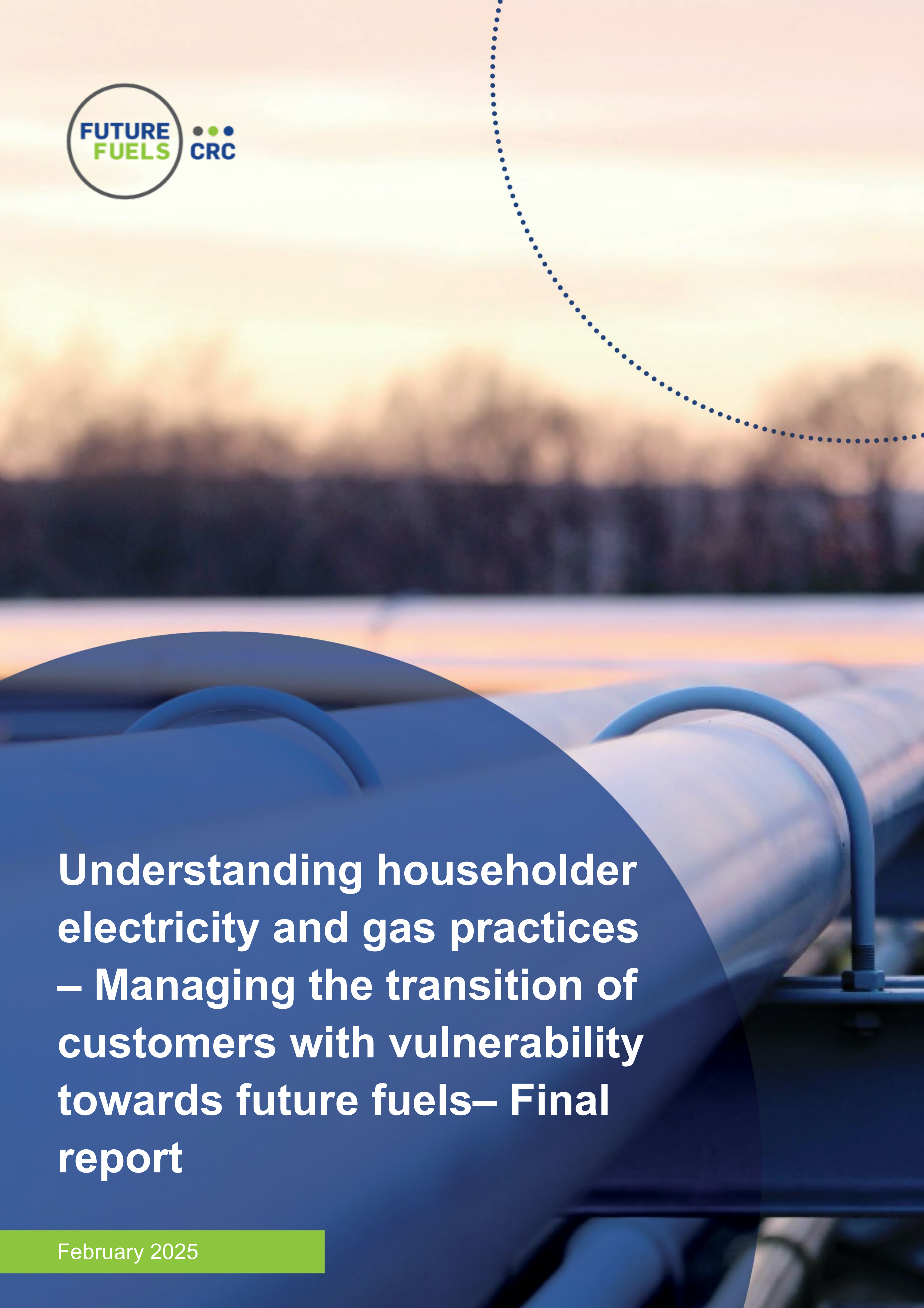

Understanding householder electricity and gas practices – Managing the transition of customers with vulnerability towards future fuels– Final report

February 2025

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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PROJECT INFORMATION	
Project number	RP2.1-10
Project title	Understanding householder electricity and gas practices – Managing the transition of customers with vulnerability towards future fuels
Research Program	Research Program 2 – Social Acceptance, Public Safety and Security of Supply
Milestone Report Number	Final report
Description	This report, the fourth and final one for the project, presents research findings based on the analysis of quantitative and interview-based data collected during the summer of 2023-2024. It also presents overall responses to the research questions drawing on this data and data from previous reports.
Research Provider	RMIT University
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Summary of Report

This final report presents the findings from a project which utilized 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 investigated a purposive sample of 48 households with gas and electricity connections, located in the northwestern suburbs of Melbourne, which were selected to cover a wide range of demographic categories. The aim was 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 objectives of this study were to provide:

- 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 final report covers the research findings based on the analysis of indoor temperatures and energy use data collected during the summer of 2023-2024 and householder interviews and presents some concluding remarks addressing the study objectives drawing on this and previous reports.

The summer data collection included the indoor temperatures and energy use data of 32 homes, which 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 used less gas and electricity on average than non-efficient houses.
- Care for thermosensitive household members and hygiene practices as well as the insulation levels and gas hot water specifications of homes shaped the range of gas usages.
- Disconnecting the gas booster of a solar hot water system saved on gas.
- High electricity usage was largely explained by intensive air conditioning use and inefficient white goods appliances.
- Many, but not all householders, considered their own electricity generation from their solar panels in their timing of their air conditioner usage.
- Energy efficient and energy inefficient homes presented similar indoor temperatures across all outdoor temperatures.
- Non-energy efficient homes seem to have used more gas for heating during colder summer days to achieve the same level of warmth as efficient homes.
- Some householders disliked air conditioning because of its noise or feelings of cold draughts. Many people preferred natural ventilation and fans, yet, air conditioning seemed a normal practice in most homes.
- Relatively high indoor temperatures were explained by a lack of fixed air conditioning.
- Bedrooms in energy efficient homes tended to be warmer than the living areas during the evening and night. By contrast, bedrooms of the non-energy efficient homes tended to be colder than the living areas.
- Householders in energy efficient homes reported that the bedrooms in the upper storey were often warmer than the ground floor areas.

Regarding the household size, the findings revealed:

- Household size influenced the amount of gas consumed to generate hot water and cooking.

- The efficiency of gas hot water systems and electric - instead of gas - appliances could mitigate the positive relationship between household size and gas usage.
- Gas usage often peaked in the mornings and evenings due to increased demand for hot water and cooking.
- Generally, as the number of residents in a household increased, so did the gas consumption for cooking.
- Electric appliances, such as rice cookers or air fryers, were used instead of gas cooktops to reduce gas usage for moral or practical reasons, e.g. to lower the home's indoor temperature.
- Low household size was generally associated with lower total electricity consumption, however, the association was less strong than with gas consumption.
- There was a pronounced temperature difference between households' living areas and bedrooms, especially those with bedrooms on a second storey.
- Participants in the low household size demographic were generally conscious about not using mechanical air conditioning, tolerating or enjoying warmer indoor temperatures, and often defaulting to passive cooling methods, such as closing blinds and opening windows in the evening.
- Non-low households consumed markedly more electricity as outdoor temperatures increased from the mid to high 20s.
- Residential occupancy did not always correlate with energy consumption. Some households with residents at home all day during the week resulted in lower energy consumption than those whose residents were absent during the 9 to 5 workday. This difference in daily living temperatures between low and non-low households could reflect more energy-efficient homes.
- Households with the lowest energy consumption actively chose not to air-condition their homes.

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

- The cost of gas and electricity use was a consideration across all the income groups (low, middle and high).
- Despite having a higher income, high-income households used the least gas. Some also monitored gas consumption and considered moving away from gas due to increased prices.
- Households with the highest use of gas, typically had gas heating and hot water systems, suggesting heating despite the period having been during summer.
- High-income households also used the least electricity.
- Mid-income households had the highest average gas and electricity use.
- High-income households were also mindful of power conversation (e.g. turning lights off).
- In both the low and middle-income groups, there were households that had high electricity use despite having solar panels, due to practices such as continuous spa heating.
- Income did not shape indoor temperature on ‘typical’ summer days. On ‘typical’ summer days, average bedroom temperatures tended to be slightly lower than average living temperatures throughout the day.
- On warmer summer days with an average outdoor temperature of 27°C, average bedroom temperatures tended to be above average living temperatures throughout the day in all income groups.
- Some low-income homes opted for cheaper operating alternatives, such as fans, blinds and shuttering, instead of using their air-conditioning.

Regarding cultural and linguistic diversity, the findings revealed:

- The CALD status of households was not a strong determinant of their gas usage during summer.

- Both CALD and non-CALD households showed morning and evening electricity usage peaks but electricity use for CALD homes was lower on average during working hours on a typical summer day and also on the warmest days.
- The CALD households were younger on average and so were more likely to be away from their homes during the working day. The non-CALD group included more older and retired people who were at home all day.
- Some CALD adults from warmer climates reported to be more heat-tolerant than Australians. The children were reportedly not so heat-tolerant.
- Electricity consumption rose with increasing outdoor temperature in both groups. On average non-CALD households use more electricity across all outdoor temperatures.
- The juxtaposition of indoor temperature and electricity use data on a typical summer day reveals that non-CALD households were slightly cooler than CALD households because they were more likely to use air conditioning.
- At higher outdoor temperatures, this difference is no longer apparent showing that on the hottest days, all households use whatever air conditioning facilities and practices that are available to them.
- These finding are consistent with the winter data reported in interim report #3 which showed that the CALD group in our sample used more heating (reflected in higher gas use and warmer bedrooms) but showed lower daytime electricity use, perhaps due to the younger age of the group and so more time spent away from the home.

In summary, this study highlights that our selected indicators of energy vulnerability—like home energy efficiency ratings, income, CALD status, and household size—do not fully explain gas and electricity consumption or indoor temperatures. Household practices of using energy and balancing electricity and gas services, aimed at achieving desired outcomes of warmth, hot food and hot water. Therefore, assessing household vulnerability during the low carbon transition requires a more comprehensive and nuanced approach.

Nonetheless, energy efficiency of the home seemed to be the best predictor of energy use. Improved thermal performance of housing (i.e., newer housing built to higher minimum regulatory standards) were found to reduce energy consumption for thermal comfort compared to older less efficient housing. Occupant practices for heating, cooling and cooking as well as cultural preferences and the efficiencies of the appliances had an important moderating role to play in overall energy and thermal comfort outcomes. More stringent requirements for the thermal performance and consideration of appliance efficiencies in the National Construction Code 2022 and the Whole of Home tool promise to reduce energy consumption and improve thermal comfort.

These findings suggest that retrofitting existing housing will be key in reducing overall energy consumption in the housing stock, enhancing affordability and thermal comfort. Financial incentives for appliance upgrades are already nudging householders to swap stoves and air conditioners, even though some households prefer gas to electricity and are reluctant to change.

The study found that solar panels were attractive to many householders and influenced their energy use behaviour. The shift of energy use to daytime helped reduce overall energy purchased from the grid in both summer and winter. Even though none of our households had a battery, battery storage systems could offer further sustainability and affordability benefits in the future, especially as the price of battery storage decreases.

The mostly bimodal diurnal patterns of energy use suggest that managing peak energy loads in a transition to future fuels must ensure that peak loads can be delivered or smoothed. An alignment of electricity supply and demand may be more critical if there is an ongoing push to electrifying homes. Battery storage and changes in householder energy practices e.g. by pre-cooling the home using self-generated solar electricity, provide opportunity to smooth peak demands.

This study has confirmed that low-income households may be at higher risk of energy poverty both in terms of affordability but also consuming enough energy to achieve basic levels of thermal comfort and liveability. Ongoing and increased support for the cost of energy as well as for retrofits is needed to help low-income households in a transition to future fuels to ensure they are not further disadvantaged.

The study revealed that culturally and linguistically diverse householders from warmer climates perceived differences in thermal sensitivity between themselves and their Australian friends. Consequently, ethnic background may predict higher energy use in winter and the inadvertent risk of heat stress in summer. Public awareness and retrofit campaigns may find it useful to tailor their measures to the practices of various ethnic groups.

A moderator of vulnerability that emerged through the analysis was the age of householders. Age seemed to translate into increased cold sensitivity, increased heating and decrease air conditioning use. Low-income older people may, thus, carry the two burdens of increasing energy and living costs. Households with young children may be equally vulnerable, carrying the double burden of higher mortgage rates and living costs. Measures are needed to reduce the vulnerability of both these population groups.

Following are the implications from this research:

Key conditions shaping household energy consumption: Household energy use is influenced by several key factors, including dwelling efficiency, the household’s income, and migration background from warm climates. However, accurately predicting energy consumption and identifying vulnerable households requires a detailed assessment of dwelling characteristics and household practices. This suggests a need for tailored approaches, such as targeted retrofitting programs, financial assistance, and educational initiatives that address specific household needs and practices. For example, retrofitting of older homes is likely to reduce energy consumption and improve affordability. Retrofits, income support and energy education may help reduce vulnerabilities.

Inadequate indoor temperatures common in winter and summer: Inadequate heating can negatively impact health, particularly for vulnerable groups such as the elderly, children, and those with pre-existing conditions. This highlights that housing energy regulations and predictions of energy use may consider the environmental, economic and health implications if all households heated (and cooled) their homes to WHO guidelines.

Thermal performance of housing: While newer, thermally efficient homes with solar PVs tend to have lower energy consumption, actual energy use is significantly influenced by householder practices, operational system characteristics and appliance efficiencies. With regards to the association of indoor temperatures with outdoor temperatures, the use of natural gas heating for central heating and electricity for controlling warmth in individual rooms highlight the complexity of energy consumption patterns. Future building regulations should consider a potential shift in energy patterns as the climate warms, including the economic feasibility of retrofit measures.

Influence of cultural backgrounds: The cultural backgrounds influenced household energy use, with CALD households from warmer climates using more heating in winter while showing greater resilience to summer heat. This suggests that areas with higher migrant populations may have distinct energy demand patterns, which should be considered in energy planning and policy. Housing design should incorporate flexible climate control solutions to provide efficient, low-carbon heating and cooling options that accommodate diverse thermal preferences. While the National Construction Code may not account for all cultural variations, there may be a need for minimum heating and cooling standards in homes. This would allow for individuals to adjust thermal comfort to meet their own needs or to recognise that there may be additional energy consumption for those who want to use additional (e.g. portable) heating and cooling systems.

Appliance replacement: The appliance replacements were often driven by necessity rather than deliberate choices about energy efficiency or carbon impact. Many households replaced appliances only when they failed, often defaulting to the tradesperson's recommendation rather than considering energy-efficient or low-carbon alternatives. Replacement practices implied non-economic rationales for changing appliances and a slower than expected swap to efficient ones. This highlights the need for better education among tradespeople on energy-efficient options and the important role of repair services in influencing household decisions.

Trust shaped new appliance uptake: The project found evidence of distrust and suspicion among a few householders that the push towards technological changes included a certain level of political opportunism and commercial avarice. To build trust and counter suspicions of commercial motives, policy and industry may need to collaborate to emphasise the clear benefits and functionalities of new technologies.

Peak energy demand challenges: The household energy use patterns showed peaks in winter (morning and evening) and summer (afternoon to evening). The transition to future fuels must address peak load management without increasing energy vulnerability. While warmer winters may help reduce winter peak loads, time-of-use pricing—whether for electricity or future gas—must be designed to avoid disadvantaging households with limited flexibility or access to smart home technologies. This highlights the need for equitable energy policies that ensure all households can benefit from the transition without facing higher costs or reduced access to essential energy services.

Renewable energy adoption: Many households aspired to install solar panels to help reduce purchased energy. The implication is that as solar energy adoption grows, managing the electricity grid will become increasingly complex. However, the development of more affordable battery storage solutions could help address this challenge by enabling higher solar adoption, improving grid stability, reducing energy costs, and balancing demand fluctuations more effectively. This highlights the need for policies and infrastructure investments that support widespread battery storage integration to enhance the sustainability and reliability of the energy system.

Energy poverty risks: Energy poverty affects a wide range of households, not just those with the lowest incomes. Low-income families struggle to maintain safe indoor temperatures, particularly in winter, which can harm health and well-being. Older adults reported higher sensitivity to cold, leading to higher winter energy use, while younger households with children faced financial pressures from mortgage and living costs. Even middle-income households experience affordability challenges, often prioritizing care, hospitality, and health over energy costs. To address these issues, governments and industry may need to reassess and strengthen energy assistance programs, ensuring support reaches both low- and middle-income groups, households with older or chronically ill members, and families. Tailored solutions for vulnerable groups, including culturally and linguistically diverse (CALD) communities, could help reduce energy insecurity and promote equitable access to efficient, low-carbon energy options. Further, current affordability metrics may be inadequate, and may need to account for expenses like housing, medical care, family responsibilities, or the costs of wood for heating, which has its own challenges.

Energy carrier preferences: The energy policies and industry strategies should prioritize affordability and low carbon emissions rather than mandating specific energy sources, as some households prioritize practical outcomes over energy type. This suggests a need for energy carrier-neutral policies and technologies that deliver outcomes in affordability and low carbon emissions. Additionally, consumer education should acknowledge different know-hows, materials and meanings of householder energy practices, e.g. cooking on an open flame.

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. To achieve the above objectives, this study employs a mixed-methods approach. Mixed-methods research (MMR) integrates elements of both quantitative and qualitative research methodologies within a single study. This involves the collection and analysis of numerical data (quantitative) alongside visual, textual, or narrative data (qualitative), enabling a comprehensive understanding of the research question.

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, interim report #2 and interim report #3.

This is the final report of the project. This report 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 final report focuses on analysis of the gas consumption, electricity consumption and indoor temperature in summer 2023-2024 with respect to efficiency of the dwelling, household size, annual income and cultural and linguistic diversity. Further, this report builds on data and analysis from both the winter findings (Interim Report #3) and the summer findings (presented in this report). It synthesizes the results across the four key demographic categories consistently applied in both reports.

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 Section 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. The winter and summer research findings are discussed in Section 8, followed by the conclusions and highlights their implications for the energy industry in Section 9.

2 Method

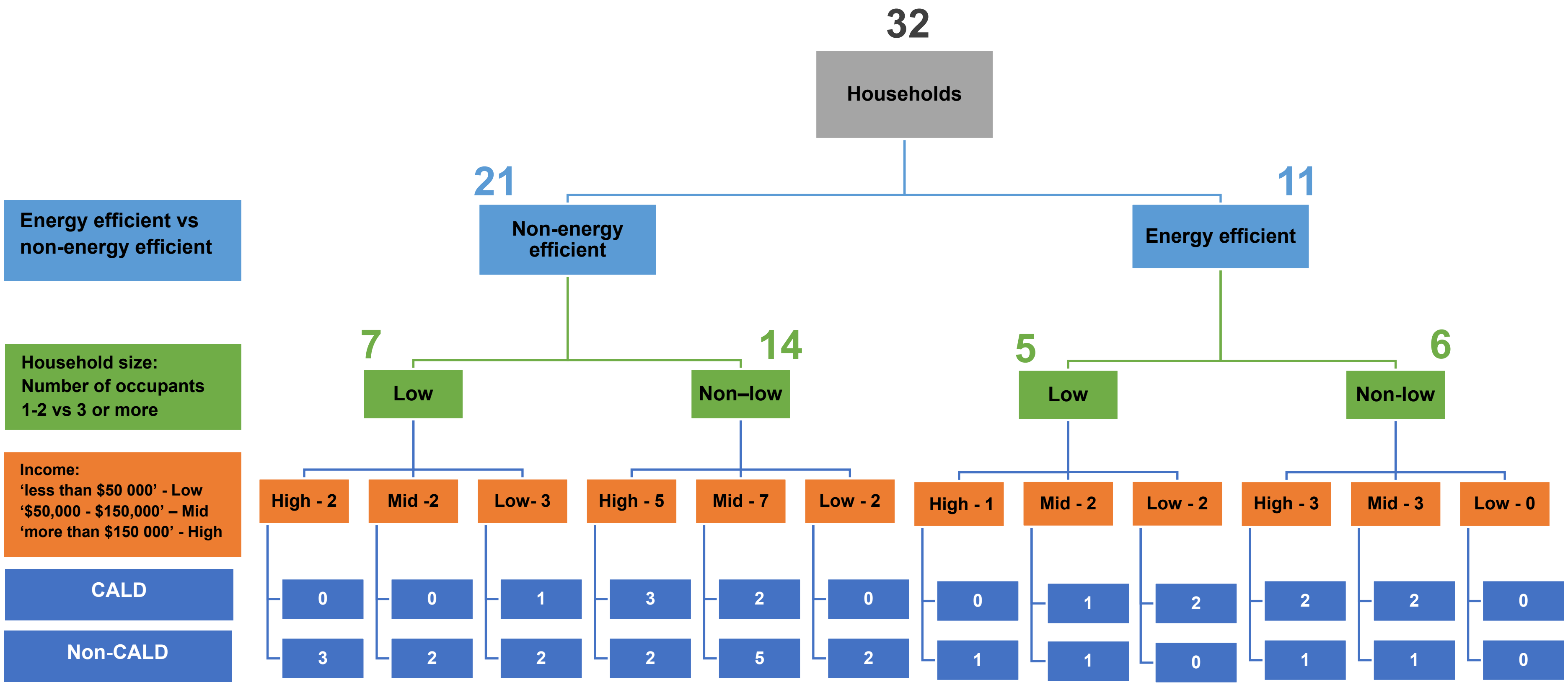
This final report covers the overall research findings for 32 households for the summer months (December 2023 – February 2024). The qualitative component used semi-structured interviews, observations during home tours, photographs and videos of the homes and energy-related activities to explore conditions that shaped 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 how the four demographic categories ‘energy efficiency of the dwelling’, ‘household size’, ‘annual income’ and ‘cultural and linguistic diversity’ have 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 were carried out in two phases: one during the summer and the other in the winter. Home visits and household interviews for the 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 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 summer home visit explored the householders’ practices and experiences related to keeping cool and cooking practices. An interview guideline was developed for the summer interviews to ask questions during the interview. The main topics covered by 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. The details on the winter interviews are presented in Interim Report #3. 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

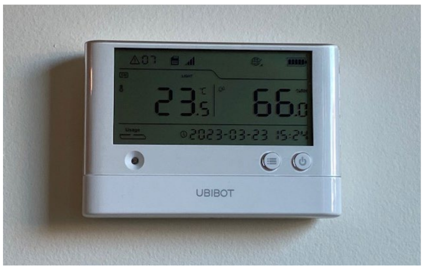
2.2.1 Data collection

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 01.12.2023 to 29.02.2024.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 31/32 homes (the data was unavailable for the home HH35 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 29/32 homes (the data was unavailable for three homes, INT4, INT19 and HH34) and bedroom temperature data was available for 22/32 homes (the data was unavailable for INT2, INT3, INT5, INT6, INT7, INT14, INT17, INT19, HH34 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 31 dwellings for December 2023 – February 2024 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 the summer months (01.12.2023 to 29.02.2024).

