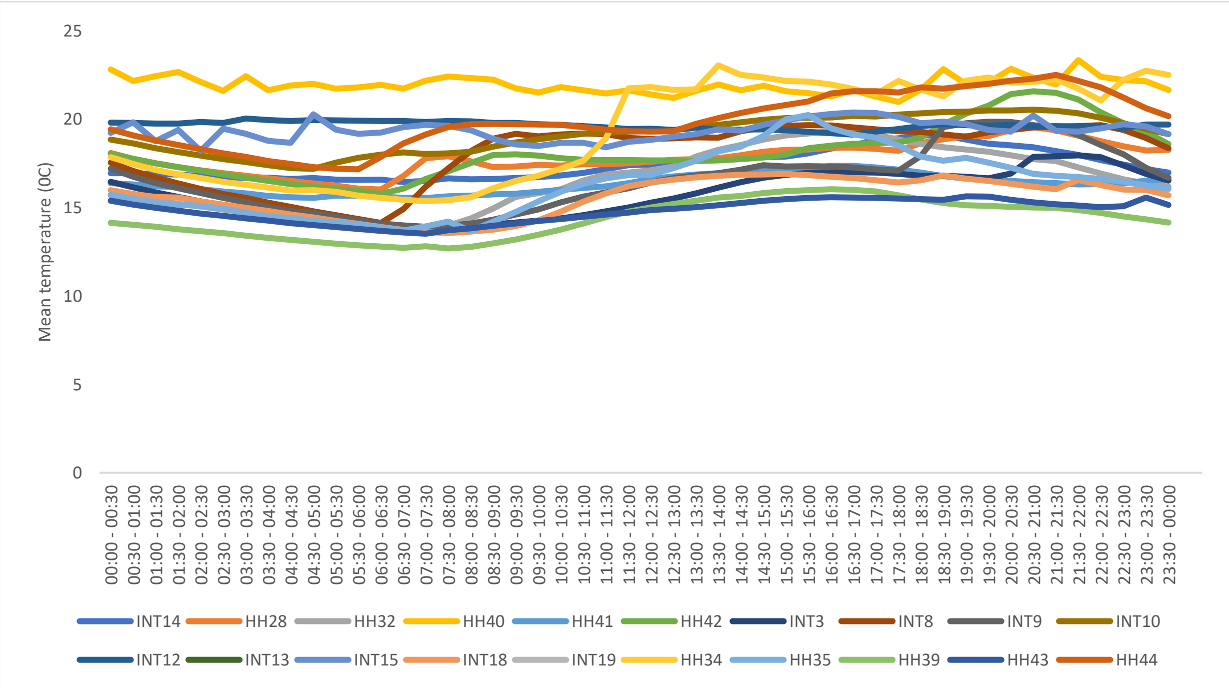


## 2.3 Living room temperature

### Low household size

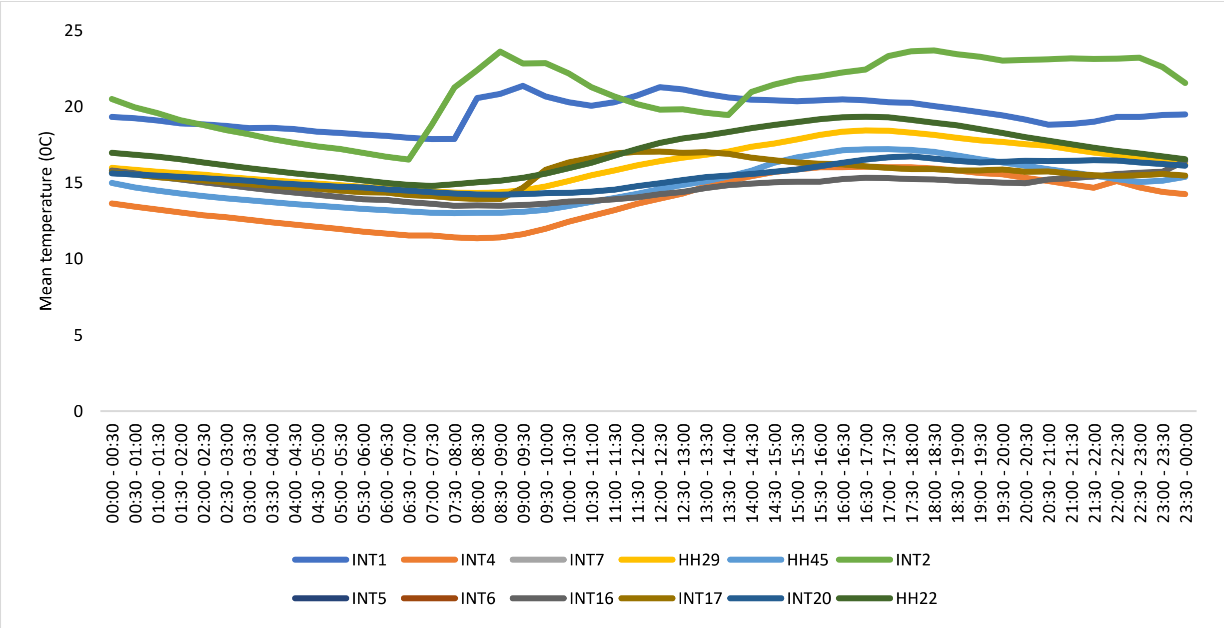



### Non-low household size

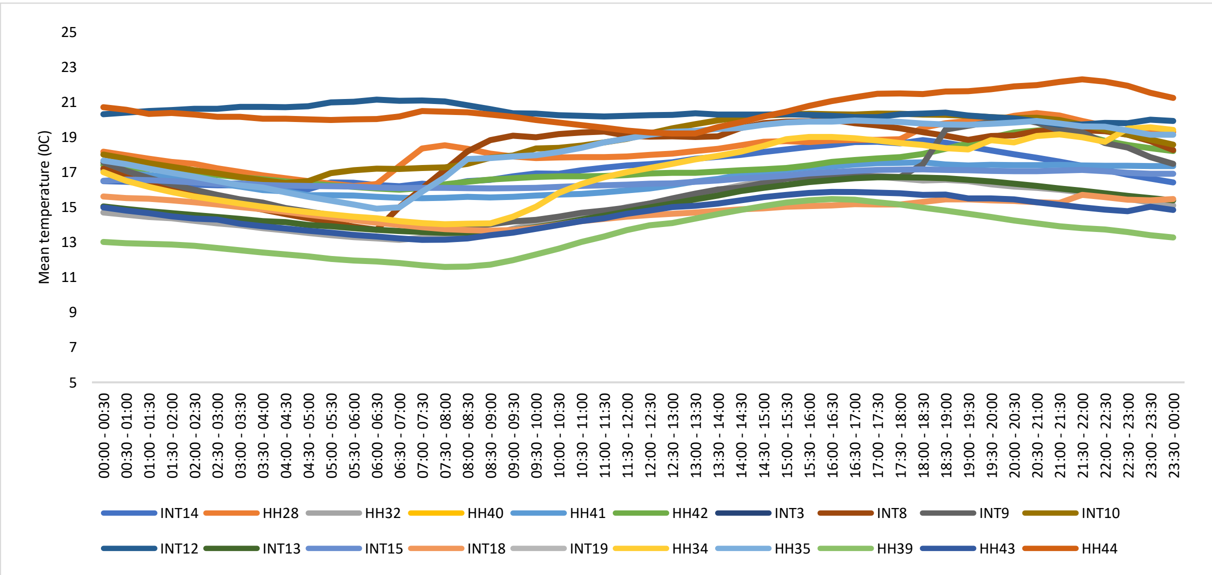