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 31 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 from December 2023 to February 2024 were extracted and organised in MS Excel files. One dwelling (HH35) was excluded from the analysis due to the unavailability of smart meter data for the selected period.

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 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.

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 and interim report #3 for further details of this standardisation method. For the summer data, the gas consumption, electricity consumption and indoor temperatures were standardised to a daily mean outdoor reference temperature of 18ºC. This reference temperature was chosen as it was the most frequent daily mean outdoor temperature during the summer period (December 2023 – February 2024). Hence indices for the reference temperature of 18ºC were interpreted as the levels of gas consumption, electricity consumption and indoor temperature on a ‘typical’ Summer 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 summer for days with a reference temperature of 18ºC 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 December 2023 to February 2024 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-one dwellings were considered in the analysis. For each dwelling, the 30-minute interval smart meter data relevant to summer months (December 2023 to February 2024) 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 summer months was mapped with the mean daily half-hourly outdoor temperature relevant for the months. 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 31 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:

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

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 home INT17 was excluded from the analysis of gas use as the data was unavailable during the summer months due to a malfunctioning of the logger.

Indoor temperature data: The living room temperature data was available for 29 homes for the summer months. The bedroom temperature data was available for 22 homes for the summer months. 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.

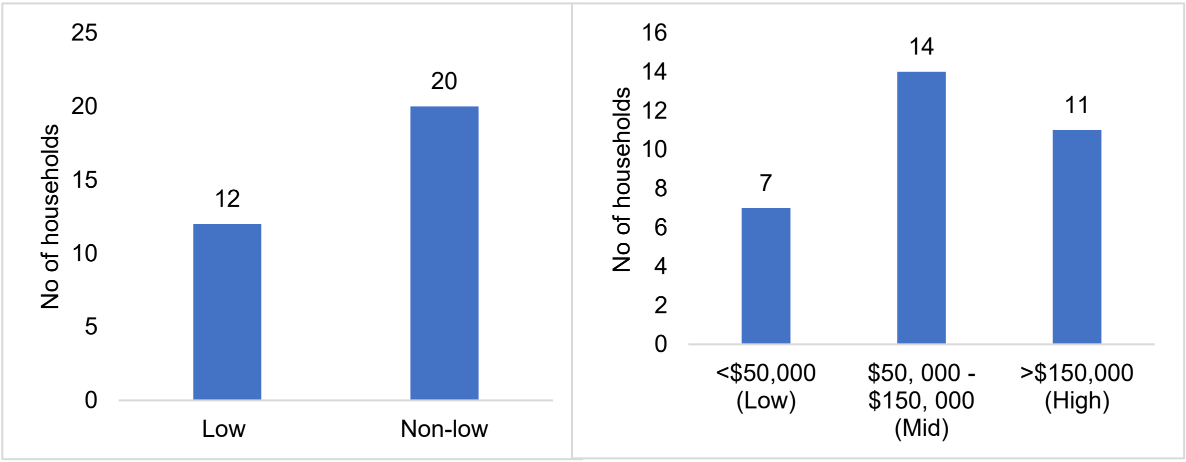
3 Household, dwelling and participant characteristics

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

3.1 Household characteristics

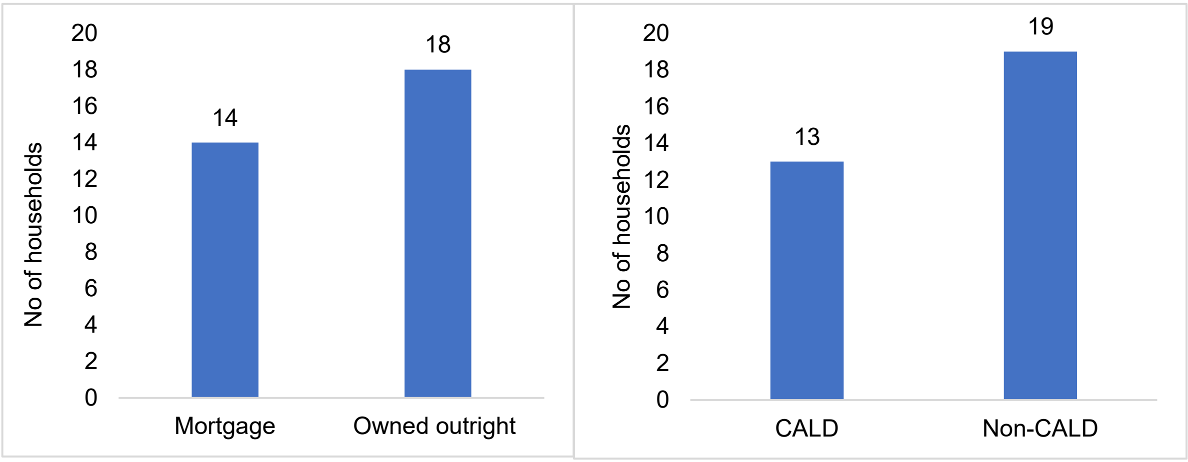
The sample included 32 households with a variety of sizes, annual incomes, cultural and language backgrounds, homeownership types, and occupancy patterns. The details of householder characteristics of the 32 householders are presented in Appendix 1 and Figure 4. As shown in Figure 4, most households (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.

Figure 4 Household characteristics



a.Household size

b.Annual income



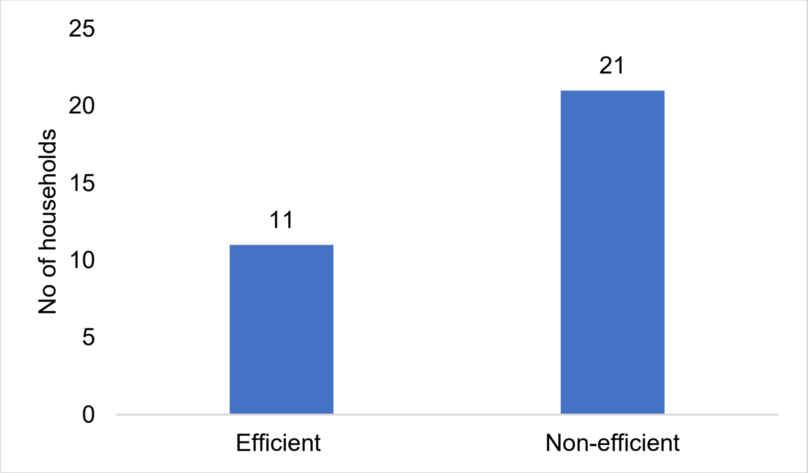
c. Home ownership

d. Cultural and linguistic diversity

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



Details about the characteristics of efficient and non-efficient dwellings can be found in Interim Report #3. Figure 6 presents the systems used for cooling during the summer months. Ducted evaporative cooling systems were commonly presented in non-efficient homes. Reverse cycle air conditioners, ceiling fans and portable fans were used as alternatives to the ducted cooling systems in both efficient and non-efficient groups.

Figure 6 Cooling systems

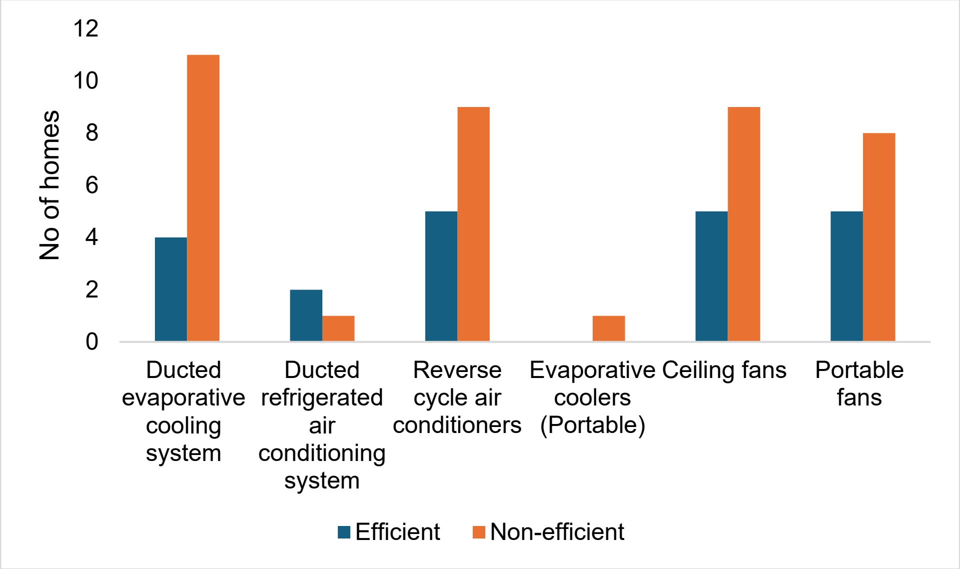
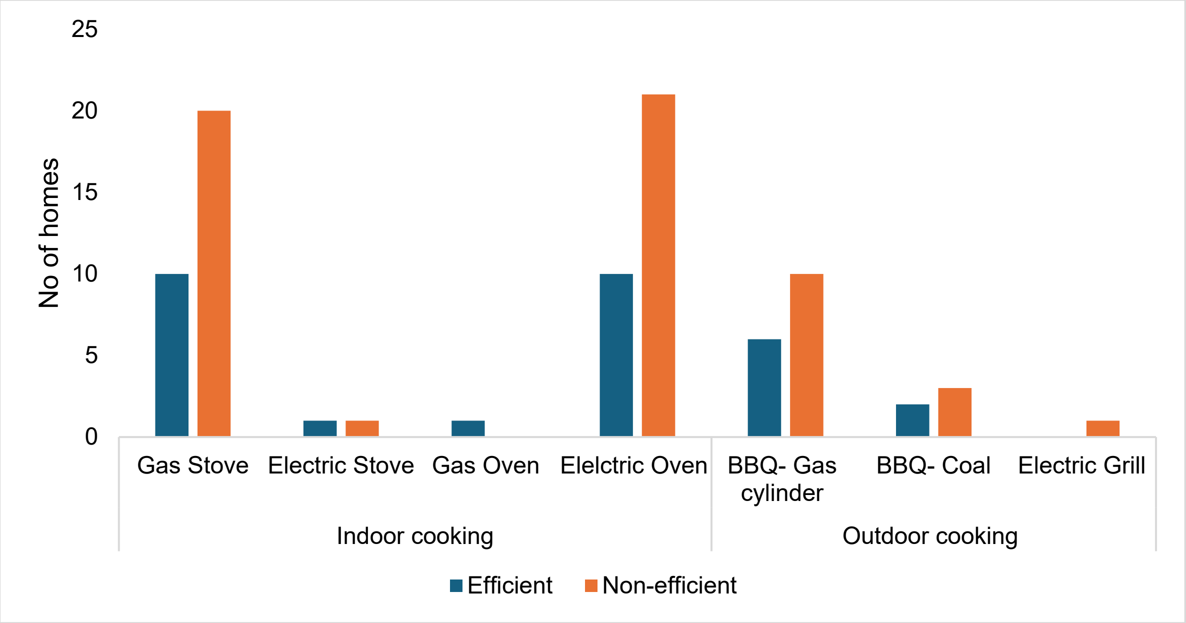


Figure 7 presents the indoor and outdoor cooking systems of efficient and non-efficient dwellings. Both efficient and non -efficient homes had gas stoves and electric ovens as the main indoor cooking systems. Further, Barbeque units operated with LPG gas cylinders were common outdoor cooking system in both groups.

Figure 7 Indoor and outdoor cooking systems



3.3 Participant characteristics

The study included 38 participants, with some households having two participants. Of these, 20 (53%) were men aged 33 to 81, and 18 (47%) were women aged 32 to 71. Most participants were in active work. Seventeen (45%) were employed full-time, eight (21%) worked part-time, one (3%) had casual work, and twelve (32%) were retired. The group was generally 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

Household	Age	Gender	Occupation	Work status	Highest level education
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
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 Householder Archetypes

Householders' perspectives on transitioning to all-electric homes can be categorized into four archetypes:

Energy Agnostic: These householders are indifferent to whether their heating, cooking, and hot water are powered by gas or electricity. Their decisions are based primarily on performance and cost considerations at the time of replacement.

Entrenched in Gas: This group strongly prefers gas for heating, cooking, and hot water, viewing it as the most cost-effective energy source.

Moving to all-electric – cost: Householders in this group believe that the rising cost of gas makes an all-electric setup more economical.

Moving to all-electric-multiple benefits: These householders prioritize reducing environmental impacts, improving health outcomes, and lowering costs by moving to an all-electric home.

Further details about the householder archetypes can be found in Interim Report #2 and Interim report #3.

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 the summer months (December 2023 - February 20204) with respect to efficient and non-efficient homes.

4.1 GAS USAGE

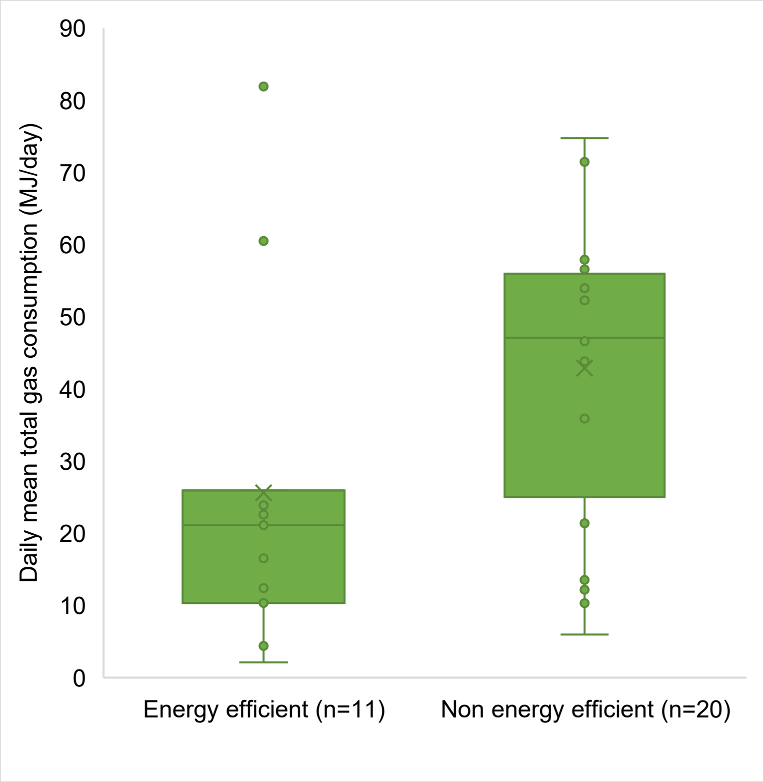
This section presents the gas consumption data with respect to efficient and non-efficient homes. Gas data was available for 31 homes (11 efficient and 20 non-efficient) for the summer period. As shown in Table 4, the range of daily mean total gas consumption of energy efficient dwellings was lower than the non-efficient group on the coldest days. However, the range of daily mean total gas consumption energy for efficient homes was higher than among the non-efficient homes on the warmest days. The group of efficient homes presented lower minimum consumption values during coldest and warmest days. The group of non-efficient homes presented a higher maximum consumption value during coldest and the warmest days. Both groups included households with zero daily mean total gas consumption on typical summer days. The average gas consumption was higher in the non-efficient homes during the coldest, typical summer and the warmest 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=20)			
	Min	Ave.	Max	Range	Min	Ave.	Max	Range
15	1	42	234	233	11	91	342	331
18 ('typical' summer day)	0	25	177	177	0	40	128	128
28	4	17	36	32	48	61	73	25

Figure 8 presents box plots comparing the daily mean total gas consumption between the groups on days with a daily mean outdoor temperature of 18^{0}C. The median gas use in efficient homes is lower than the non-efficient homes. The box plots reflect the gas consumption data of 31 homes (11 efficient and 20 non-efficient) for the summer months. The interquartile range of the efficient group is lower (16MJ/day) than the non-efficient group (32 MJ/day). The non-efficient group showed a higher dispersion of mean gas consumption than those for homes in the efficient group: the highest and lowest consuming households were found in the efficient dwellings group. Both groups of data appear to be right skewed (positively skewed). The box plot of the efficient dwelling group presents two high outliers, HH40 and INT14.

Figure 8 Box plot for mean gas usage on days with a daily mean outdoor temperature of 18^{0}C

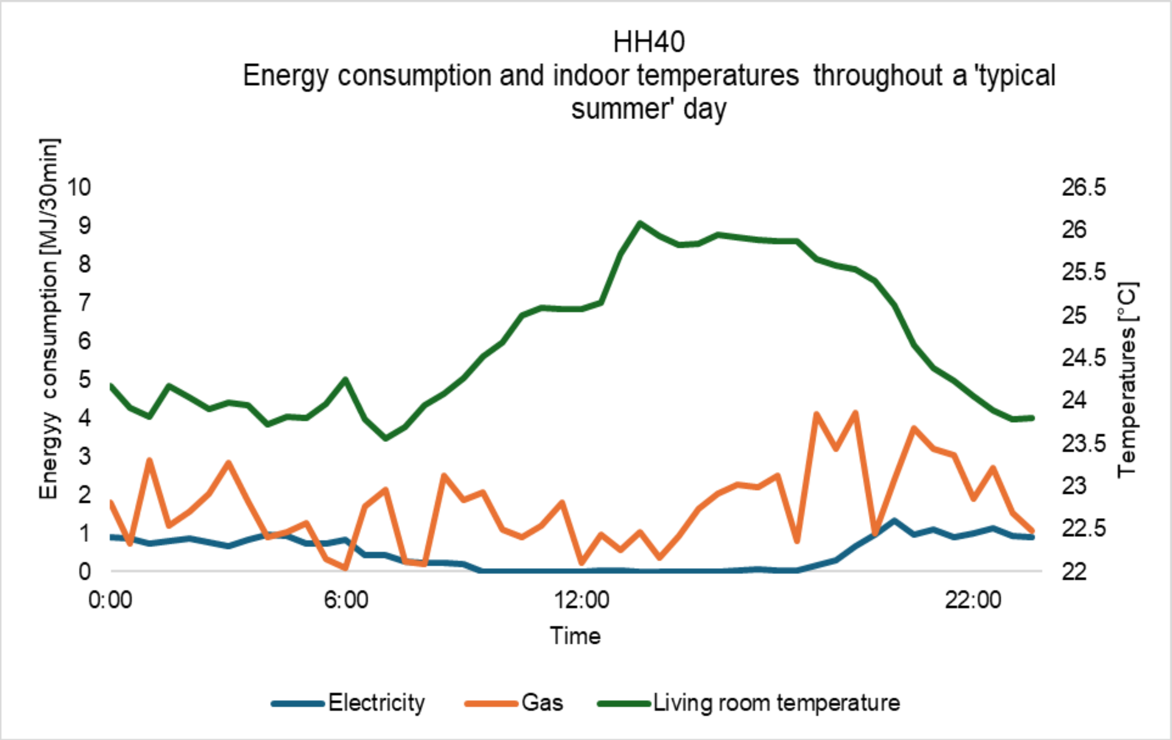


Energy efficient household HH40 presented the highest daily mean total gas consumption of all homes on typical summer days (82 MJ/day), which was more than three times the average in that group of households (25 MJ/day). HH40 was a mid-income Indian household with two adults and one child characterised as ‘entrenched in gas’. Their 4-bedrooms, 2-bathrooms home was a 5-star rated home. Details of their energy use are shown in Figure 9.

The relatively high gas consumption seems to have been the result of a combination of factors. Firstly, gas was used for heating at all hours of the day to provide thermal comfort for the participant’s older mother who was visiting from a warmer climate. The living room temperatures on a typical summer day never dropped below 23°C. The dwelling featured a gas-based ducted forced air heating system with ceiling outlets. Secondly, the dwelling may not have been very energy efficient compared to other homes in the group. Even though the dwelling was in the energy efficient category, the dwelling reportedly only had ceiling insulation. No insulation in the walls and only single-glazed windows would have allowed relatively high heat loss through the envelop and demanded continuous heating.

Thirdly, the household used the gas stove in the morning and afternoon. In the mornings, the gas stove was used to boil milk. Milk was always boiled before consumption and mostly drunk warm. In the evening, the gas stove was used to cook curries and roti bread. The householder shared that he was “thinking of going to induction actually” for convenience, because “that’s a little bit less of maintenance in terms of from a cleaning point of view”, however he had not tried it yet and was a bit sceptical. Firstly, gas cooking was engrained in his culture: he only knew gas cooking in his childhood, and his friends had shared that “[electric stove] doesn’t cook well […], especially our way of cooking, which is curry making”. He shared that Indian cuisine required fine control of the temperature for optimum taste and to ensure that the roti bread is cooked thoroughly in the middle without burning on the outside. The regular peaks during the day and evening may also be associated with hot water use. The dwelling had a gas-fuelled instantaneous hot water system that would have used gas during washing and cooking practices. However, the homeowner was exploring a solar hot water system to take better advantage of the electricity from the solar panels. Currently, the excess electricity was fed into the grid.

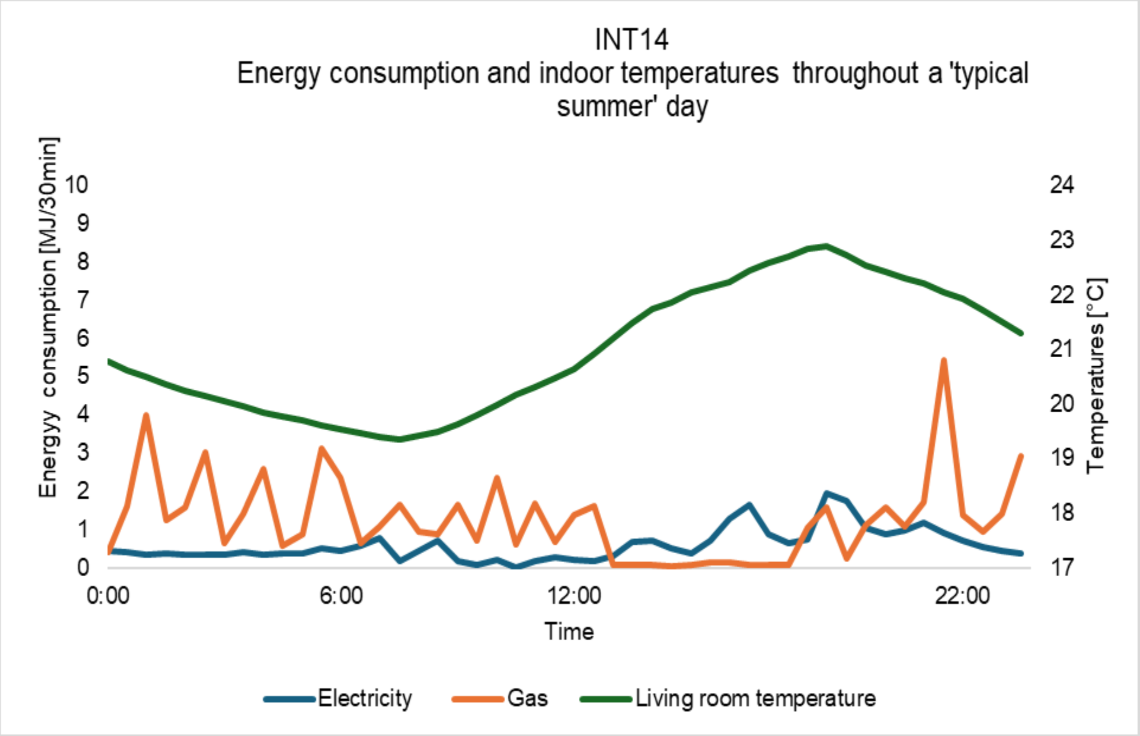
Figure 9 HH40 energy consumption and indoor temperatures throughout a 'typical summer' day



Another apparently energy efficient household INT14 presented the second highest daily mean total gas consumption of all homes on typical summer days (61 MJ/day), which was more than twice the average in that group of households (25 MJ/day). Details of their energy use are shown in Figure 10.

INT14 was also a mid-income household, however, with an Anglo-Saxon background and a family of two adults, four children and four pets. The detached house featured 5 bedrooms, 2 bathrooms, was also rated 5-stars, but it was unclear if the walls were insulated. Similar to HH40, the windows were single glazed, heating was afforded through a gas-based ducted forced air heating system with ceiling outlets, an instantaneous gas-fuelled hot water system and solar panels.

Figure 10 INT14 energy consumption and indoor temperatures throughout a ‘typical summer’ day

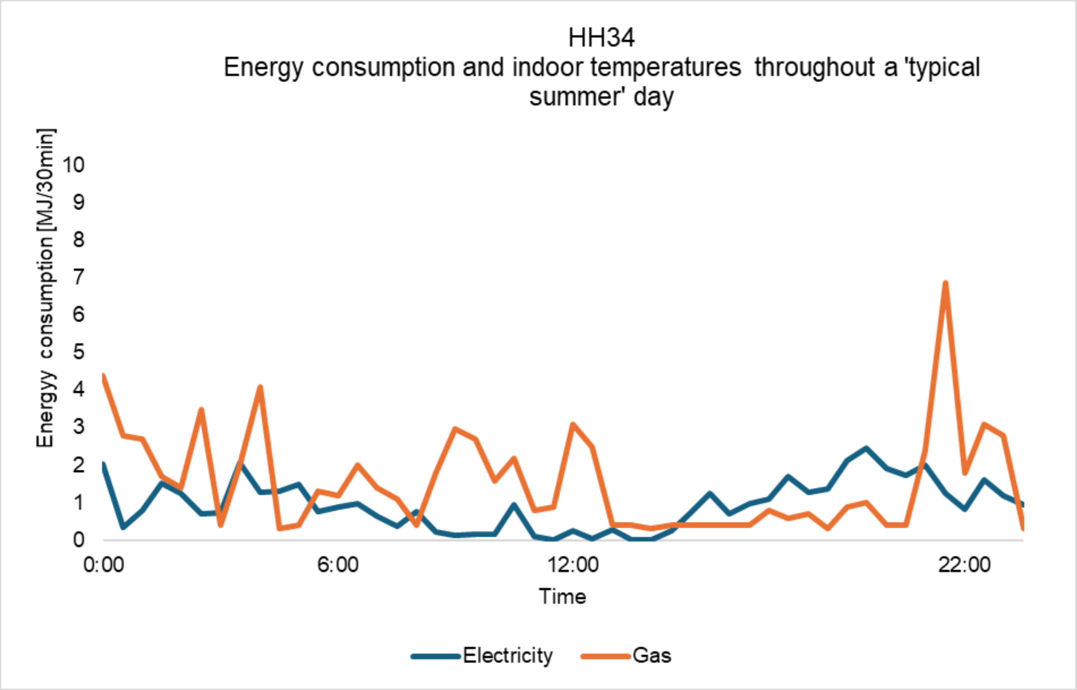


Similar to HH40, the diurnal variation in gas use was characterised by a series of peaks with the highest in the evening. As the indoor temperatures on typical summer day did not drop below 19°, the high gas consumption may also have been partly shaped by the poor thermal performance of the building. In contrast to HH40 however, INT14’s diurnal variations showed higher peaks, e.g. up to 4MJ/30min in the early hours of the morning and up to 5.4MJ/30min in the evening. This may have been due to the children using showering at the same time. This practice also prompted them to have an instantaneous gas-fuelled hot water system rather than a storage one:

> *“We used to have a big hot water tank, but it kept having problems with the ignition and we just wanted to go with that one. It was - we knew that we could - it would just give us better options, especially when the kids got older and we’d have kids in both showers at the same time.” (INT14)*

In the non-energy efficient group, HH34 presented the highest gas usage of all homes on typical summer days (75MJ/day) (Figure 11). HH34 was a low-income Australian household with six adults and one child characterised. Their 4-bedrooms, 2-bathrooms home built in 1994, reportedly had roof and wall insulation but single glazed windows and solar panels. The home had a gas-based forced air heating system with ceiling outlets and a gas storage hot water system but only electric cooking in the kitchen. Someone was at home at all times. Indoor temperatures were not available for this home. However, it is possible that the high gas usage was due to heating. Another factor would have been several members of the family taking showers at night.

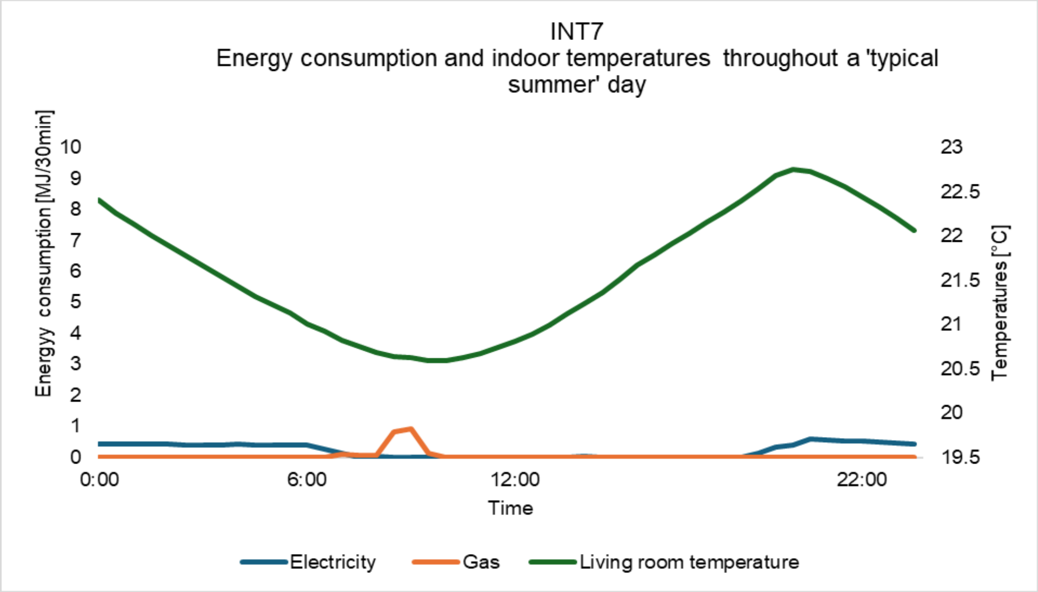
Figure 11 HH34 energy consumption and indoor temperatures throughout a 'typical summer' day



INT7 was the household with the lowest daily mean total gas consumption of all efficient homes on typical summer days (2MJ/day). INT7 was a high-income household with a single Australian retiree who reported being at home. The 5-star rated house had 3 bedrooms, 2 bathrooms, with ceiling insulation, double glazed windows and solar panels but no wall insulation. The house was equipped with a gas-based ducted forced air heating system with floor vents, reverse-cycle air conditioning in the bedroom, gas cook stove and a solar hot water system with a gas booster.

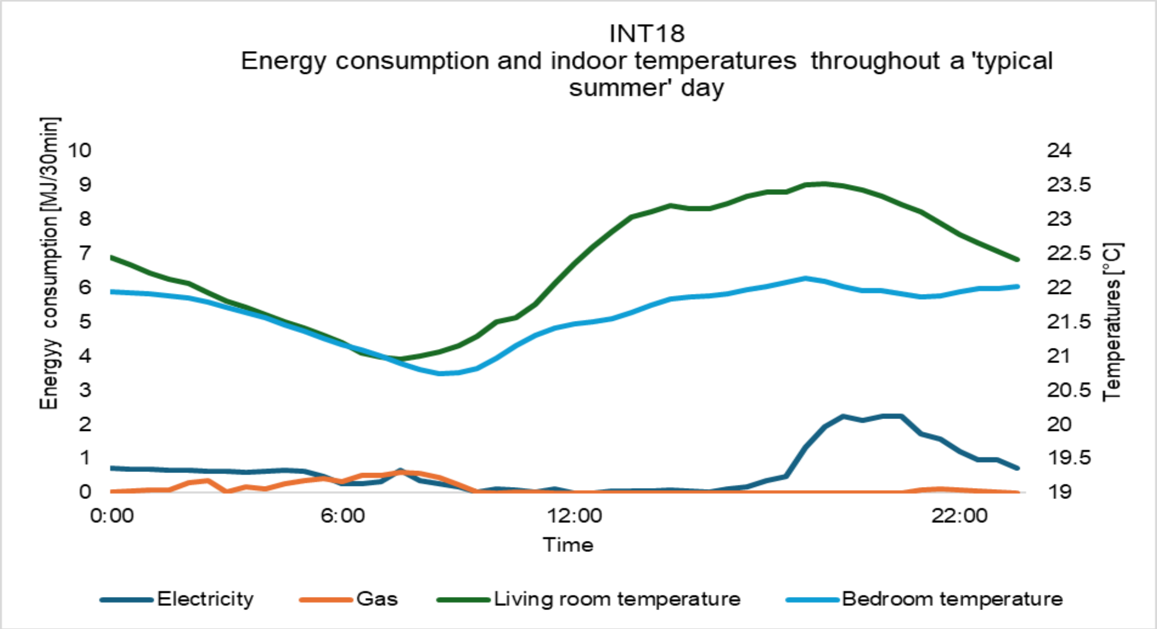
The household only used gas in the morning, and the living room temperatures followed a smooth curve over the course of a typical summer day (Figure 12). The participant wanted to "get rid of gas" to avoid the daily charge costs. He reported that he did not use gas for heating except very briefly on a very cold winter morning. He had switched off the gas booster of the hot water system, because did not think that "the booster is running heating during the night, even during summer" was sensible. He had seen a "noticeable … $2 or $3 a week" reduction in costs. He felt he needed the gas boosting during winter but that the water temperature was "more than adequate" in summer. The gas use peak in the mornings would have been associated with cooking: "I use one burner and that's about it, boiling some water." Once the prices of induction stoves came down, he was going to install an induction stove. He said: "I use one burner and it's the smallest one and it's not small enough, even in minimum setting, it still generates more heat than I want a lot of the time. Induction would give better control."

Figure 12 INT7 energy consumption and indoor temperatures throughout a ‘typical summer’ day



INT18 was the household with the lowest daily mean total gas consumption of all non-efficient homes on typical summer days (6MJ/day). INT18 was a high-income Chinese household with three adults, one child and one pet that was moving to an all-electric home. The weatherboard house from 2000 had 3 bedrooms, 1 bathroom, with ceiling and roof insulation, single glazed windows and solar panels. The house was equipped with a gas-based ducted forced air heating system with ceiling vents. The gas instant hot water system was replaced with a heat pump during the study. Gas was only used for cooking. The diurnal gas profile on a typical summer day (Figure 13) showed gas use only during the night and in the morning, which may have reflected hot water use during the night and showering and cooking in the morning.

Figure 13 INT18 energy consumption and indoor temperatures throughout a ‘typical summer’ day



4.1.1 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 (Energy efficient: 15-28^{0}C and non-energy efficient: 15-27^{0}C). 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 summer. When the outdoor temperature was 27^{0}C -28^{0}C, the mean total gas consumption of non-efficient homes presented a positive association. However, this result should be interpreted with caution due to the comparatively low number of data points at the high end of the outdoor temperature range.

The relationship of gas usage to outdoor temperatures was likely due to heating during colder days. The higher gas use in the non-energy efficient dwellings agrees with the assumption that poor thermal performance may lead to higher heating energy use to achieve similar indoor temperatures (Figure 31).

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

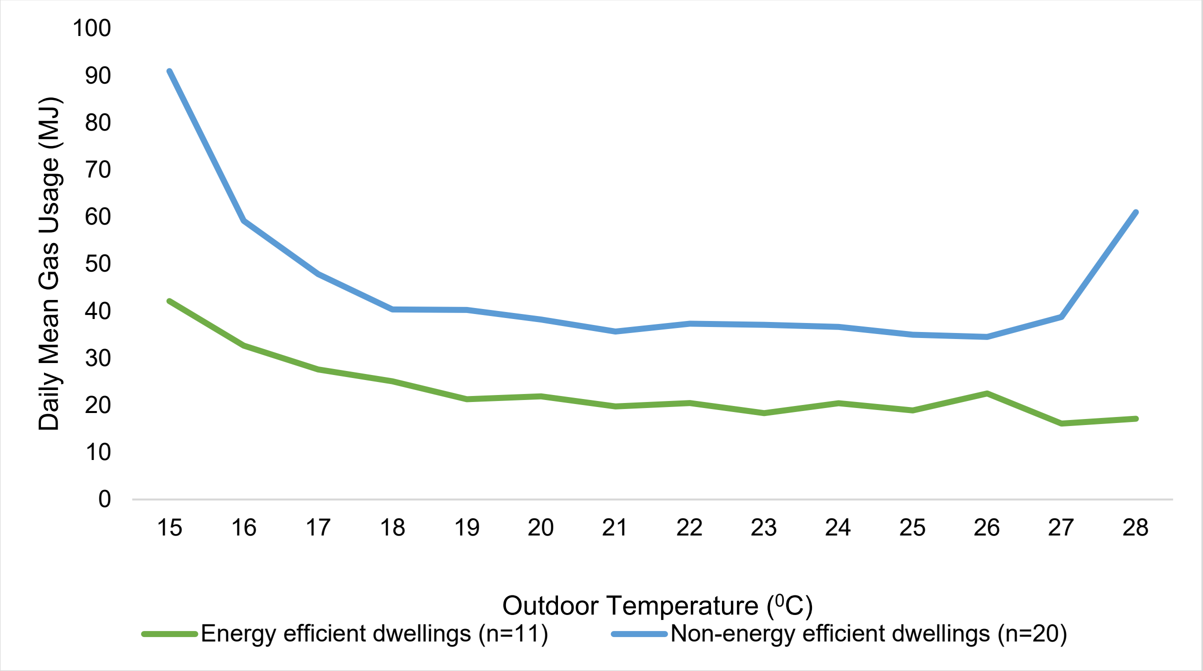
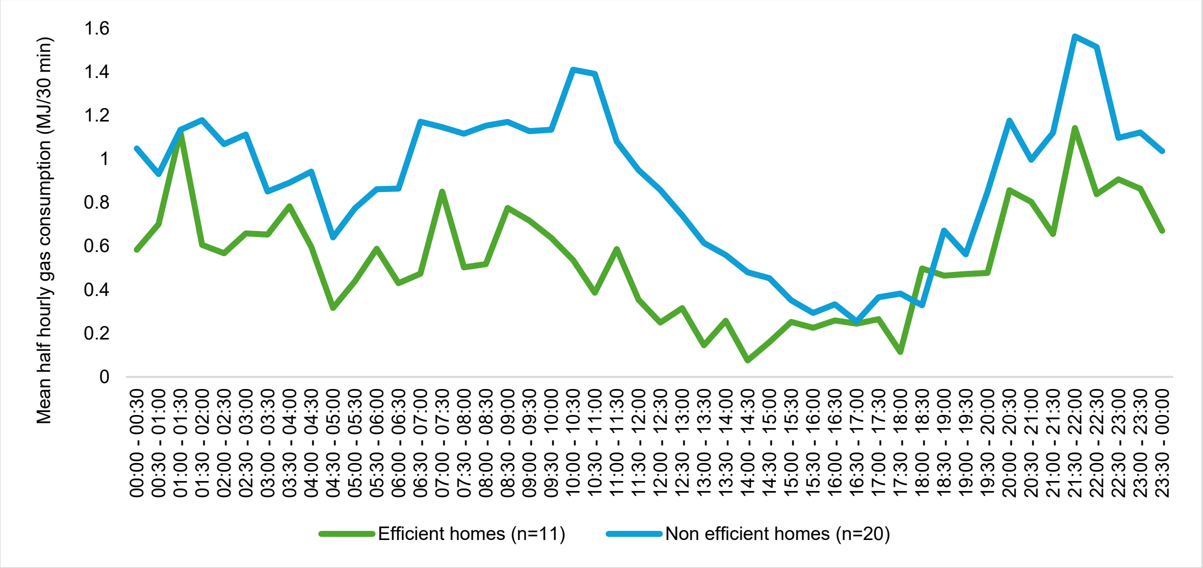


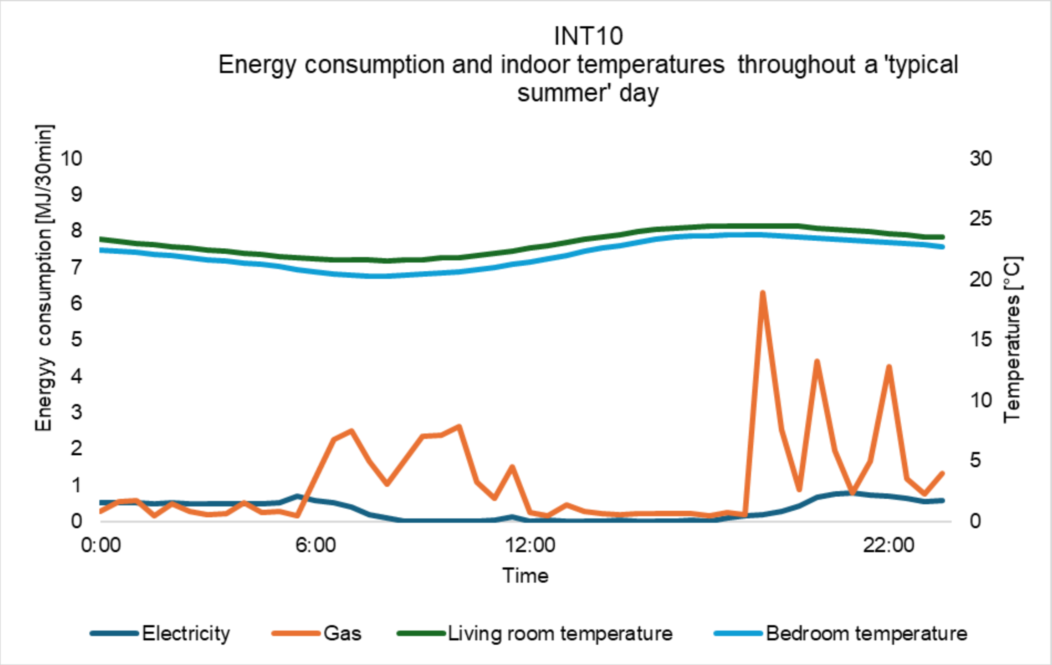
Figure 15 compares the diurnal variations in average half-hourly gas consumption on ‘typical’ summer days of efficient and non-efficient dwellings. The distribution of half-hourly gas use in both groups is bimodal. The evening peak in the non-efficient group of homes is slightly higher than its morning peak. In the inefficient dwelling group, INT10, INT19 and HH34 had higher gas usage in the evening.