## 2.4 Bedroom temperature

### Low household size



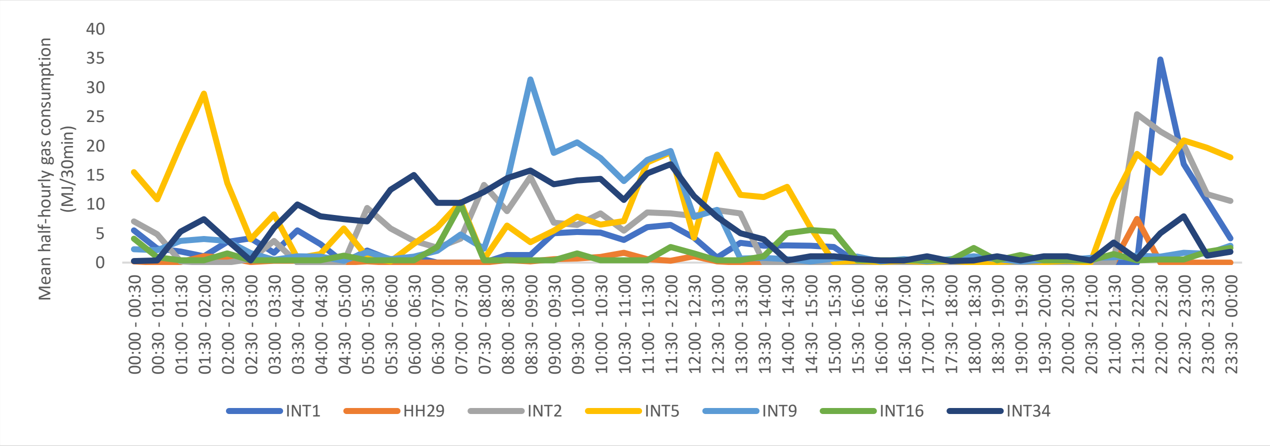

### Non-low household size



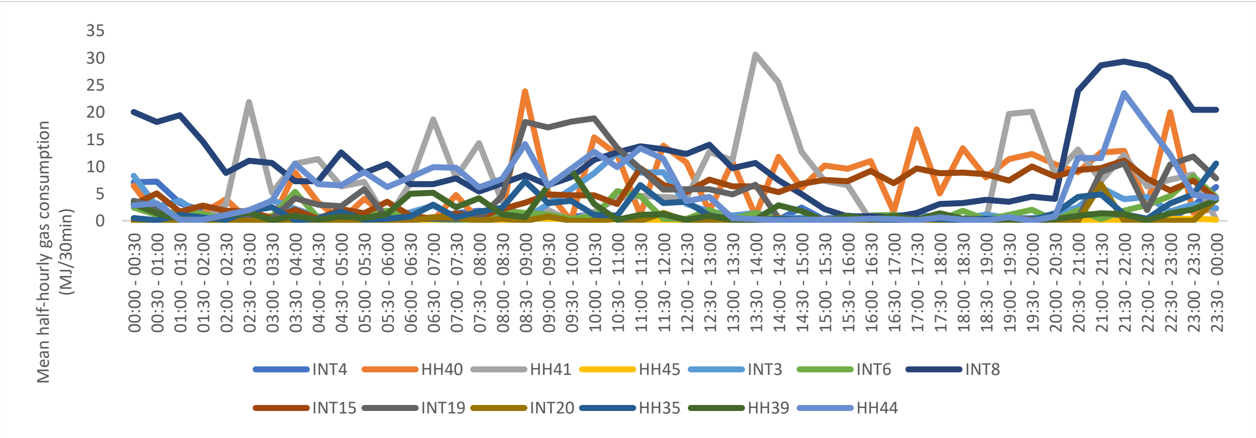
## 3. Annual income

### 3.1 Gas

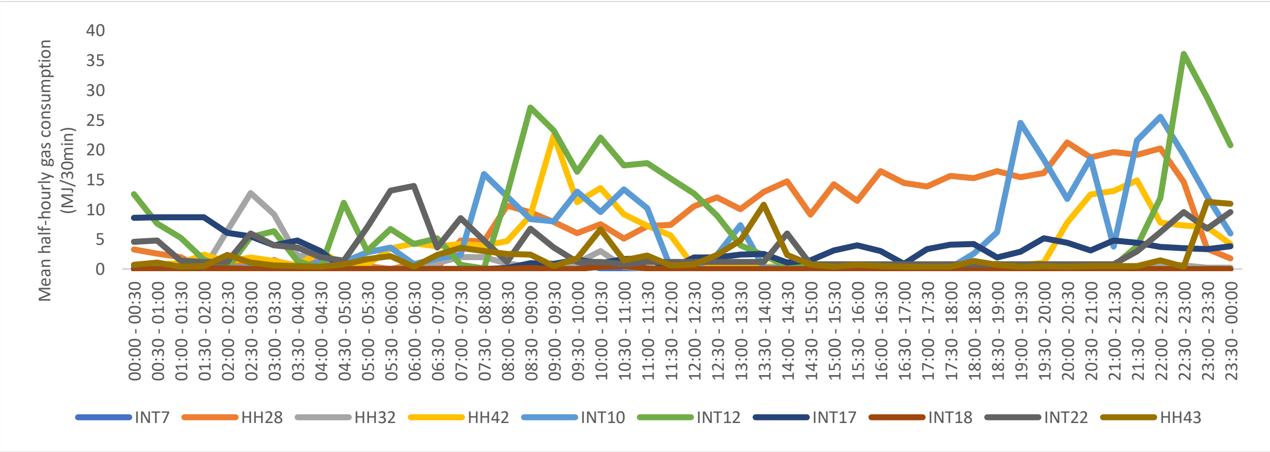