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 18^{0}C



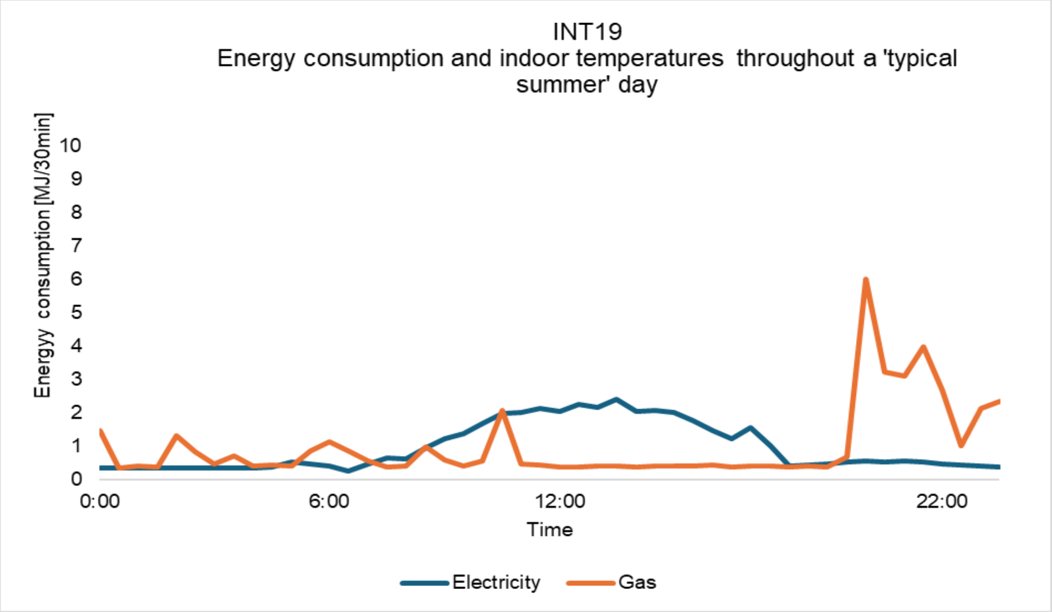
INT10 (Figure 16) was a high-income Italian-Australian household with two adults, two children. The family was absent on most days during the week, returning at 4pm. The energy inefficient house from 1998 had 3 bedrooms, 1 bathroom, with ceiling insulation, unknown wall insulation, single glazed windows and solar panels. The house was equipped with a gas-based ducted forced air heating system with ceiling vents that was as old as the house and 4-year-old gas storage hot water system. As shown in Figure 16 the indoor temperatures were even throughout the day and similar in the living room and bedroom. The morning and evening gas us peaks may have been connected to the hot water system. The householder reported that it was unusually large: “We’ve got quite a big hot water unit, so it’s bigger than what an average home this size would have.”

Figure 16 INT10 energy consumption and indoor temperatures throughout a ‘typical summer’ day



INT19 (Figure 17) was a high-income Scottish household with three adults and two pets. Someone was always at home. The energy inefficient weatherboard house from the mid-1970s had 3 bedrooms, 1 bathroom, with ceiling and roof insulation, single glazed windows and solar panels. The house was equipped with a gas-based ducted forced air heating system with floor vents that was 5-year-old and a 28-year old gas storage hot water system. They switched their gas stove over to an electric one a few months earlier because the gas stove had been leaking for about a year It was a glass cook top but not an induction stove. The high gas use may have been connected to their 28-year old gas storage hot water system.

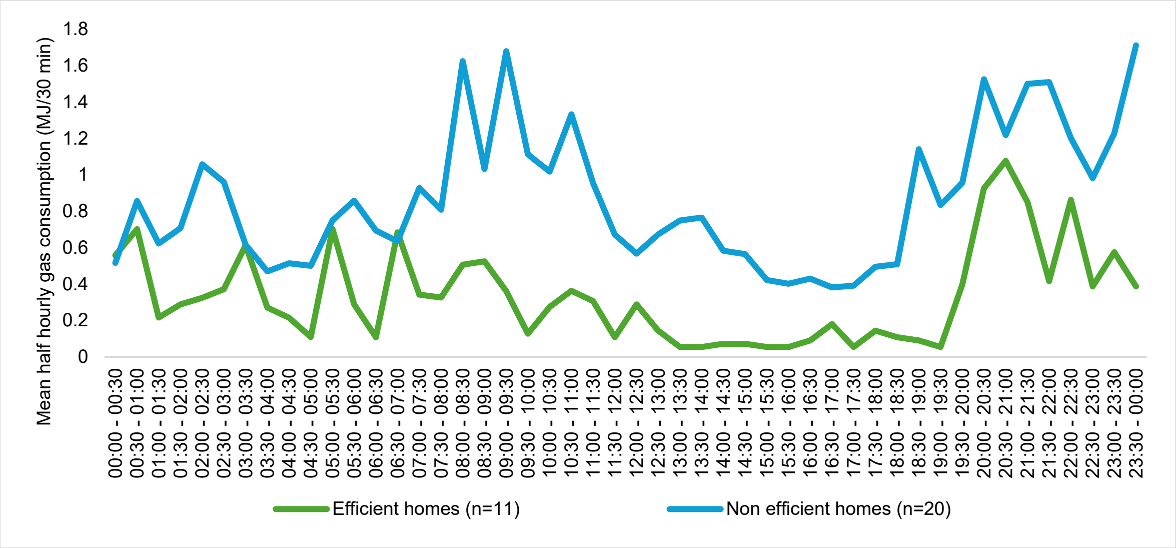
Figure 17 INT19 energy consumption and indoor temperatures throughout a 'typical summer' day



The high evening gas use in HH34 was likely due to several evening showers in this 6-adult household. HH44 and HH34 has higher gas usage in the early morning. The high morning gas use in HH34 was also likely due to several morning showers in this 6-adult household. The efficient dwelling group exhibited a peak in the early mornings (1.00 am -1.30 am) which was slightly higher than its evening peak. The cause for this peak was the gas usage of efficient homes INT14, HH40 and INT1 during the early morning period. All three dwellings were equipped with an instant gas hot water system. The average half-hourly gas consumption appeared to be higher in the non-efficient dwellings group at all times except during 6.00 pm - 7.00 pm period. Overall, HH40 had a higher gas usage during typical summer days. INT14 displayed a higher gas usage early morning and in the evening. INT1 has the lowest gas usage during the daytime.

Figure 18 compares the diurnal variations in average half-hourly gas consumption on days with a daily mean outdoor temperature of 27^{0}C, comparing efficient and non-efficient dwellings. Visual analysis shows that there is a slight increase in the gas use in non-energy efficient homes in the morning compared to typical summer days. The interview data did not offer a plausible explanation.

Figure 18 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 27^{0}C



4.2 ELECTRICITY USAGE

This section presents the electricity consumption data with respect to efficient and non-efficient homes. Electricity data was available for 31 homes (11 efficient and 20 non-efficient) for the summer months.

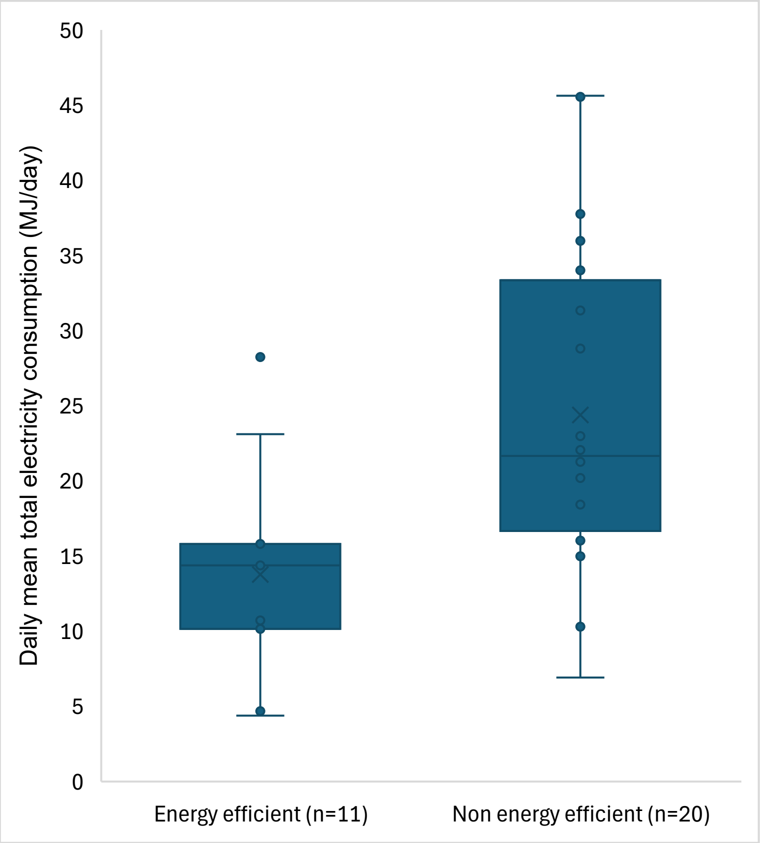
Table 5 Descriptive statistics of daily mean total electricity consumption in relation to daily mean outdoor temperatures

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
15	4	20	57	53	5	26	128	123
18 ('typical' summer day)	3	14	56	53	4	24	63	59
28	8	29	50	42	6	44	63	57

The range of daily total electricity consumption on the coldest, warmest and typical summer 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 typical summer days. However, the minimum total electricity consumption on the warmest day was higher in the efficient group of dwellings. Out of the 32 homes the highest total daily electricity consumption 195MJ was presented at INT14 (an energy efficient home) when the daily mean outdoor temperature was 26^{0}C. This household was a high gas user too as described earlier.

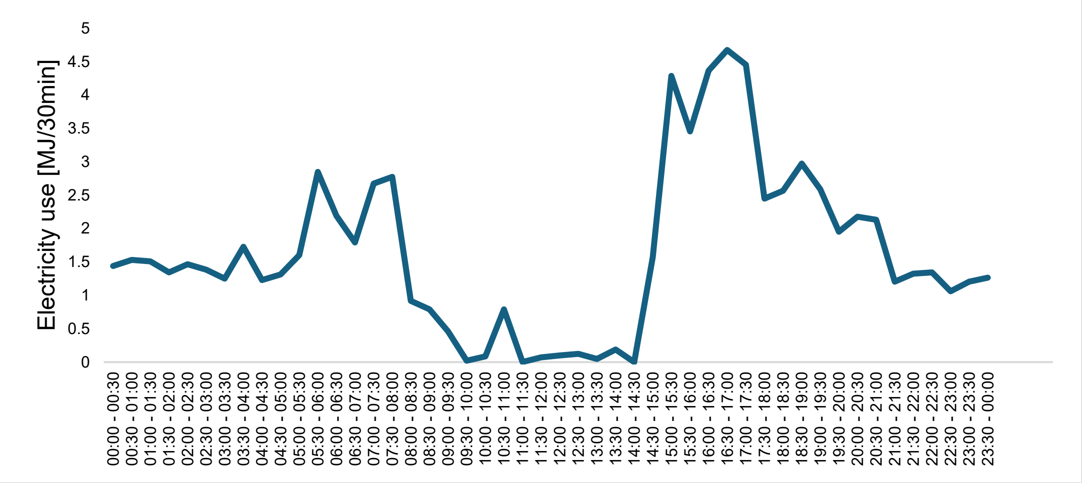
Figure 19 presents a box plot comparing the daily mean total electricity consumption between the groups. The interquartile range of the efficient group is lower than the non-efficient group. Further, the median electricity consumption of the efficient group is lower than the non-efficient group. However, the non-efficient group shows a higher dispersion of mean electricity consumption than the efficient group. Both distributions are positively skewed. A high outlier is visible in the box plot of the efficient dwelling group (INT14). As explained earlier, the high use could be attributed to the use of a large evaporative air conditioning to cool the large house with 5 bedrooms and to the use of electronic devices by the four children.

Figure 19 Box plot for mean electricity usage on days with a daily mean outdoor temperature of 18^{0}C



INT14 was a large two adults, four children and four pets living in an energy efficient home. The electricity use pattern reflected the occupancy pattern. The high usage at the daily mean outdoor temperature was 27^{0}C (Figure 20), which would be a hot day, suggest the use of electric air conditioning. In fact, the household reported to have a new but “one of the biggest units” evaporative cooling systems that they need to cool the five bedrooms. They reported to “cool the house, it’s only on days that we know it’s going to be hot, like 30 plus and we try to get it on in the morning, so when it’s still cool in the house we try and just maintain that temperature from the evening cool.” The electricity pattern suggests that they switched it on in the afternoon, too. The interview seemed to confirm this: “We can turn it off and it will have created enough cool to be comfortable for the night.” The self-generated electricity from the solar panels may have compensated for occasional use in the late morning.

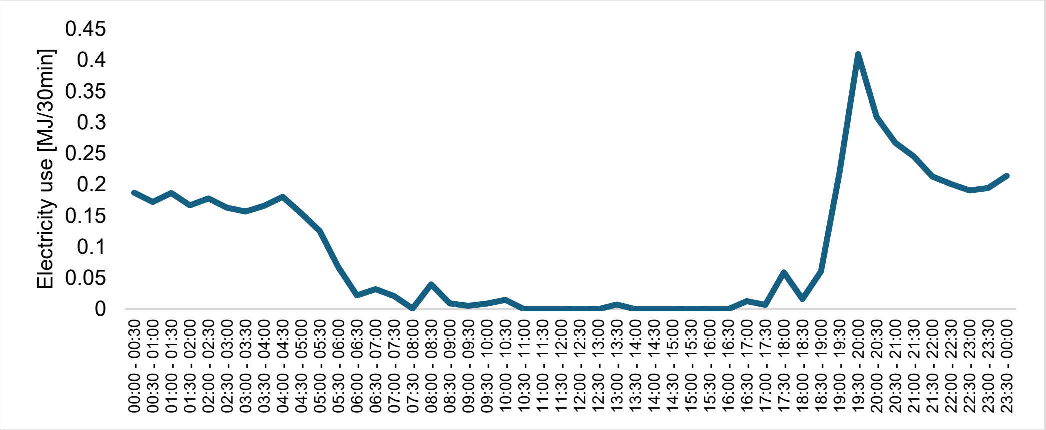
Figure 20 INT14 electricity use on a day with mean outdoor temperature of 27^{0}C



The lowest daily total electricity consumption was presented at HH32 (2.3 MJ) also an energy efficient home when the daily mean outdoor temperature was 18^{0}C (Figure 21). HH32 was a high-income Indian household with two adults and two children. Someone was always at home. The 6-star rated house had 4 bedrooms, 2 bathrooms, with ceiling and roof insulation, double glazed windows and solar panels. The low electricity use was explained by the household's rare use of air conditioning. The house was equipped with two split system air-conditioners, one in the parents' bedroom, the other in the living area. The participant shared that they did not feel that they needed air conditioning very often because "Melbourne doesn't get that hot [..] There's only two months for hot summer, and even half of that you don't". Usually, they would use natural ventilation by opening the "sliding windows in every room with the flyscreens […] and then we get good wind, chilly winds in Melbourne." In addition, they had standing fans for warmer nights. The air conditioners were sometime used for half an hour or an hour in the afternoon when the children came homes and "I know it's hot for them". The participants shared that they did not use the fans all night either as they disliked the cold draughts:

> *In the night so when the kids are sleeping, or we are sleeping on the bed, then we have a fan on for two hours maybe but not the whole night. You don't require them, else it's a bit cold and the kids have to rush to the bathroom. So sometimes we wake up in the night and turn it off for them because they can't, they forget.(HH32)*

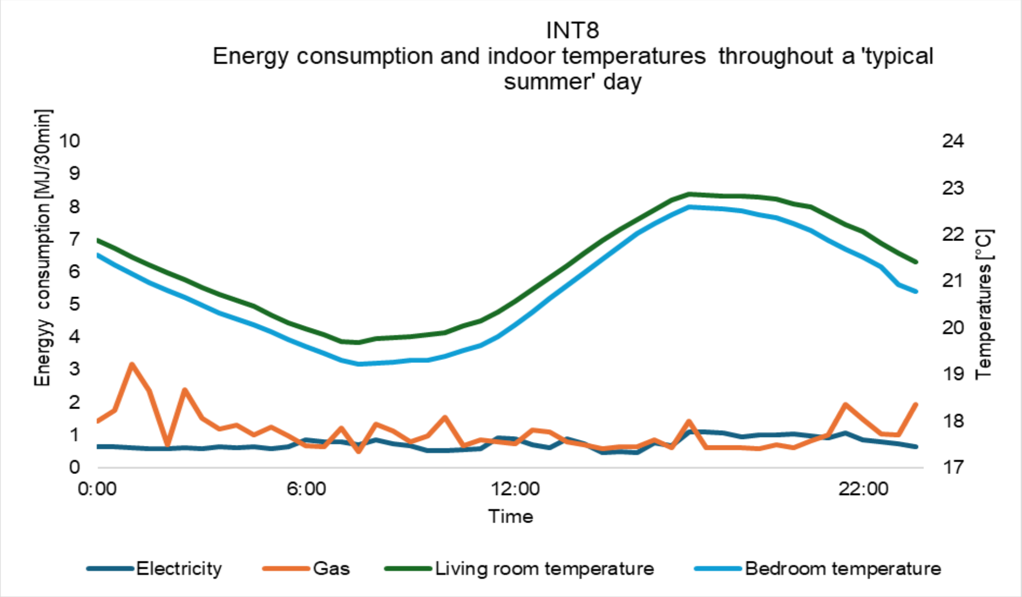
Figure 21 HH32 electricity use on a typical summer day with a mean outdoor temperature of 18^{0}C



In the non-efficient group, the highest daily total electricity consumption was presented by INT8 which was 128 MJ at 15^0C daily mean outdoor temperature, that is a slightly colder than ‘typical’ day.

INT8 was a mid-income Australian household with three adults and three pets. Someone was always at home. The 1978-built house had 2 bedrooms, 2 bathrooms, with ceiling but no roof insulation, single glazed windows and solar panels. The house had gas-based ducted forced air heating system with floor vents and gas instantaneous hot water system. The diurnal pattern of electricity usage on a ‘typical’ summer day (Figure 22) showed an almost consistent electricity use throughout the day. Because a 15^0C daily mean outdoor temperature a slightly colder than ‘typical’ day, and the electricity use pattern on a typical day did not present any peaks that may have suggested use of the evaporative air conditioner, it is likely that the high energy use was associated with the inefficiency of old appliances. The couple had a “fridge [was] 49 years old. I never had one thing done to it. They don't make them like that anymore”, a dishwasher that was “25, 30 years old and an electric stove that was 30 years old.

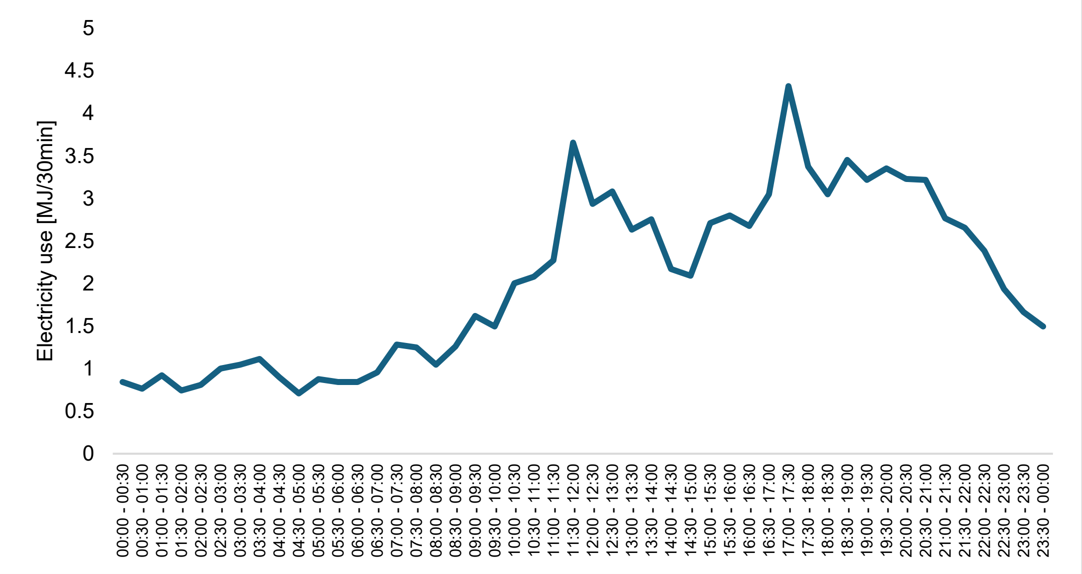
Figure 22 INT8 energy consumption and indoor temperatures throughout a ‘typical summer’ day



On hotter days (see Figure 23 below), their energy use was higher. The use of the evaporative cooling system is likely to be responsible for the much higher use in the afternoon and evening. The older couple turned the cooling system on by demand without determined alignment with the electricity generation by the solar panels. They were candid about this:

> *“We try to think about [air-conditioning in relation to when the solar panels are likely to be generating], but no. We put it on when we’re hot. […] We’re conscious of the fact that it costs and that’s why we try and turn it down over night-time. But, realistically, we just use it when we want to use it, to be honest”.(INT8)*
>
> *The air conditioning was thermostat regulated: “if we’re going to bed at, say, 10, we might start turning it off a little bit earlier. Although now what we’ve been doing is setting it on a temperature over night-time. So, mainly in the night-time we lower it down and if it comes on it comes on or goes off. But it’s automatic.”*

Figure 23 INT8 electricity use on a day with mean outdoor temperature of 27^{0}C



In the non-energy efficient group, INT12 presented the lowest total electricity consumption of 4.01 MJ at daily mean 19^{0}C outdoor temperature.

INT12 was a high-income Vietnamese household with four adults, two children and two pets. Someone was always at home. The house built in 2003 had 3 bedrooms, 2 bathrooms, with ceiling and roof insulation, single glazed windows and no solar panels. The house had gas-based ducted forced air heating system with ceiling vents, gas storage hot water system and gas cook stove. Even though the house did not have solar panels, the diurnal pattern of electricity usage on a 'typical' summer day showed an almost consistently low electricity use throughout the day (Figure 24). A 19^{0}C daily mean outdoor temperature a slightly warmer than 'typical' day. The electricity use pattern on a typical day did not present any peaks that may have suggested use of the refrigerative air conditioner. This cooling system for the whole house was only used when "it's extremely hot or if the kids are home.". At other times, the mother only turned on the standing fan in her study. The stove/oven was 18 months old, the appliances in the renovated kitchen were chosen for their high energy efficiency ratings, and they "tried to limit the devices that are turned on." Even on a hot day with a mean outdoor temperature of 27°C, the household used very little electricity (Figure 25).

Figure 24 INT12 Energy consumption and indoor temperatures throughout a ‘typical summer’ day

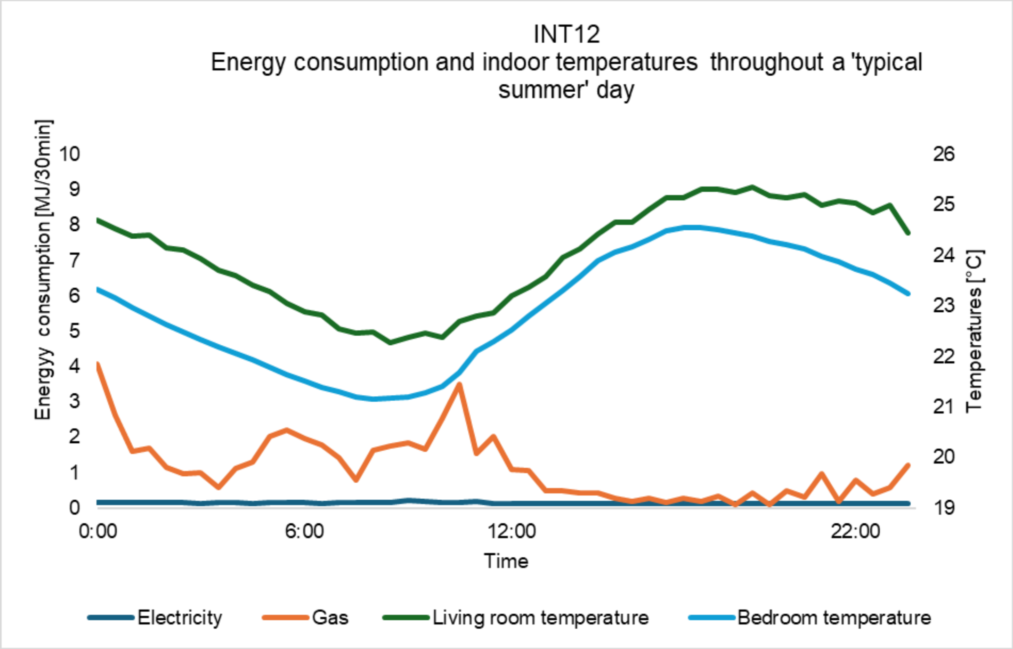
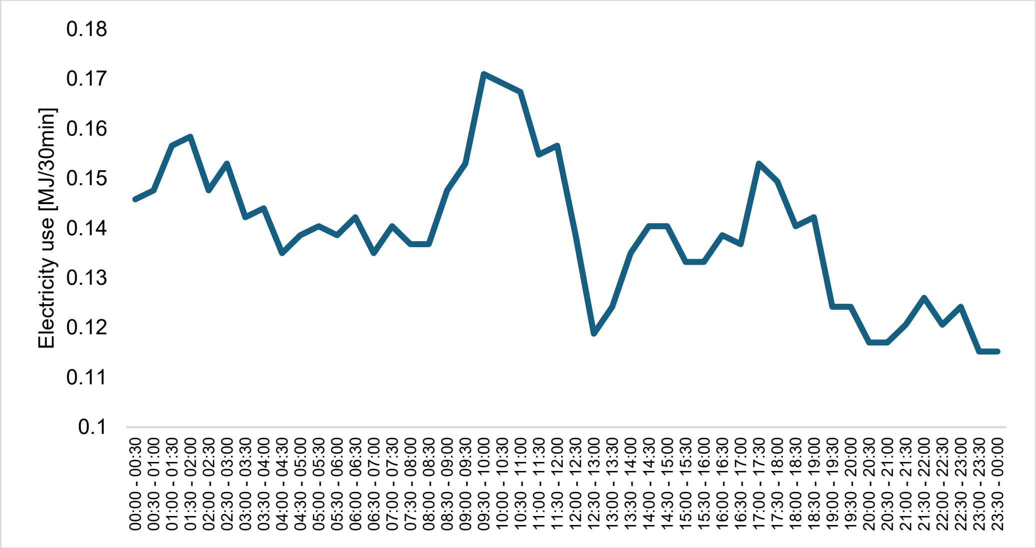


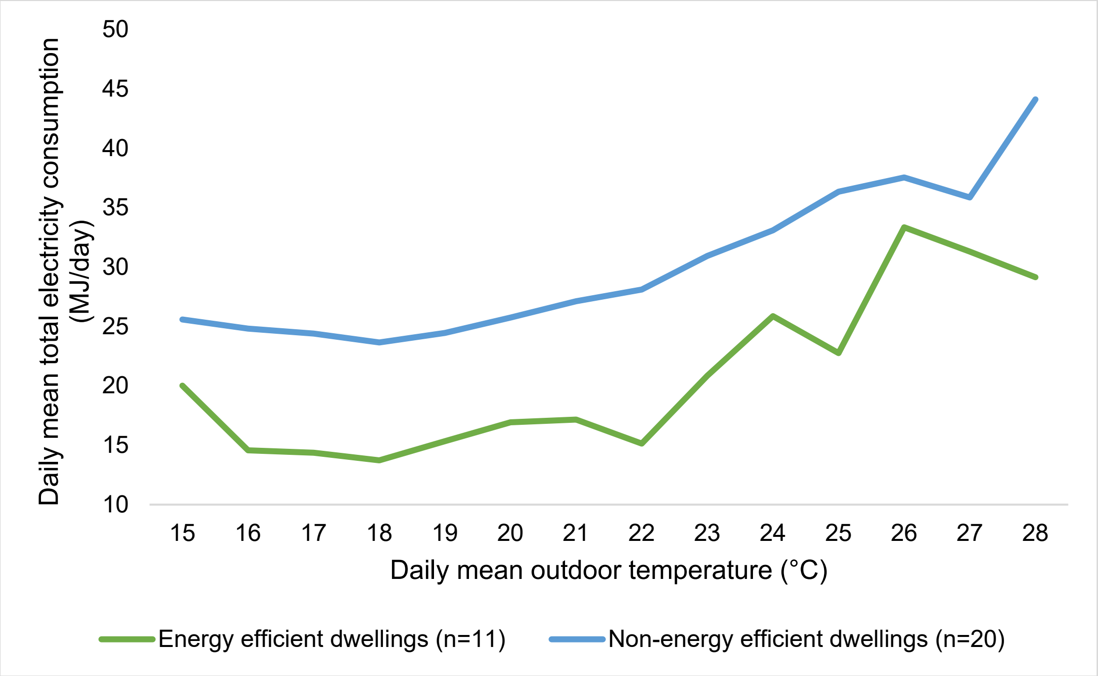
Figure 25 INT12 Electricity consumption throughout a day with mean outdoor temperatures of 27°C



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

Figure 26 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. 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. On average, the daily mean total electricity consumption in non-energy efficient dwelling group presented a positive association between 15-26°C mean outdoor temperatures. The daily mean total electricity consumption in non-energy efficient dwelling group drops slightly at 26°C and increases from 27-28°C.

Figure 26 Comparison of daily mean total electricity consumption at daily mean outdoor temperatures - efficient/non-efficient dwellings

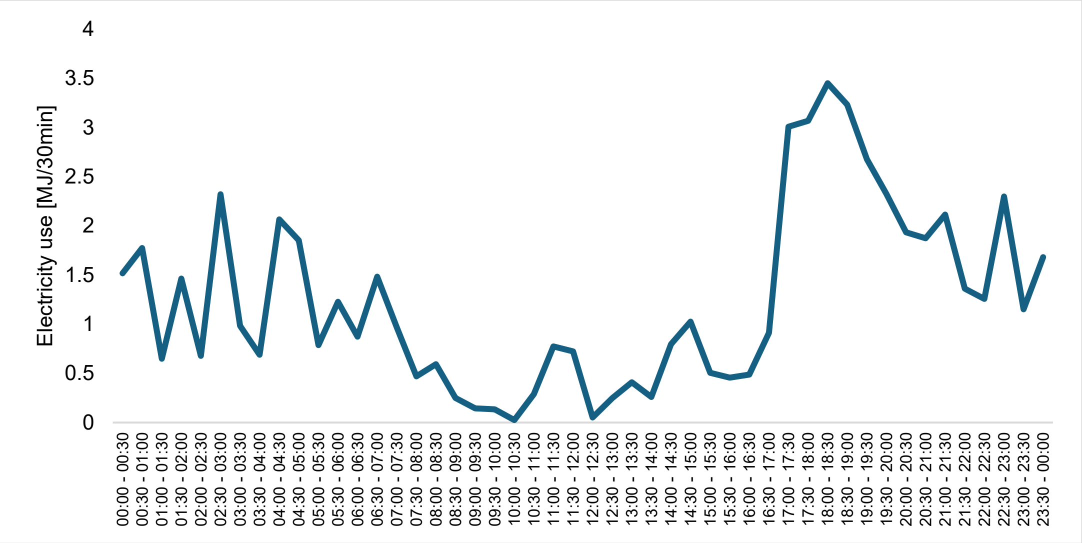


The highest electricity consumption at 28^0C mean outdoor temperature was HH34 (63.31MJ). This was likely due to the use of the evaporative air-conditioning in this energy inefficient house, even though it was only one year old. The evaporative air-conditioning was cooling all bedrooms and the living area. The predominant time of use was during the evening and night on very hot days:

> *"We only use it when it's hot. Generally, it doesn't get put on until like five o'clock at night. And then if it's really hot throughout the night, it will stay on at night and get turned off the next morning. [it is] just on off".* (HH34)

Because of the costs, they did not use it throughout the day. The lower electricity use in the middle of the day may also have reflected solar panel electricity generation (Figure 27).

Figure 27 HH34 electricity use on a day with mean outdoor temperature of 27^0C



On average, the daily mean total electricity consumption in energy efficient dwelling group presented a positive association between 16-21 °C, 22-24°C and 25-26°C mean outdoor temperatures. The daily mean total electricity consumption in energy efficient dwelling group has a negative association 15-16°C, 21-22°C, 24-25°C and increase from 26-28°C. The difference in daily mean total electricity consumption between the two groups appeared to be smaller during warmer summer days.

HH34 had the highest electricity consumption during the following time periods: midnight to 1.00 am, 1.30 am to 7.00 am, 5.30 pm to 6.30 pm, 7.30 pm to 8.30 pm, and 10.30 pm to midnight. INT17 showed a higher electricity use in the morning 8.00 am to 9.30 am. INT18 showed a higher consumption from 6.30 pm to 9.00 pm.

Figure 28 compares the diurnal variations in average half-hourly electricity consumption on typical' summer day of efficient and non-efficient dwellings. The distribution of electricity use in both groups shows a peak in the evening after 5.00 pm. The average electricity consumption appears to have always been higher in the non-efficient dwellings. However, the average electricity consumption became higher and the peaks more pronounced in the efficient dwellings group in the evening (6.00 pm – 9.30 pm). Energy efficient home HH40 had higher electricity usage during the early morning (1.30 am – 7.00 am) and later evening 8.00 pm to midnight). Also, an energy efficient home INT14 had had two peaks in the electricity usage in the morning (7.00 am – 8.30 am). HH29 also had a peak in the electricity use at 10.00am in the morning. INT14 had the highest electricity usage from 12.30 pm to 8.00 pm. In efficient group HH32 had the lowest electricity usage from 6.00 am to 5.00 pm. In the non-efficient group homes, INT19 has the highest electricity usage from 9.00 am to 6.00 pm. HH34 had the highest electricity consumption during the following time periods: midnight to 1.00 am, 1.30 am to 7.00 am, 5.30 pm to 6.30 pm, 7.30 pm to 8.30 pm, and 10.30 pm to midnight. INT17 showed a higher electricity use in the morning 8.00 am to 9.30 am. INT18 showed a higher consumption from 6.30 pm to 9.00 pm.

Figure 28 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 18^{0}C

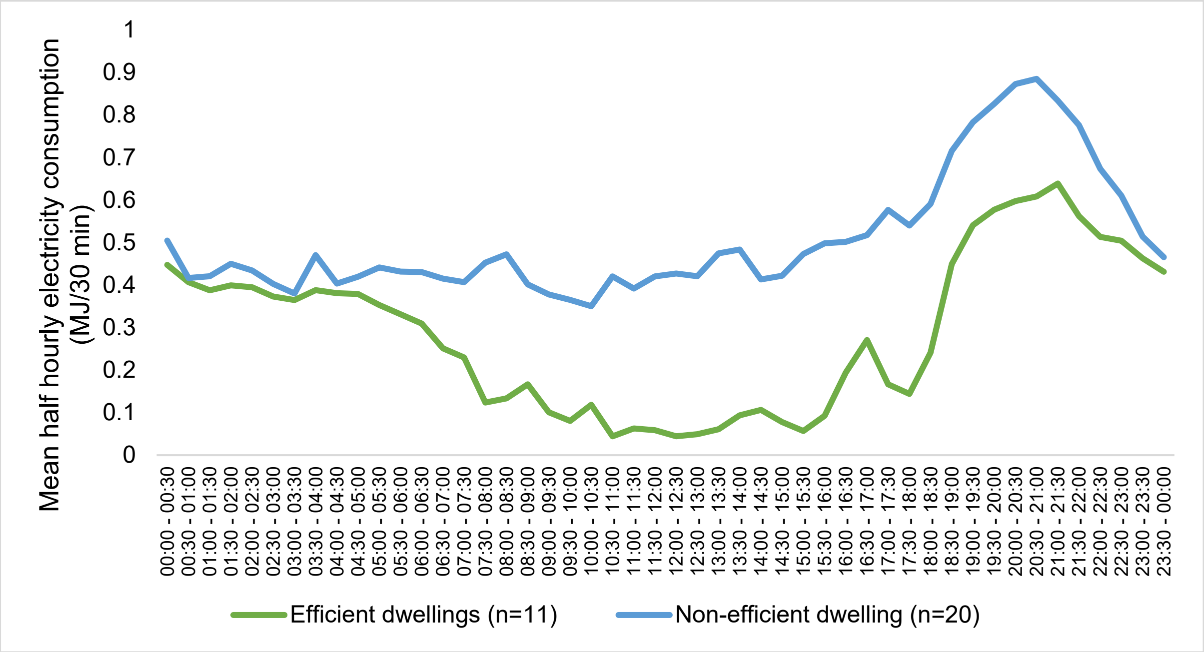
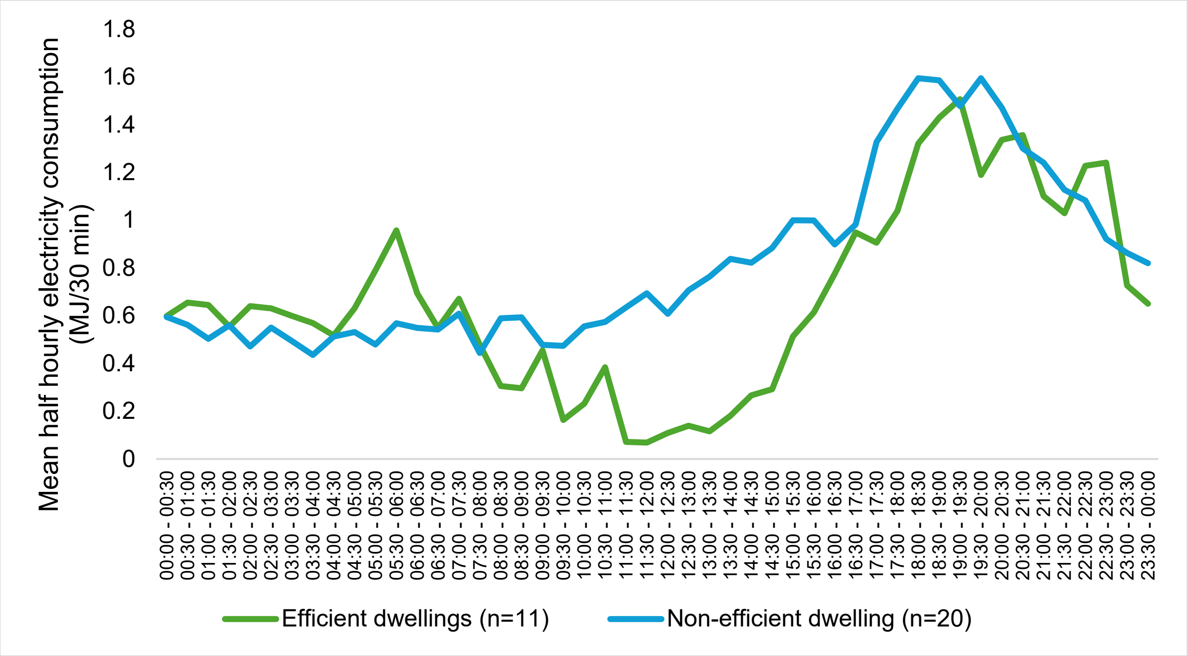


Figure 29 compares the diurnal variations in average half-hourly electricity consumption on days with a daily mean outdoor temperature of 27^{0}C, comparing efficient and non-efficient dwellings. Visual analysis showed that there was an increased electricity usage in both groups on hot days with daily mean outdoor temperature of 27^{0}C. This was likely attributable to air conditioning use.

Figure 29 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 27^{0}C



4.3 INDOOR TEMPERATURES

This section provides the results from the analysis of the indoor temperature data in December 2023 to February 2024 with respect to efficient and non-efficient homes. Living room temperature data was available for 10 efficient homes and 19 non-efficient homes. The range of daily mean living room temperatures on the coldest days was the same in both groups. However, the range on the warmest days was bigger in the efficient group of dwellings than in the non-efficient group of dwellings (Table 6). The range on a typical summer day was same in both groups.