### Low income




### Mid income

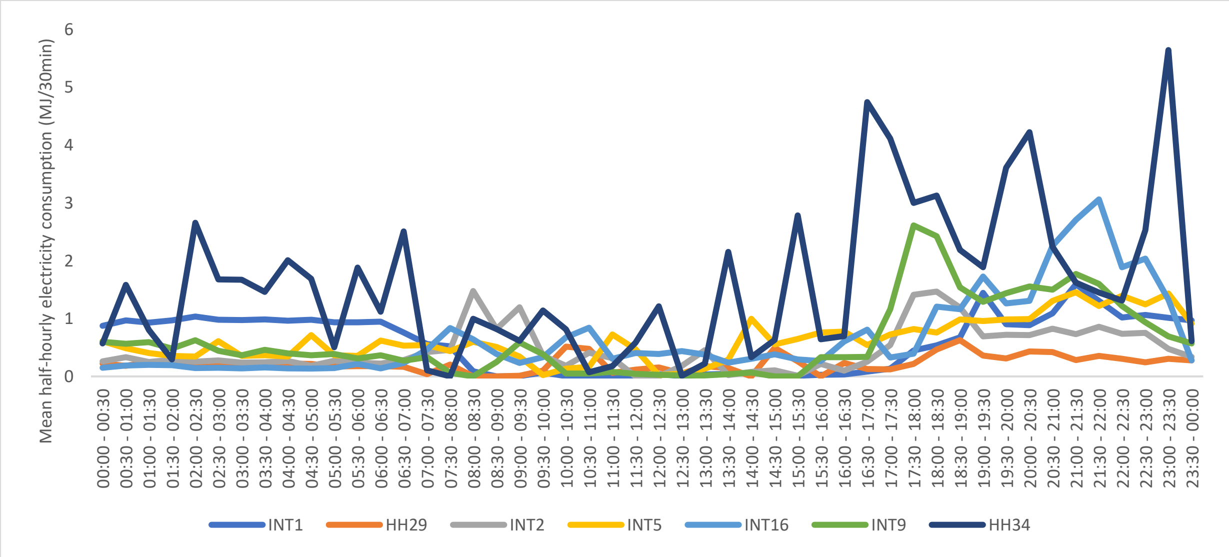



### High income

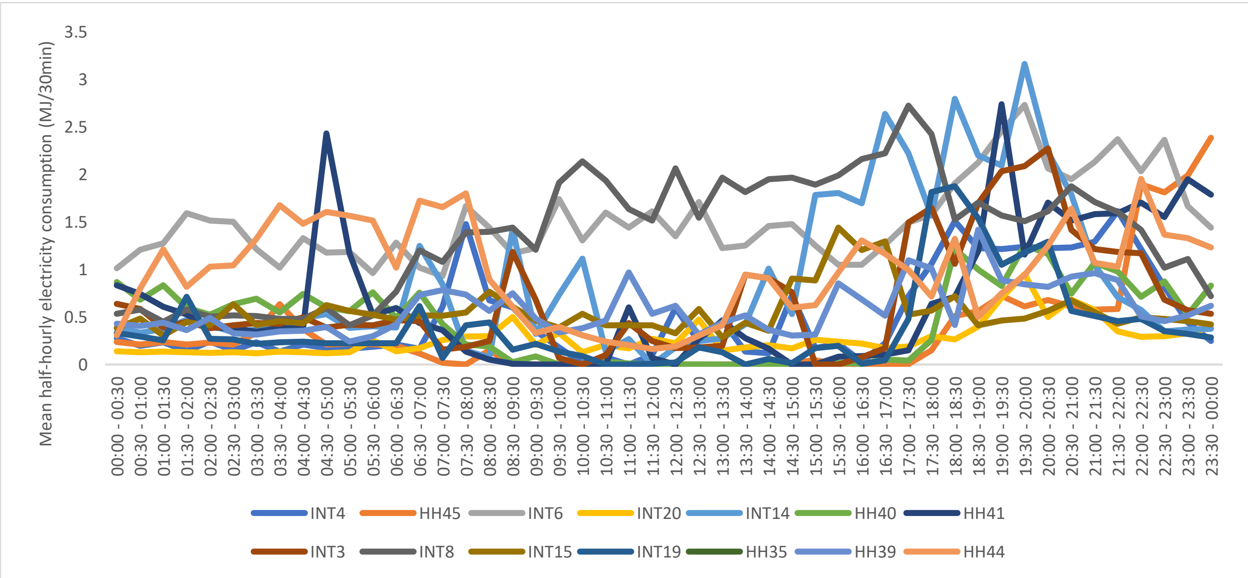


## 3.2 Electricity

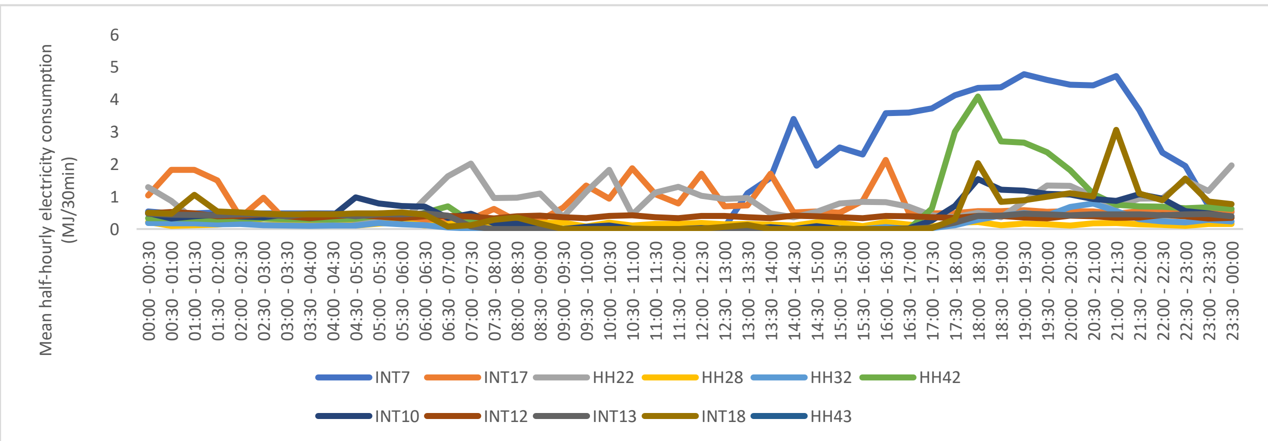
### Low income




### Mid income

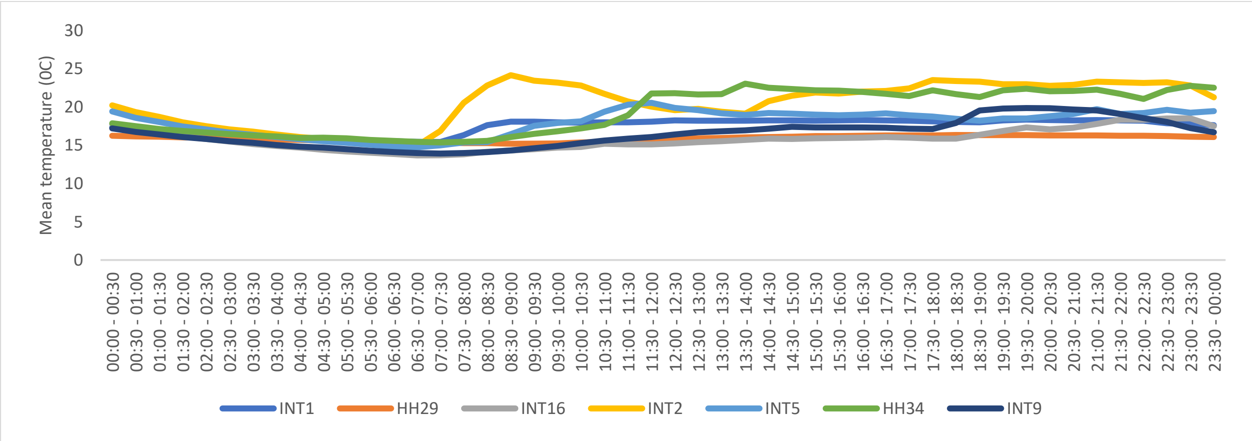



### High income

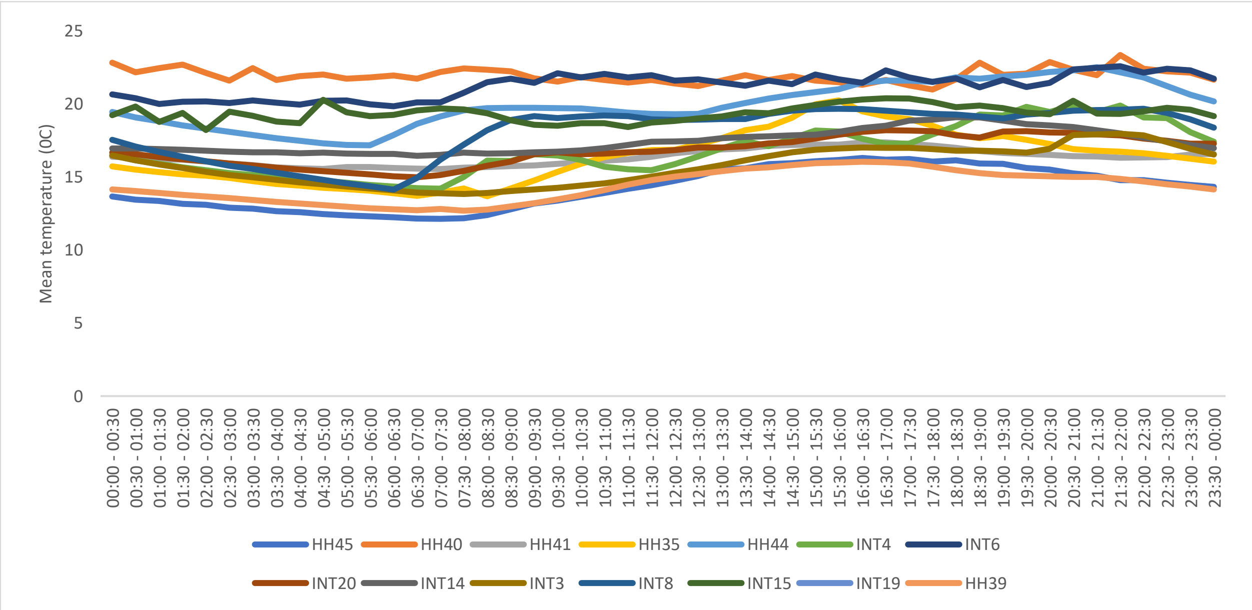


## 3.4 Living room temperature

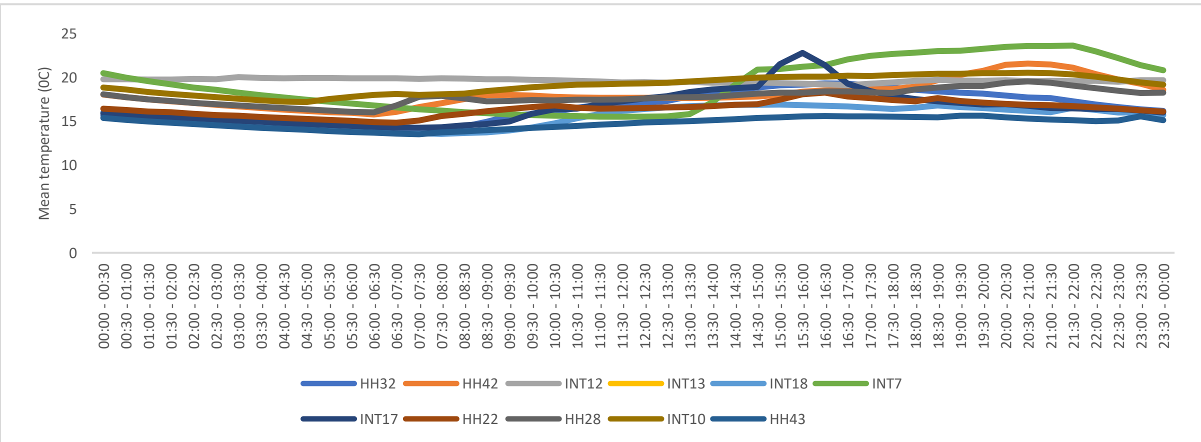
### Low income




### Mid income