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=10)			Non-efficient group (n=19)		
	Min (°C)	Max (°C)	Range (°C)	Min (°C)	Max (°C)	Range (°C)
15	19	24	5	18	23	5
18 (‘typical’ Summer Day)	19	27	8	19	27	8
28	21	28	7	23	27	4

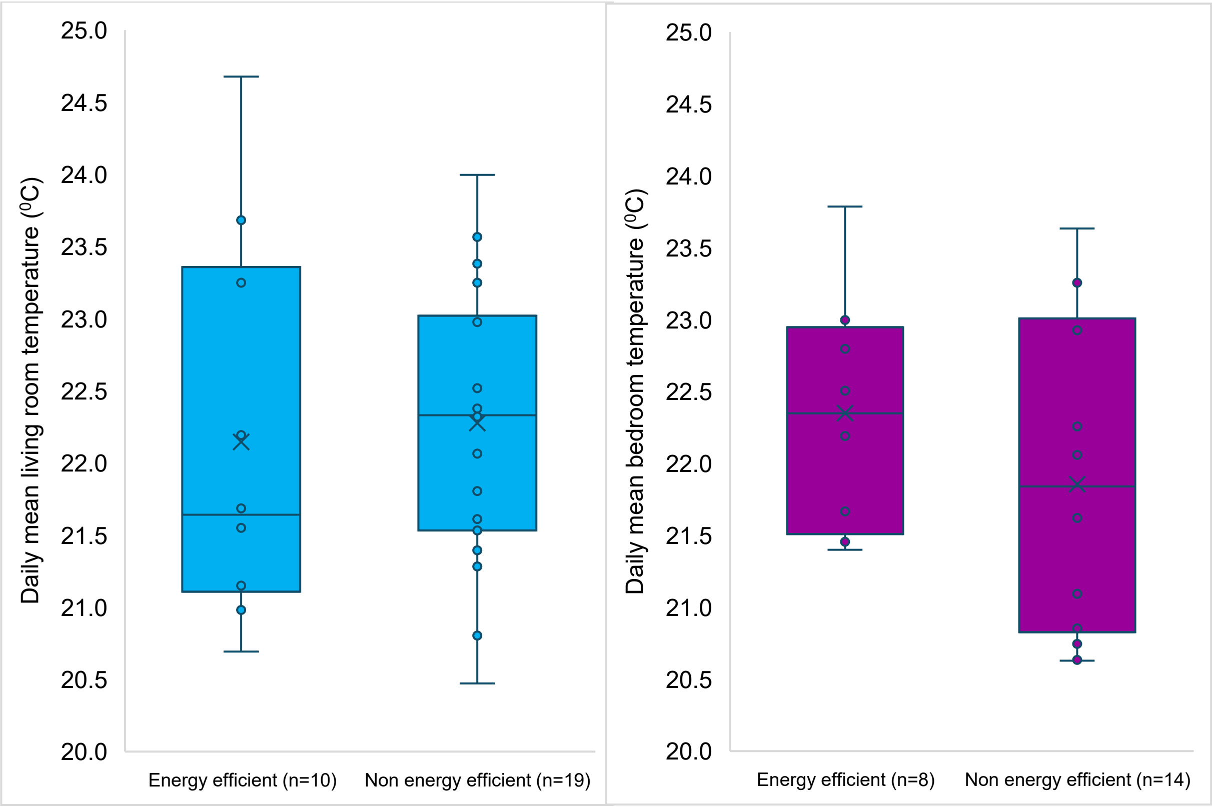
Bedroom temperature data was available for 8 efficient homes and 14 non-efficient homes. The range of daily mean bedroom temperatures on the coldest days was higher by one degree in the efficient group of dwellings than in the non-efficient group of dwellings (Table 7). However, the range of daily mean living room temperatures on the warmest days was bigger in the efficient group of dwellings than in the non-efficient group of dwellings (Table 7). The range on a typical summer day was same in both groups.

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=8)			Non-efficient group (n=14)		
	Min (°C)	Max (°C)	Range (°C)	Min (°C)	Max (°C)	Range (°C)
15	17	22	5	18	22	4
18 ('typical' Summer Day)	20	26	6	19	25	6
28	22	30	8	25	27	2

Figure 30 presents the box plots comparing the daily mean living room and bedroom temperatures between the groups. The interquartile range of the efficient group was higher than the non-efficient group in the daily mean living room temperatures. However, the efficient group has a lower interquartile range than the non-efficient in daily mean bedroom temperatures. With regards to the daily mean living room temperatures, both groups showed a similar dispersion of mean temperature. As shown in Figure 25, daily mean living room temperatures of efficient homes and non-efficient homes were right skewed.

Figure 30 Box plot for mean indoor temperature on days with a daily mean outdoor temperature of 18^0C



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

Figure 31 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 bedroom temperatures in the energy efficient dwellings appeared to be higher than those in non-efficient dwellings in higher outdoor temperature levels. The mean indoor living room temperatures in the non-energy efficient dwellings appeared to be higher than those in efficient dwellings in warmer outdoor temperature levels. However, there was no difference in living room warmth between the two groups when the outdoor temperature was between 15°C to 16°C. Further, during periods of "typical' summer days with a daily mean outdoor temperature of 18°C, the difference in warmth between these two dwelling groups was less than 1°C.

Figure 31 Comparison of daily mean indoor temperature at daily mean outdoor temperatures - efficient/non-efficient dwellings

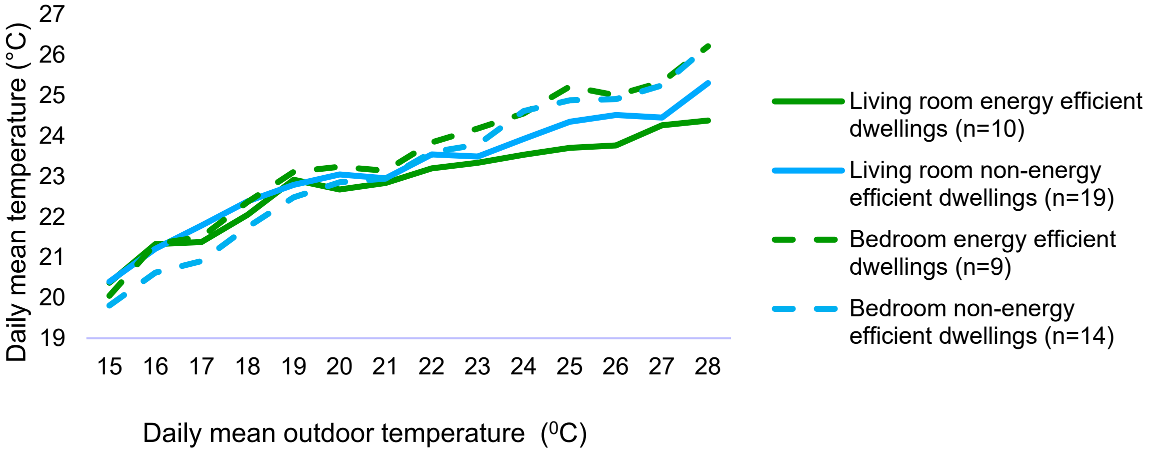


Figure 32 presents the diurnal variations of mean living room and bedroom temperature on 'typical' summer days with a daily mean outdoor temperature of 18°C in efficient and non-efficient dwellings respectively. The living room temperatures in both groups dropped overnight until about 7.00 am. The mean living room temperatures of both efficient dwellings group and non-efficient dwelling group rose during the day and afternoon until they peaked in the evening (6.00 pm - 6.30 pm). The peak in the non-efficient homes was more pronounced. The mean living room temperatures of the efficient dwellings achieved a plateau around 6.00 pm and stayed at this level of warmth until about 7.30 pm.

Figure 32 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 18^{0}C

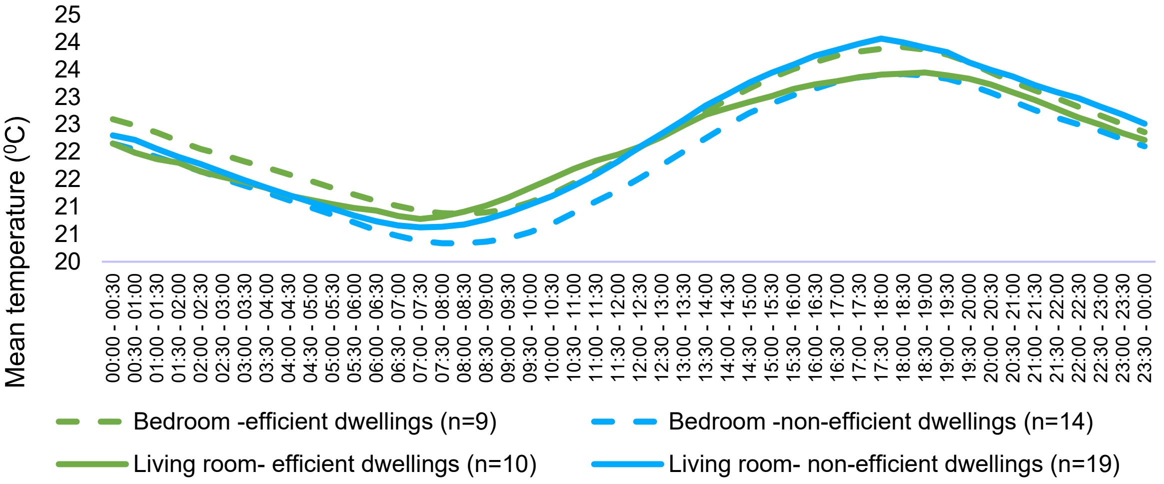
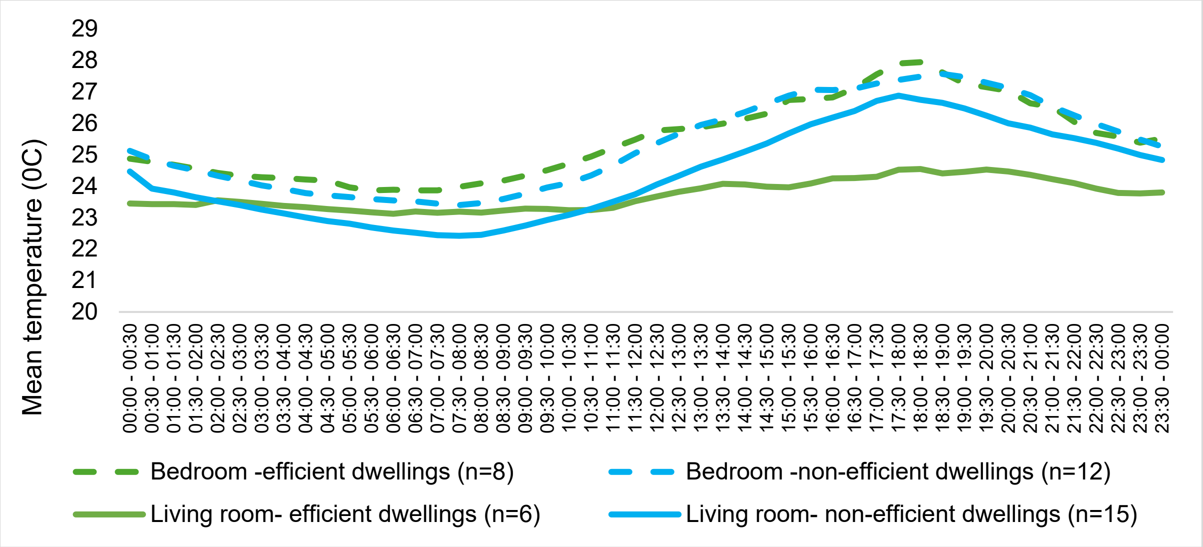


Figure 33 compares the diurnal variations in average half-hourly indoor temperatures on days with a daily mean outdoor temperature of 27^0C, comparing energy efficient and non-energy efficient dwellings. Visual analysis showed that there is an increased bedroom temperatures of the two groups. Energy inefficient homes presented more even but hotter temperatures. There was an approximately 4^0C difference between the living room temperature and bedroom temperature of the energy efficient dwellings in the evening peak on days with daily mean outdoor temperature of 27^0C. This suggests that householders in energy efficient homes may have cooled their living areas more than the bedrooms.

Figure 33 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 27^0C



HH40 had the highest mean living room temperatures of the efficient dwellings during typical summer days. This Indian household consisting of father, grandmother and child did not possess a fixed air conditioner. The family used two tower fans with a water tank:

> *"We put the water and just it gives like a cool breeze. That's only when it is really touching 40s. But otherwise I don't use that, because there's no need of it actually because this place is really – stays cool, nice actually".* (HH40)

They had been satisfied so far, using natural ventilation that was supported by the front door security screen and locked flyscreens. Other factors that, according to the participant contributed to the adequacy of the current cooling practices, was the height of the rooms and tiles on the floor:

> *"The best part of – there's two things; one is the height of the house is 2.7 metres, so most of the heat goes up so we don't feel it. And it's a tiled area, so it gets cold during the whole day, so there is no need – we never felt the need actually".*

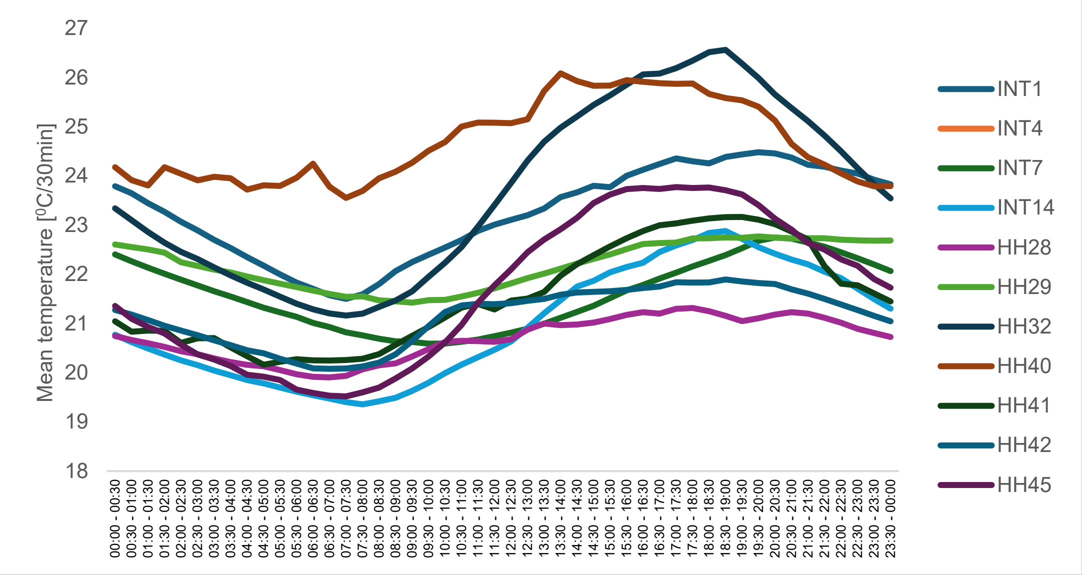
However, they were planning to take advantage of the heat pump subsidy to install a ducted air conditioner with ceiling vents and zoning for heating and cooling throughout the house, because the bedrooms were sometimes uncomfortable. The daughter's room was west facing and thus the hottest room of the house. According to the father, she was not as acclimatised to hot weather as he was:

> *"[The fan] is enough actually yeah. Given I come from a warm weather country, so for me it's okay. My body adapts to different things, so it doesn't have to be always cool. But when it comes to my daughter - she was born here, she wants always that cold weather, so she always wants a fan – she wanted AC and I said, 'Okay, you need to learn these things as well.' So I gave her the small fan".*

The “main reason” for the planned air conditioner installation, however, was convenience and the prospect of higher resale value. The fans were stored in their original boxes in the garage. The participant explained the tedium of this system, and that his Australian guests seemed more heat sensitive than him:

> *“Because every year it’s a bit of work for me, I need to pack everything, put it back, bring it out. And sometimes when it is really too hot, like when it’s really touching 40, I mean as householders we are okay, but if a guest comes it’s a bit warm because they are coming from outside, so it’s not really comfortable for them. So we thought okay, since the rebate is on we might take advantage of it. Yeah I know we have to spend a bit of extra money, but it’s going to add value to the property as well at a later stage”.*

Figure 34 Average living room temperatures of energy efficient homes on typical summer days with a mean outdoor temperature of 18^{0}C



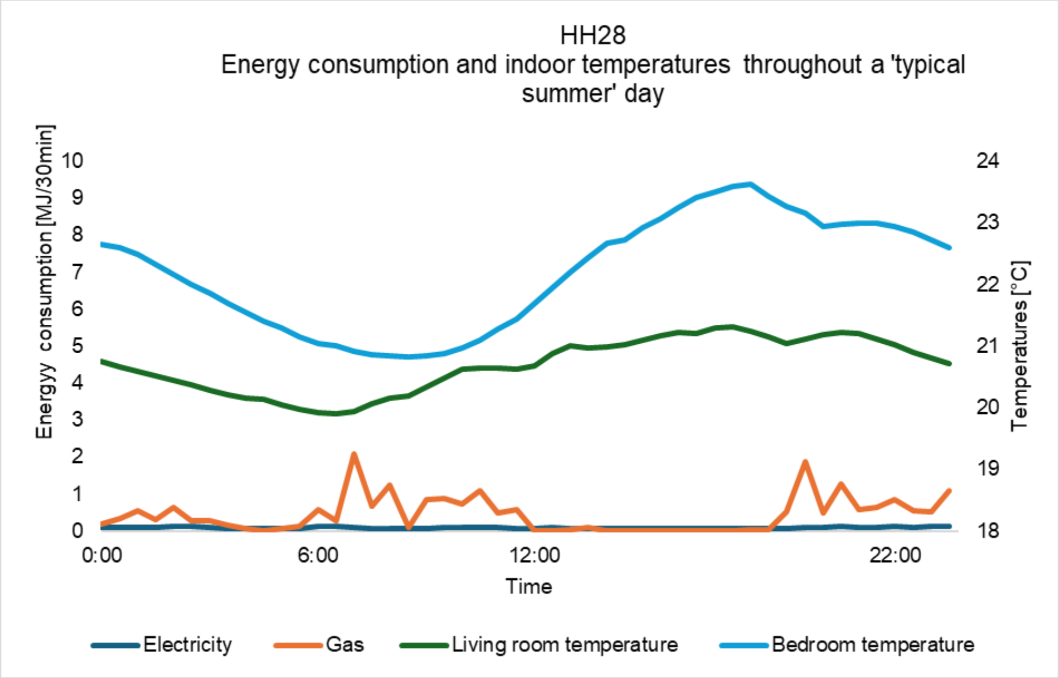
As shown in Figure 34, INT14 and HH28 had relatively low mean living room temperatures among the efficient dwellings during typical summer days. The low indoor temperatures presented by INT14 seemed to reflect the effectiveness of the reportedly large air conditioning unit running in the morning.

HH28 (Figure 35) was a high-income household with single Australian household with 2 adults, two children and one pet, with always someone at home. The 6-star rated house had 4 bedrooms, 2 bathrooms, with ceiling and roof insulation, double glazed windows but no solar panels. The house was equipped with a ducted air conditioning that allowed separate zoning for the lower and upper storeys. The participant’s partner preferred continuous air conditioning at 23°C with consequent high electricity bills, whereas she could have tolerated slightly higher temperatures:

> *“My partner's like, "If you leave it on and you set it at, like, 23 and then you don't turn it on and off, you just have it constantly on, that that saves you energy." Whereas I'm like, "You should turn it off because that will save energy." So, it's on now, set at, like, 22 or 23. So during – like, our electricity bills during summer are ridiculous and our gas because then it's like the heating and the cooling run off the same system, but one's electricity and one is gas. So, in summer our electricity bill is high, and our gas bill is quite low, and then in winter it changes, if that makes sense”.*

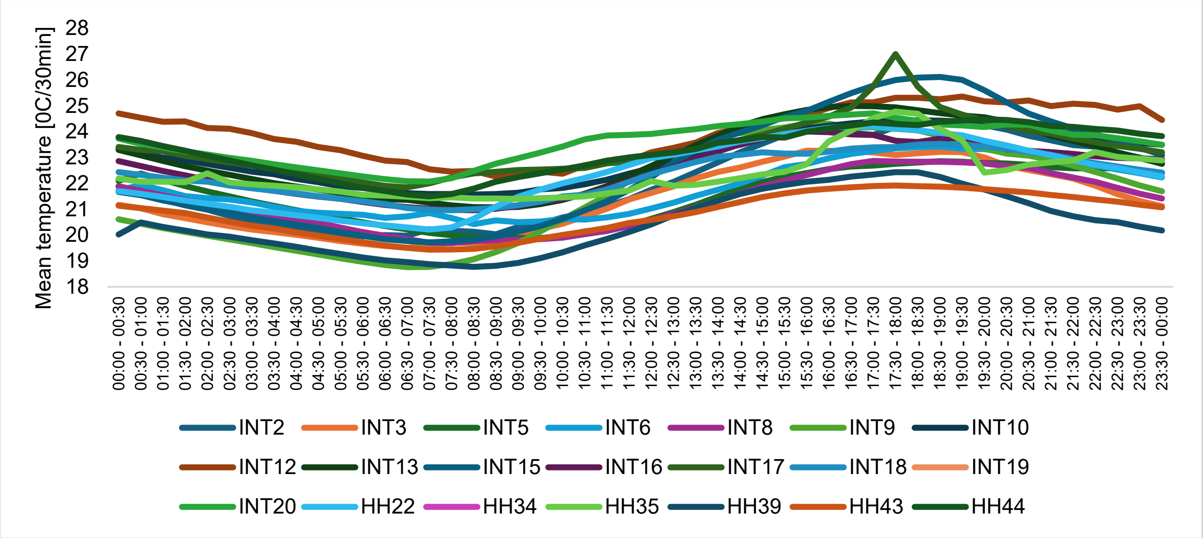
The measured data suggested that the thermostat setting for the living area may have been set at 21°C. The participants stated that "upstairs is always hotter than downstairs", an observation that was supported by the data.