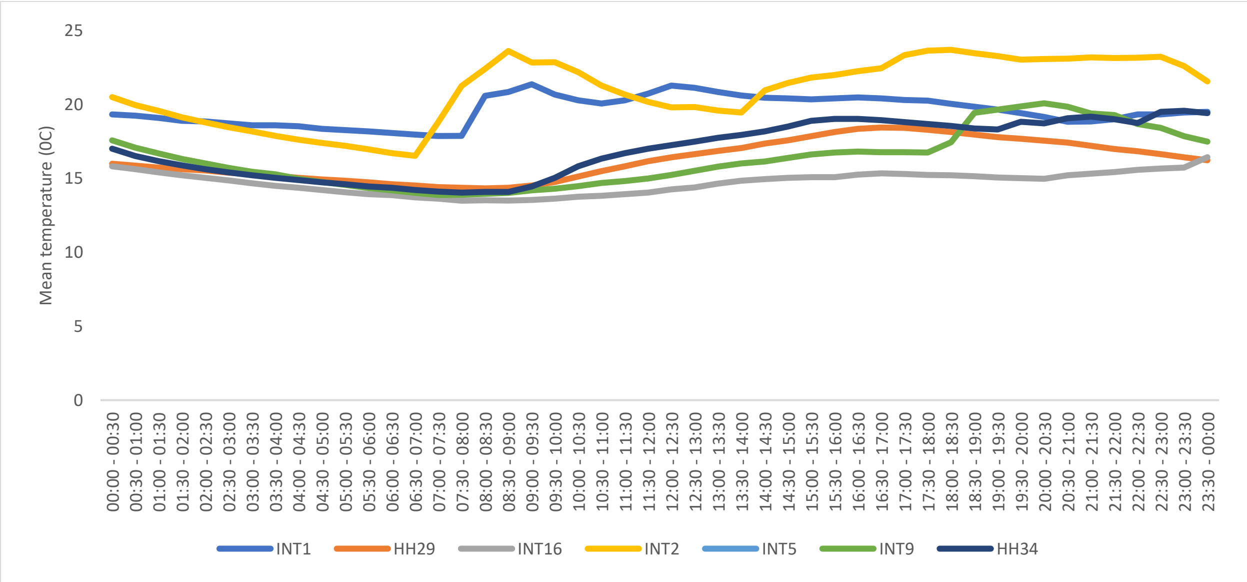



### High income

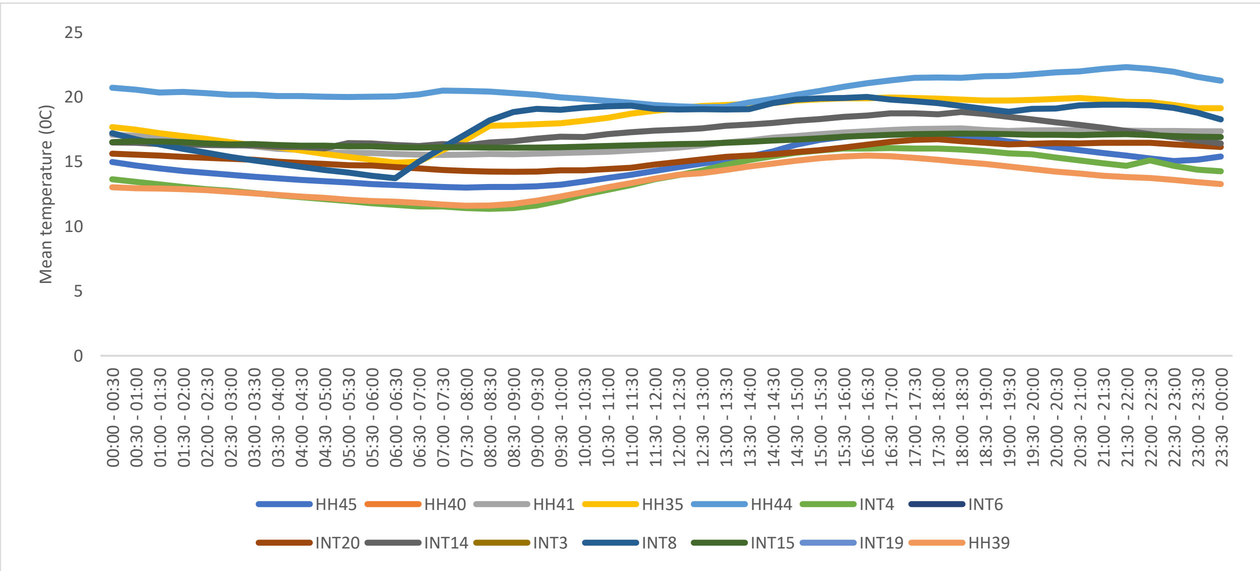


## 3.4 Bedroom temperature

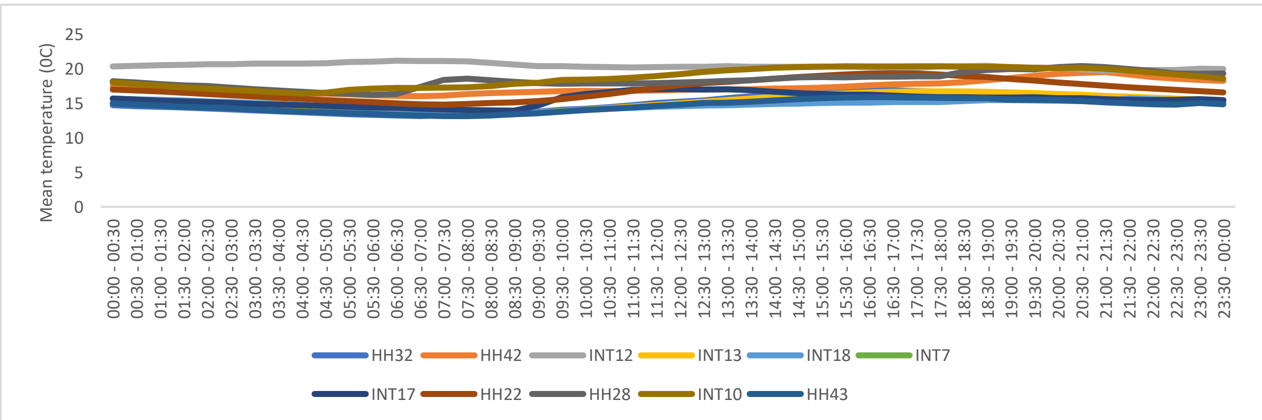
### Low income




### Mid income



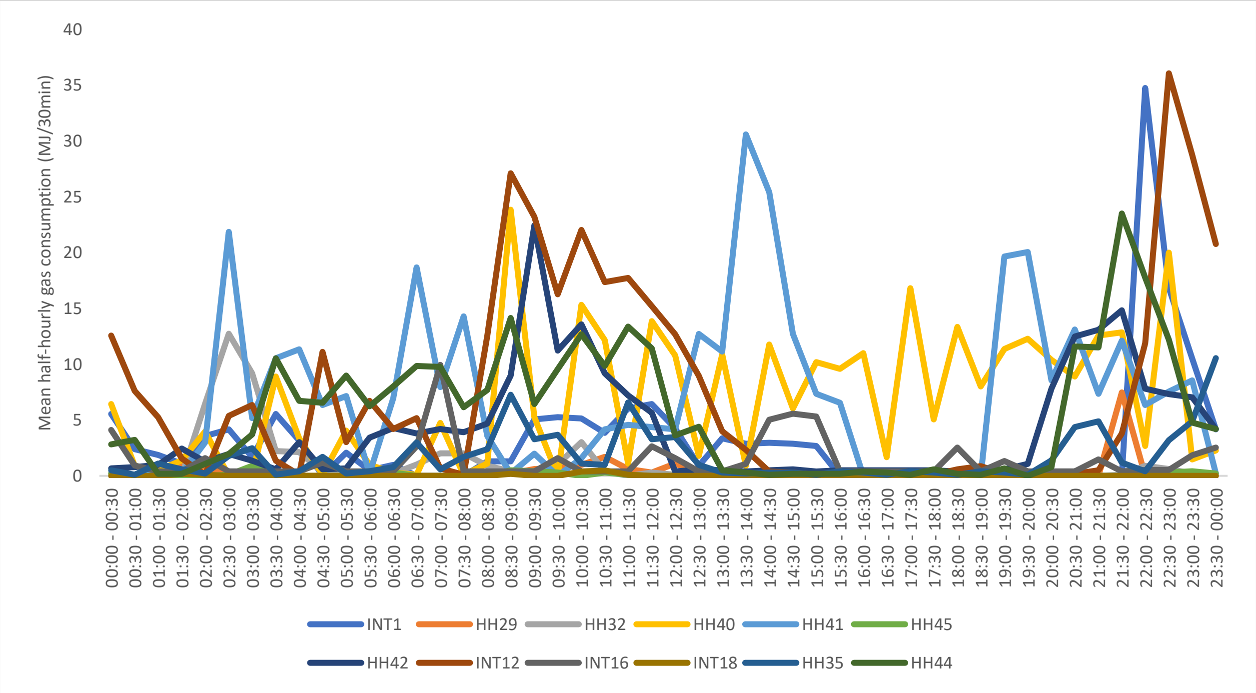

### High income



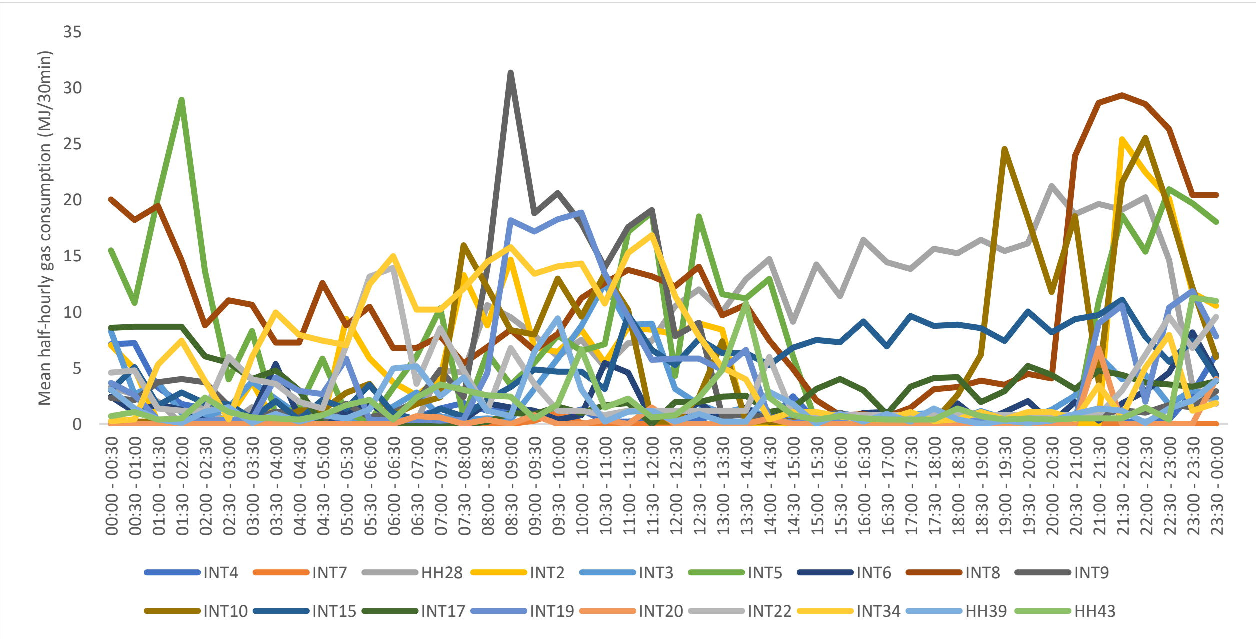
# 4. Cultural and linguistic diversity

## 4.1 Gas

### CALD homes

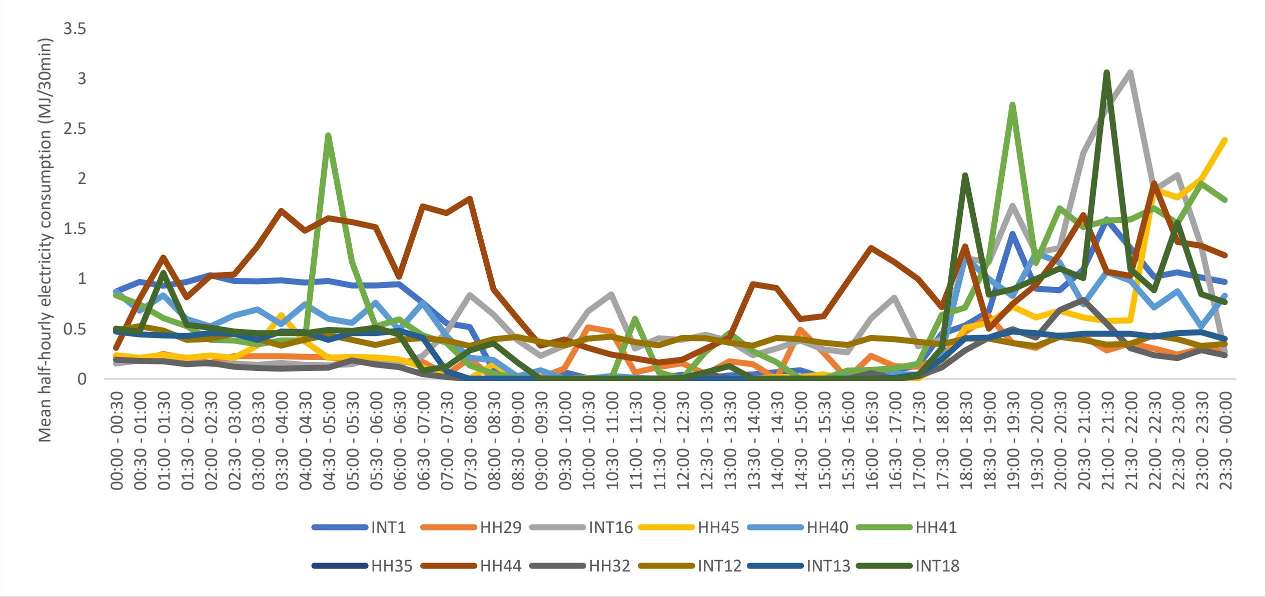