Figure 35 HH28 energy consumption and indoor temperatures throughout a typical summer day



In the non-energy efficient dwellings, INT12 had the highest mean living room temperatures overnight to 8.00 am and was also among the warmest during other times (Figure 36). In this Vietnamese household, the cooling system for the whole house was only used when was very hot and when the children came home from school. At other times, the mother only turned on the standing fan in her study. During the night, the family only used a fan.

Figure 36 Average living room temperatures of non-energy efficient homes on typical summer days with a mean outdoor temperature of 18⁰C



HH39 had the lowest mean living room temperature in the non-energy efficient group of households. HH39 was a mid-income household Australian household with four adults and two pets with always someone at home. The brick house from 2002 had 3 bedrooms, 2 bathrooms, with ceiling and wall insulation, single glazed windows and no solar panels. The house was equipped with an air conditioning and a 25-year-old split system but none of them were used. The air conditioner was considered “a bit noisy” and the participants did not “like that real coldness of an air-conditioner.” They had a ceiling fan in the main bedroom but refrained from using it because they felt “it a bit too noisy.’ The son was using a pedestal fan that may have run all night day before the interview. The participant was concerned about the costs: “I'm not looking forward to my next power bill.” The participant felt that it was “not an overly hot house”. The house was situated close to “the wetlands”, and the householders made use of the cool breezes. The energy consumption and indoor temperatures throughout a typical summer day of HH39 are presented in Figure 37.

Figure 37 HH39 energy consumption and indoor temperatures throughout a typical summer day

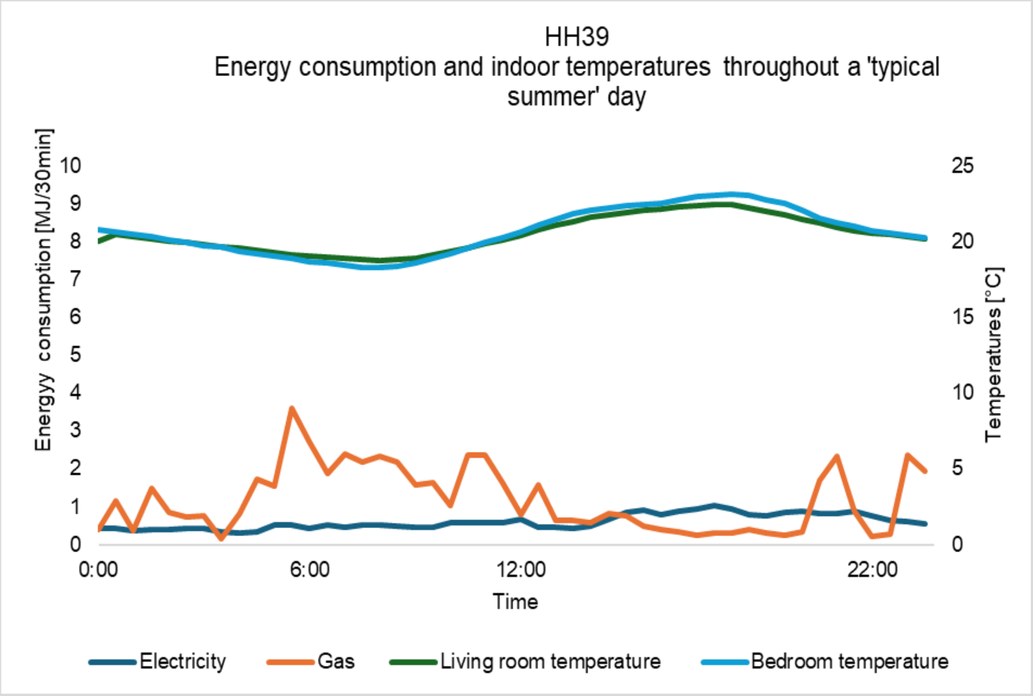
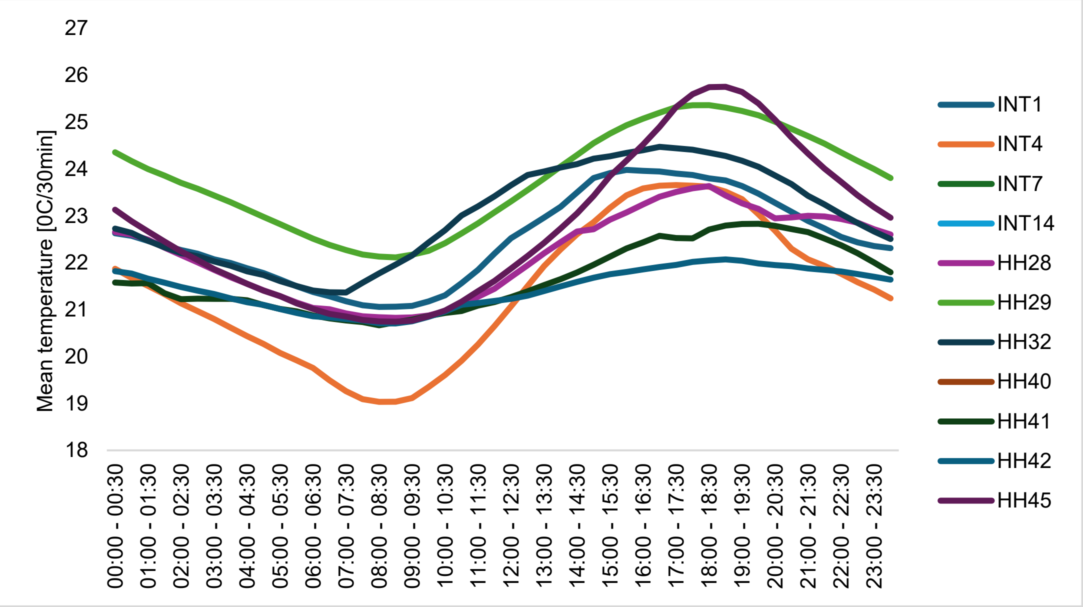


Figure 38 and Figure 39 shows the average bedroom temperatures of energy efficient homes and non-energy efficient hones on typical summer days respectively. The bedroom temperatures in both groups dropped overnight until about 7.30 am. The mean bedroom temperatures of both efficient dwellings group and non-efficient dwelling group rose during the day and afternoon until they peaked in the evening (6.00 pm - 6.30 pm). The peak in the efficient homes was more pronounced than the non-efficient homes. The mean bedroom temperatures of both groups achieved a plateau around 6.00 pm and stayed at this level of warmth until about 7.30 pm - 8.00 pm.

HH29 had the highest mean bedroom temperatures of the efficient dwellings throughout the day during typical summer days. HH29 was a low-income Chinese household with 2 adults with always someone at home. The 6-star rated house had 5 bedrooms, 3 bathrooms, with ceiling and roof insulation, double glazed windows and solar panels. The house did not have a cooling system, and the participant was not concerned about the heat. He thought that in Melbourne the night were cool so that he could "open the door, so the cool air will come in, come like chimney." In addition, he attributed his lack is heat sensitivity to his advanced age. The 65-year old participant said: "I'm in the old age, so I'm not really afraid of hot. But I'm afraid of cold in summer." He felt that it was hotter in the top storey, and on hot days he tended to stay up late because "when it's really hot, I'm not sleepy."

INT4 had generally lower mean bedroom temperatures than other efficient dwellings during typical summer days even though there was no air conditioner in the bedroom. INT4 was a mid-income older Italian couple with one pet with always someone at home. The 5-star rated townhouse had 3 bedrooms, 2 bathrooms, with ceiling but no roof insulation, single glazed windows and solar panels. The house has evaporative cooling, but they couple thought that "with the summers getting more humid, it just doesn't work very well". Instead, they were using a heat pump reverse cycle air conditioner in the main living area. The participant said: "But it's on now, and you can feel the cool breeze around your feet." The participants felt that the bedrooms upstairs were warmer than the ground floor. They had considered but not actually slept in the lounge. They felt more comfortable since they had installed a ceiling fan in the bedroom.

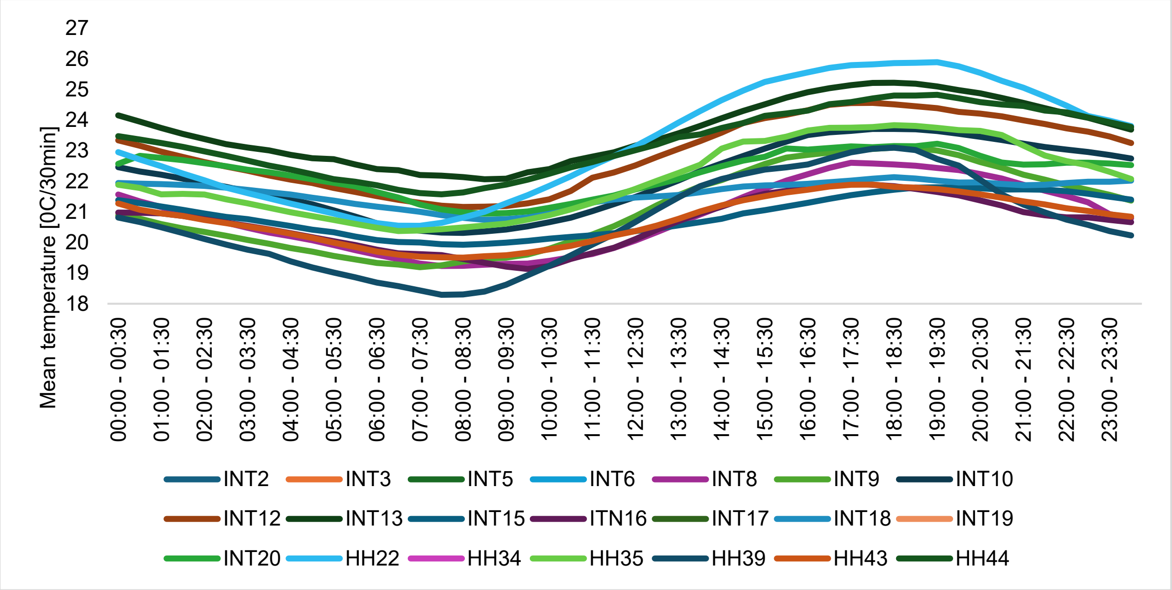
Figure 38 Average bedroom temperatures of energy efficient homes on typical summer days with a mean outdoor temperature of 18^{0}C



In the non-energy efficient dwellings, INT13 had the highest mean bedroom temperatures overnight to noon. INT13 was a high-income Indian couple with a baby with always someone at home. The house, built in 2000, had 4 bedrooms, 2 bathrooms, with ceiling and roof insulation, single glazed windows and solar panels. The couple used roller shutters to “maintain the temperature of the living room” which became “really hot during summer” and standing fans. They only switched on the newly installed evaporative cooling in the master bedroom on very hot days. The couple “more comfortable with the summer than the winter” in Melbourne.

HH39 relatively low mean bedroom temperature. Even though the house had air conditioning, it was seldom used due to its noisiness. The household used natura ventilation and took advantage of the cool breezes from the nearby wetlands to cool the house.

Figure 39 Average bedroom temperatures of non-energy efficient homes on typical summer days with a mean outdoor temperature of 18^{0}C



4.4 SUMMARY

During colder, typical and warmer summer days, energy efficient homes used less gas than energy inefficient homes. However, this observation cannot be generalised to all households, as care and hygiene practices as well as the insulation and gas hot water specifications of homes shaped the range of gas usages. Heating throughout the day to accommodate cold sensitive relatives and a high number of people taking gas-fuelled showers translated into high gas use. Having a very old gas hot water system seemed to explain very high gas usage peaks in the evening. Disconnecting the gas booster of a solar hot water system saved on gas.

Similarly, during colder, typical and warmer summer days, energy efficient homes used less electricity than energy inefficient homes. High electricity usage was largely explained by intensive air conditioning use and inefficient white goods appliances. Many, but not all householders, considered their own electricity generation from their solar panels in their timing of their air conditioner usage.

On average, energy efficiency and energy inefficient homes presented similar indoor temperatures across all outdoor temperatures, however energy inefficient homes seem to have used more gas for heating during colder summer days to achieve the same level of warmth. Relatively high indoor temperatures were explained by a lack of fixed air conditioning. Even though some householders disliked air conditioning because of the noise or feeling of cold draughts, and many people preferred natural ventilation and fans, air conditioning seemed a normal practice in most homes. On average, bedrooms in energy efficient homes were warmer than the living areas during the evening and night, while the bedrooms of the non-energy efficient homes, on average, were colder than the living areas. Householders in energy efficient homes reported that the bedrooms in the upper storey were often warmer than the ground floor areas.

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 31 homes (12 low household size and 19 non-low household size) for summer months. 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, typical summer days and the warmest days. Both groups presented the same daily mean total minimum gas consumption value during coldest and the typical' summer days. The minimum consumption on the warmest days was higher in the non-low household size homes. The low household size group had the same minimum, average and maximum daily mean total gas consumption on the warmest days. This is due to HH29 and HH45, only experiencing an outdoor temperature 28^{0}C. The average daily mean total gas consumption was higher in the non-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=19)			
	Min	Ave.	Max	Range	Min	Ave.	Max	Range
15	1	63	261	260	1	77	342	341
18 ('typical' summer day)	0	21	119	119	0	44	177	177
28	4	4	4	0	25	52	73	48

Figure 40 presents box plots comparing the daily mean total gas consumption between the groups on days with a daily mean outdoor temperature of 18^{0}C. The box plot presents gas consumption data of 31 homes (12 low household size and 19 non-low household size) for the summer months. The interquartile range of the non-low household size group is slightly higher (35 MJ) than the low household size group (34 MJ). In addition, the non-low household size group showed a higher dispersion of mean gas consumption than those for homes in low household size group.

For the low household size group, INT7 had the lowest daily mean gas consumption (2 MJ/day). INT7 was a single retiree living independently as a self-declared "recluse", spending most of his time, "95 per cent", in his efficient, three-bedroom, three-bathroom home. INT7's low gas consumption was motivated by cost, "Not because of the climate change problem." INT7's hot water was heated by a solar system with a gas booster; however, to save energy costs, the gas booster was turned off to save gas usage. Additionally, this participant cooked with a gas cooktop, which he intended to "replace with an induction cooktop as soon as the prices get to what I consider a reasonable level." INT7 commented he would "like to eliminate" gas because of "cost."

On a 'typical' summer day, INT5 had the highest daily mean gas consumption (47 MJ/day) of the low household-size homes. INT5 was a two-person, four-bedroom household—a woman and her disabled daughter—which meant that at least one person was home most of the week, and both residents were home at night. Despite being the highest gas consumer in the low household-size home, INT5 was motivated to decrease gas consumption due to "cost" and concern for the environment. INT5 only used their gas cooking appliances when cooking food that was not conducive to cooking in a microwave, pressure cooker or air fryer. This participant wanted to transition to an induction stove but was prevented due to cost. A gas booster solar system generated hot water.

INT 18 had the lowest daily mean gas consumption (6 MJ/day) of the non-low household size homes on a ‘typical’ summer day. This family of 4 occupied their three-bedroom, one-bathroom, non-efficient home consistently during the week as residents primarily work from home. In this household, gas was used for hot water and cooking; however, the household was motivated to “get rid of gas” because they wanted to stop paying “the service charge, [and] the network fees.” This household intended to replace the instant gas hot water service and ducted gas heating once their solar system was installed, and they plan to upgrade their oven to induction hotplates.

HH40 had the highest daily mean gas consumption (82 MJ/day) of the non-low household size homes on a ‘typical’ summer day. Since the winter interviews, the number of residents in the HH40 household had increased from 2 to 3 with the addition of a visiting older relative from overseas. HH40’s high gas consumption may be explained by the increase in gas due to the presence of the visitor: more gas was used in their storage hot water system, more cooking occurred with gas hot plates and the use of their gas ducted heating increased to ensure the house temperature was 24°C degrees. The use of the heating was attributed to the visiting relative who was not used to the cold. Even though this was considered the summer period, Melbourne experienced a few cold days in December. HH40 commented when using the gas heating, “We don’t switch it off (the heater), always leave it at like 24”. HH40 noted that the ducted gas heater would be replaced in the same month of the interview with a heat pump financed through a government support program. HH40 also mentioned that they were “thinking of going to induction [cooking]”, as it was “a little bit less of maintenance in terms of from a cleaning point of view”.

The median consumption of gas in the low household size group was lower than that of the non-low household size group. The low household size homes consumed less gas than the non-low household size homes. Both groups of data appear to be right skewed. The overall difference in gas consumption between non-low and low households was influenced by household size and the corresponding energy demands. Additionally, low-household-size participants were more likely to have high-performance gas hot water systems, with 64% of these households using solar hot water systems with gas boosters, compared to only 10% among non-low households. Furthermore, 67% of low household size participants belonged to the "Moving to all-electric" archetype, reflecting their proactive approach to reducing gas consumption. In contrast, only 35% of non-low-household participants fell into this category, with 50% categorised as "Energy agnostic."

Figure 40 Box plot for mean gas usage on days with a daily mean outdoor temperature of 18^{0}C

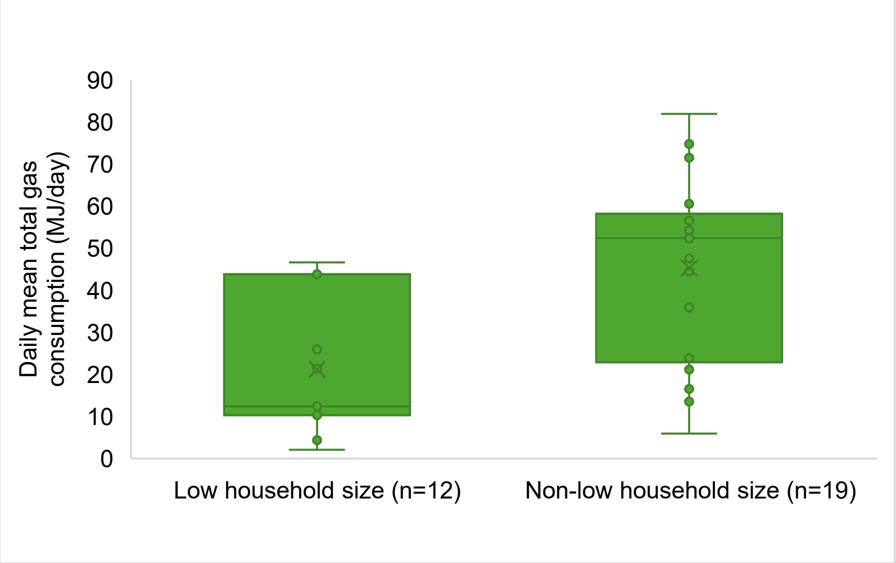


Figure 41 shows the comparison of the daily mean total gas consumption for the low and non-low household size groups in relation to the daily mean outdoor temperatures. On average, the daily mean total gas consumption in both low and non-low household size groups presented a negative association with the mean outdoor temperatures (low household size: 15-28 ^{0}C and non-low household size: 15-27 ^{0}C). 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 lower during the coldest days in summer. The difference became wider at the warmest temperature. Part of the difference is no doubt due to personal (as opposed to household) energy use, but the data suggests that some of the difference is also due to energy archetypes. Fifty percent of non-low households were categorised as the energy agnostic archetype compared with 8% of low households; 7% of non-low households compared with 67% of non-low households were categorised as the Moving to all-electric archetype and 67% of non-low households compared with 15% of low households were categorised as the Entrenched in gas archetype.

Figure 41 Comparison of daily mean total gas consumption at daily mean outdoor temperatures - low/non-low household size

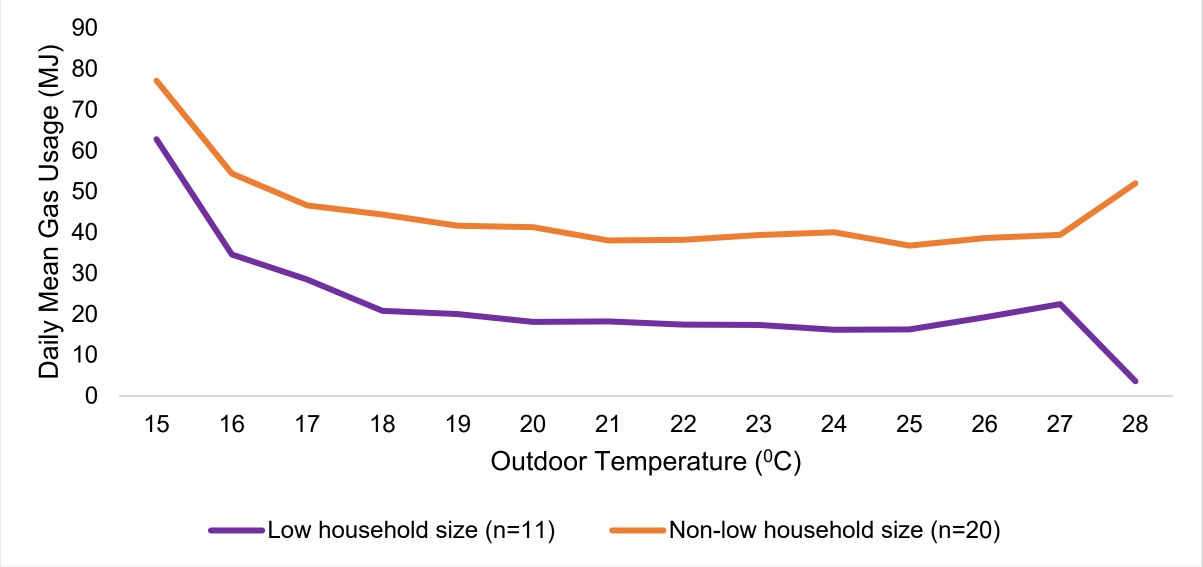


Figure 42 compares the diurnal variations in average half-hourly gas consumption on ‘typical’ summer days of low and non-low household size homes. The distribution of half-hourly gas use in both groups is bi-modal. The evening peak in both the low household size group and non low household size group of homes are higher than its morning peak. The low household size group of homes exhibit a higher peak in the morning starting from 6.00 am to 10.00 am. The average half-hourly gas consumption appears to be higher in the non-low household size group.