### Non-CALD homes

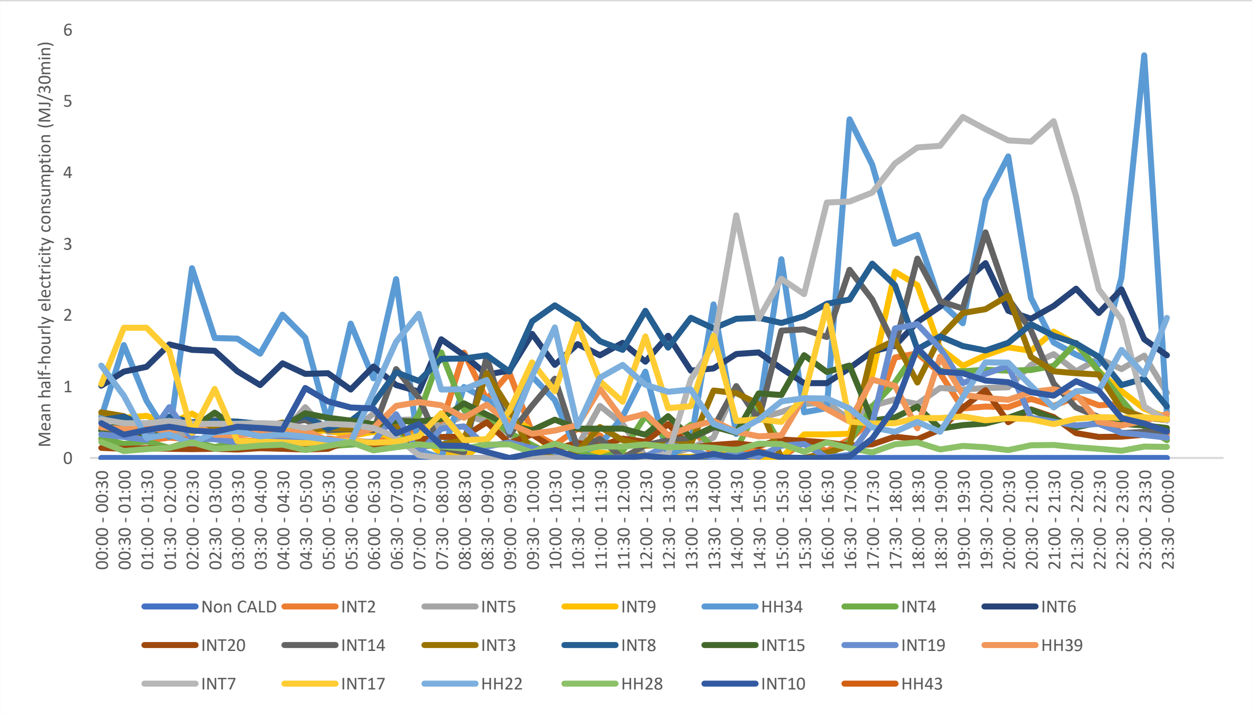


## 4.2 Electricity

### CALD homes

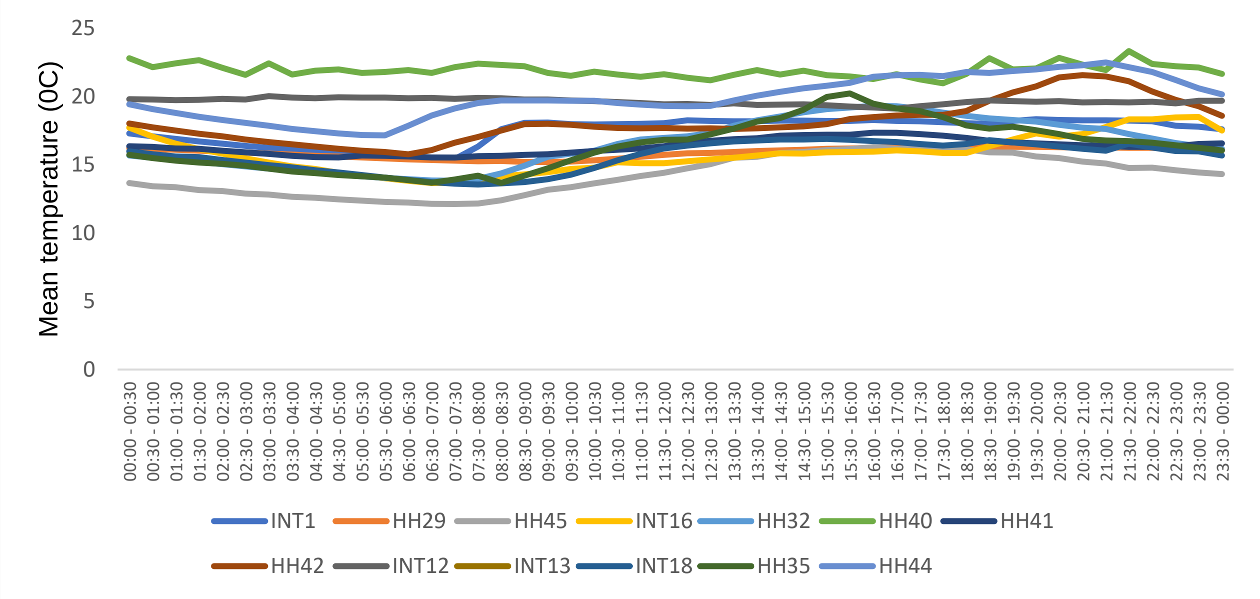



### Non-CALD homes

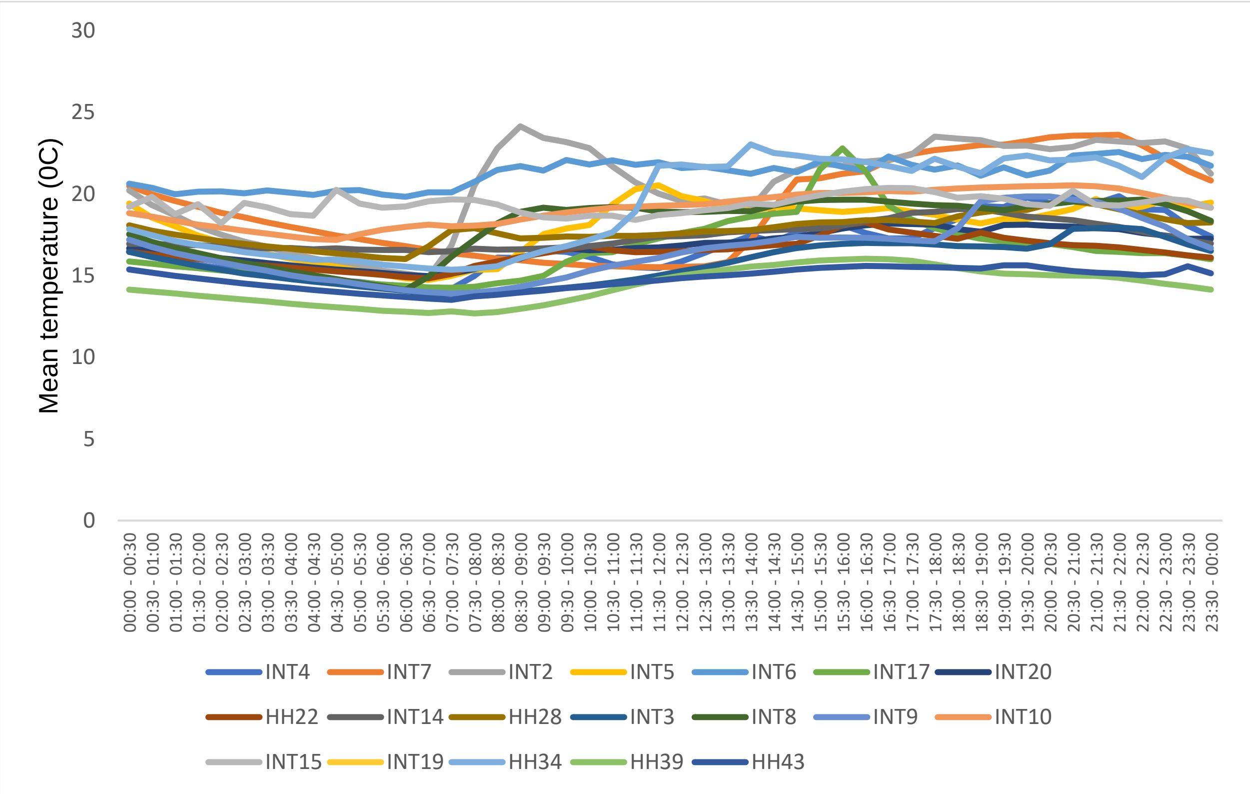


## 4.3 Living room temperature

### CALD homes

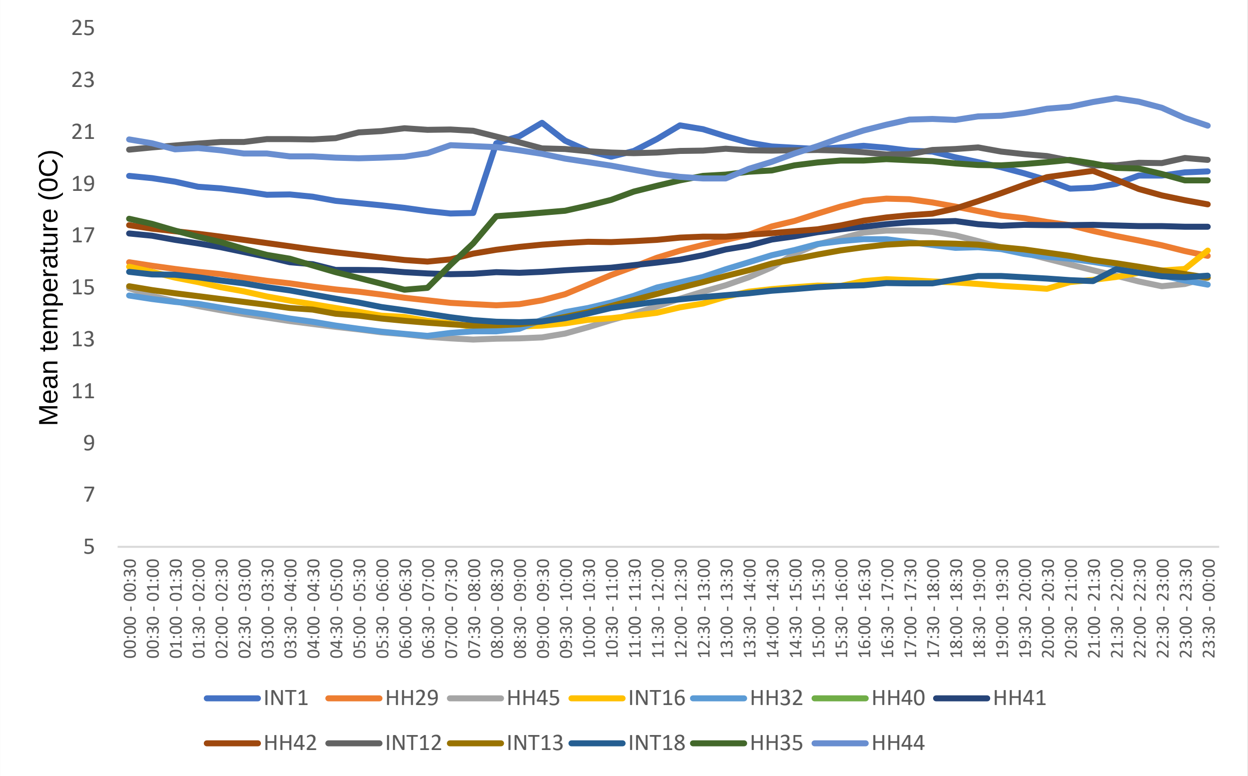



### Non-CALD homes

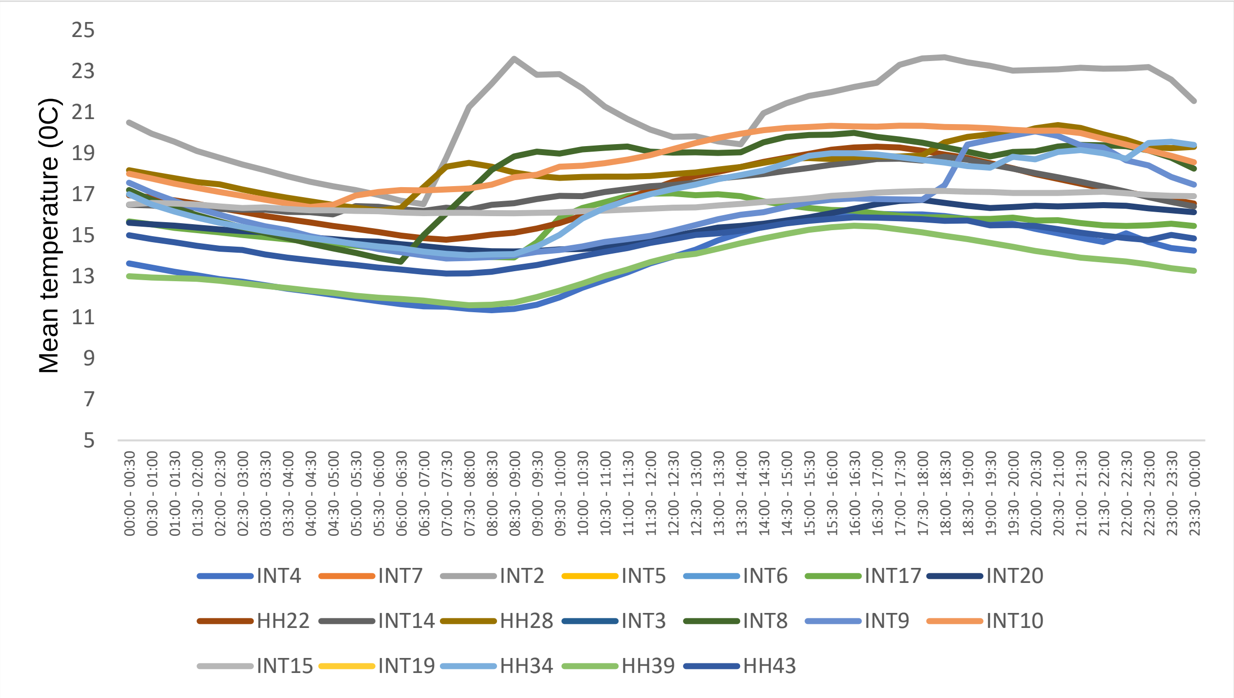


## 4.4. Bedroom temperature

### CALD homes




### Non-CALD homes



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