Low household size: INT5 has a higher gas consumption 1.00 am to 4.30 am and 6.30 am to 8.30 am. INT6 has a higher gas consumption from 8.00 am to 9.00 am. INT16 has higher consumption from 10.30 am to 3.30 pm. Notably, INT5 limited gas cooking due to its impact on indoor heat, adversely affecting her daughter's health. INT6 and INT2 has higher gas consumption in the evening. Further, INT4 had the highest gas consumption from 10.00 PM to 11.30 pm. INT2 had the lowest gas consumption from midnight to evening. INT4 restricted gas usage for environmental reasons, though gas was initially installed for its “resale value.” Despite these exceptions, most participants preferred cooking with gas and did not curtail their daily usage, even when concerned about costs. Morning gas spikes, in contrast, were linked to bathing activities. HH45 also had the lowest gas consumption in the low household size group. For participants from low-household-size groups, gas consumption was primarily associated with cooking and hot water use. Gas usage for cooking was common throughout the day due to gas cooktops, except for INT2, whose household did not have any gas cooking appliances, relying solely on gas for heating.

Non low household size: Among non-low-household-size participants, gas was similarly consumed for cooking, hot water, and heating. HH44 has the highest gas consumption during the early morning period 1.30 am to 4.30 am. INT9, HH39 and INT4 had higher gas use from 5.30 am to 7.30 am. HH35 had higher gas use around 10.00 am to 11.00 am. INT10, INT19 and HH34 had higher gas use peaks in the evening. INT 18 presented a lower gas use in the non-low household group. INT18, as discussed earlier, had transitioned to an all-electric household for ethical reasons. Like their low-household counterparts, gas usage spikes among non-low households were also linked to cooking, hot water, and heating during cooler summer days.

Figure 42 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 18^{0}C

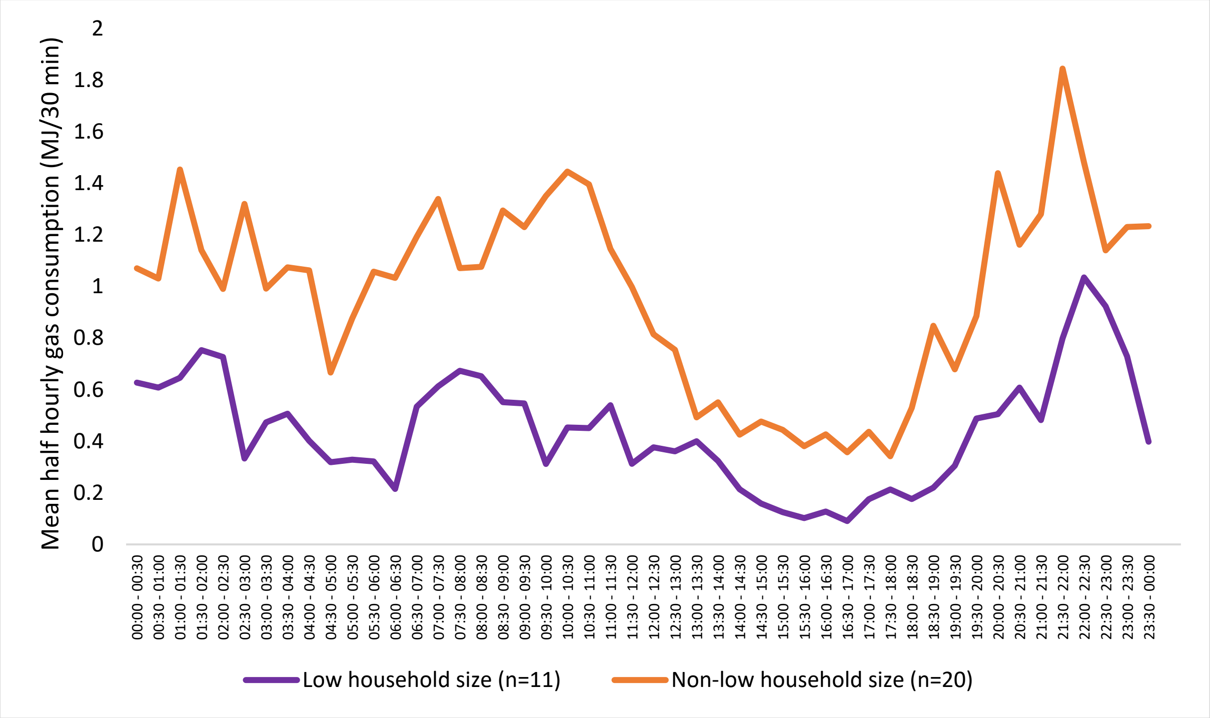
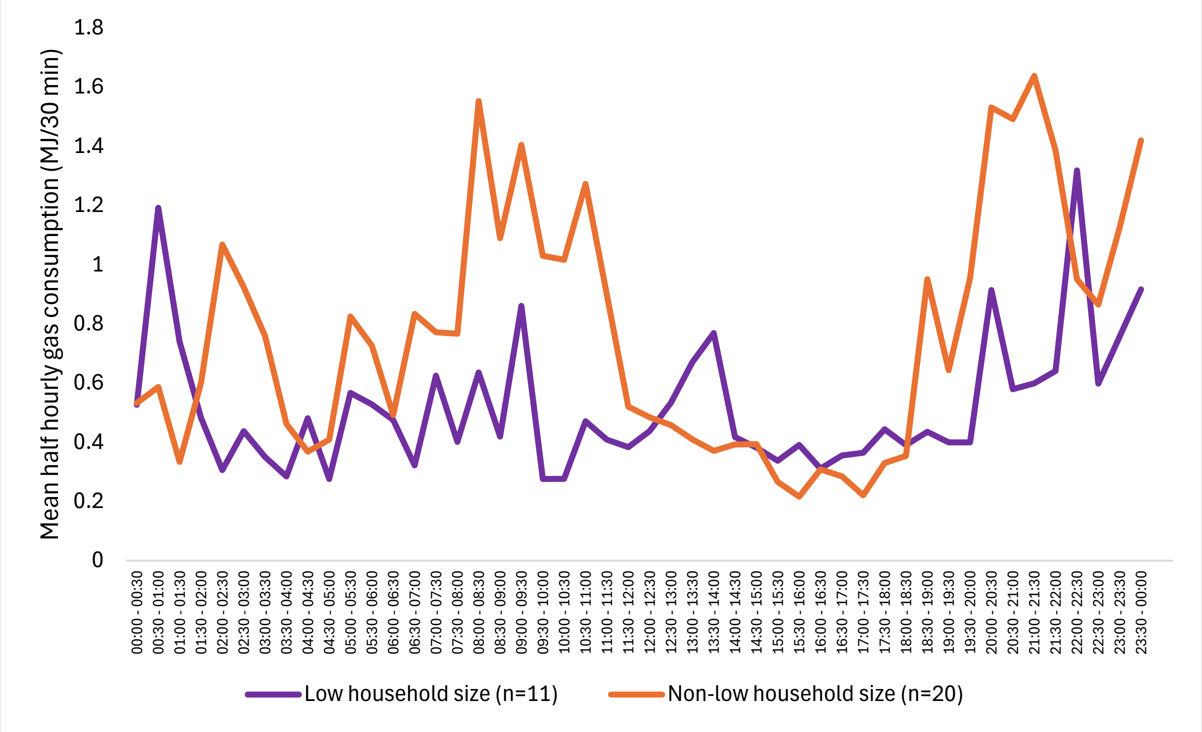


Figure 43 compares the diurnal variations in average half-hourly gas consumption on days with a daily mean outdoor temperature of 27^{0}C, comparing low and non-low household size dwellings. Visual analysis shows that there is a minor increase in the gas use in both groups in the morning compared to typical summer days. The distribution of half-hourly gas use during hot days with a daily mean outdoor temperature of 27^{0}C is similar to that on typical summer days. The diurnal variations are bi-modal and in both groups with more pronounced peaks in the non-low household size group. However, the night time gas use in the non-low household size group is lower during these hotter days, presumably because no space heating occurred to keep cold-senstive household members warm.

Figure 43 Comparison of diurnal variations of mean half-hourly gas consumption in low and non-low household size dwellings on days with a daily mean outdoor temperature of 27^{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 31 homes (12 low household size 19 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 and the warmest day was higher in the non-low household size group. The difference in the average mean electricity consumption on a typical summer day between the two household sizes is 2MJ/day, which is low. Also, the difference between the ranges of the two groups on a typical summer day is quite low (1MJ/day). However, the maximum electricity consumption on a typical summer day is the same in both groups (63 MJ/day). At the warmest temperature the non-low household size displays a significantly higher range (57 MJ/day) compared to the low household size, which has a much narrower range of 8 MJ/day. A significantly higher range at the lower summer temperature was also noted between the low households, with a range of 57 MJ/day, and non-low households, with a range of 128 MJ/day.

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
15	11	22	57	46	4	24	128	124
18 ('typical' summer day)	4	19	63	59	3	21	63	60
28	8	12	16	8	6	45	63	57

The highest total daily electricity consumption in the low householder size group, at 92 MJ, was recorded at INT6 on a day with a mean outdoor temperature of 27°C. While indoor temperature data was unavailable, an interview with one resident suggested that this high usage was due to the dwelling patterns of the two occupants. One occupant was active during the day, while the other was active at night, resulting in a consistently elevated energy peak between 12.00 pm and 12.00 am. The house featured an open-plan layout and weatherboard construction with single-glazed windows. It was classified as not energy efficient. Cooling was provided by a split-system air conditioning unit, activated when indoor temperatures reached 24°C to lower the temperature to 23°C. The system remained operational whenever the residents were home, with the internal thermostat maintaining the desired temperature, 23°C or less. The cooling system was only turned off when the house reached 23°C, or the residents went out. Additionally, portable fans were used to distribute cool air into the bedroom at night, and if the house temperature was below 24°C, the mechanical cooling was switched off. Ceiling fans were used in the bedroom at night to maintain comfort. The majority of cooking within this household was using electric appliances.

The lowest daily total electricity consumption in low household size was presented at INT4 (4 MJ) when the daily mean outdoor temperature was 18^{0}C. Despite the presence of an additional household member (a visiting relative), this energy-efficient home, with a solar panel system, only used the reverse cycle air-conditioning to cool the ground floor living area “after sunset if it’s a particularly humid day”, noting that “as far as just temperature is concerned, it’s simply not a problem downstairs.” Ceiling fans in the bedroom are used at night when the indoor temperature increases. When using their air conditioning, this household set it to 24°C on an 18°C day. The household's indoor air temperature did not exceed 22.9°C, leaving electricity consumption for cooking and hot water. To decrease electricity consumption, this household washed at “one o'clock” during summer and switched their cooking appliance to electric; however, they have retained a gas stove top, as discussed in the preceding section. On a day of 27°C, this household's highest peak in mean energy consumption correlates with the highest peak in bedroom temperature of 31°C at 4 pm. The bedroom temperature decreases after 9.00 pm to 24.5°C, reflecting the householder's comments that the air conditioning unit is set to 24°C. These energy efficiency measures allow them to save on their electricity consumption and maximise the energy generated by their solar panels.

In the non-low household size group, despite the home being energy efficient, INT14 had the highest total daily electricity consumption, 195 MJ, when the daily mean outdoor temperature was 26°C. INT14 had the second largest household, with six residents – 2 adults and four school-aged children; electricity consumption peaked between 6.00 am and 8.00 am, remaining relatively negligible until it peaked again between 3.00 pm and 5.30 pm, with a slow decline in use until 9.00 pm. This energy use reflects the pattern of household occupation: “We’re out of the house during school times, so we’re out of the house from about quarter past 8.00 to about quarter to 4.00 daily during school term.” Energy is consumed through washing, evaporative cooling and cooking and is offset by solar panels. To decrease energy use, cooling is used “only on days that we know it’s going to be hot, like 30 plus”, and it is turned on “in the morning, so when it’s still cool in the house.” However, the participants recognised that they needed to open windows when the evaporative cooling was on to reduce the internal humidity.

The lowest daily total electricity consumption was HH32 (2 MJ), when the daily mean outdoor temperature was 16^{0}C. Energy consumption associated with cooling this household was low as all members felt “Melbourne doesn’t require much cooling. There are only two months of hot summer, and even half of that, you don’t feel like air conditioning.” On hot days, this household believes if air conditioning is left on for too long, it leaves them feeling uncomfortable. Decisions about cooling are based on comfort rather than costs, as the solar panel installed in this house offsets the electricity costs. As this household cooks with a gas oven and stove top, minimal energy is used in this household activity.

The Figure 44 presents a box plot comparing the daily mean total electricity consumption between the low household size and non-low household size groups when daily mean outdoor temperature was 18^{0}C. The interquartile range of the low household size (11MJ/day) is lower than the non- low household size group (15MJ/day). Further, the median electricity consumption of the low household size group (15 MJ/day) is lower than the non-low household size group (21MJ/day). The non-low household size group shows a higher dispersion of mean electricity consumption than the low household size group. Both distributions are positively skewed.

Figure 44 Box plot for mean electricity usage on days with a daily mean outdoor temperature of 18⁰C

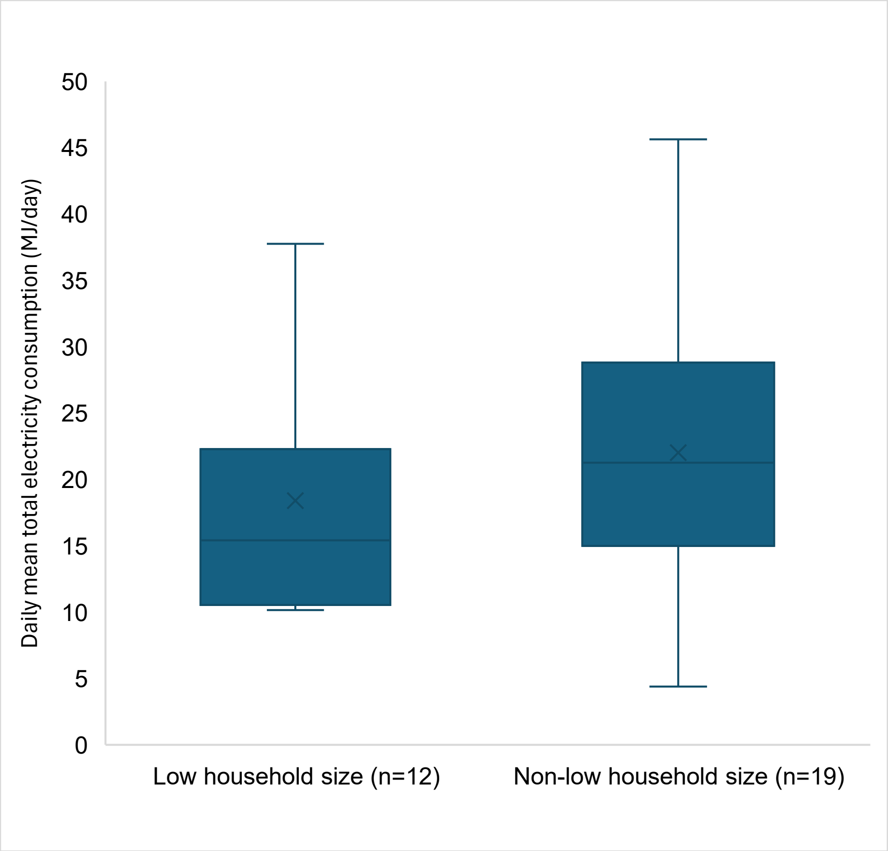


Figure 45 shows the comparison of the daily mean total electricity consumption between the low household size and non-low household size groups in relation to the daily mean outdoor temperatures.

The visual analysis of the graph reveals that the daily mean total electricity consumption in the low household appeared to have been lower than those in non-low household size homes across all outdoor temperature levels. The daily mean total electricity consumption in non-low household size group presented a positive association between 16-17°C, 18-21°C, 22-24°C, 26-26°C, and 27-28°C mean outdoor temperatures. The daily mean total electricity consumption in non-low household size group slightly drops at 15-16°C, 17-18°C, 21-22°C, 24-25°C and 26 -27°C.

The daily mean total electricity consumption in the low household size group presented a positive association between 16-19°C, 22-23°C and 24-25°C mean outdoor temperatures. The daily mean total electricity consumption of the low household size group had a negative association 15-16°C, 19-22°C, 23-24°C, and 25-28°C. The difference in daily mean total electricity consumption between the two groups appeared to be smaller during colder summer days. However, during warmer temperatures, the difference in daily mean total electricity consumption between the two groups is much wider. The drop in electricity consumption at 28°C for low household size is due to homes HH29 and HH45, which have low electricity use and only experienced an outdoor temperature of 28°C.

Figure 45 Comparison of daily mean total electricity consumption at daily mean outdoor temperatures - low/non-low household size

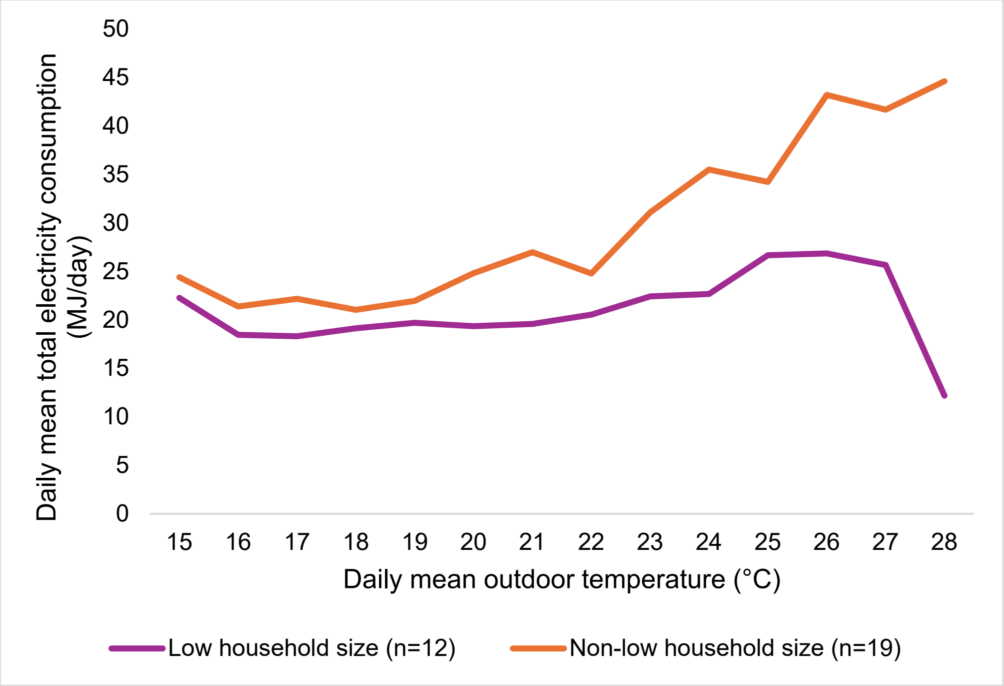


Figure 46 compares the diurnal variations in average half-hourly electricity consumption on 'typical' summer day of the low and non-low household size groups. The distribution of electricity use in both groups is bi-modal in both groups with the second, higher peak in the afternoon. The average electricity consumption appears to be higher in the non-low household size at all times except 6.30 am -10.30 am. The average electricity consumption peaks are more pronounced in the non-low household size group from 6.00 pm to 9.30 pm. In the low household size group, the peaks are more pronounced from 6.00 pm to 9.00 pm in the evening.

Low household size: INT17 showed a higher electricity use in the morning 8.00 am to 9.30 am and 3.00 pm to 4.00 pm in the afternoon. INT17's resident was not home during the day, hence the greater use of electricity before and after work hours. The low energy consumption aligns with the absence of mechanical air conditioning. INT6 showed a higher electricity use from midnight to early morning and 5.00 pm to 10.00 pm, which aligns with behavioural patterns in the household, as discussed in the preceding section. INT20 presented the lowest electricity use from 7.30 pm to early morning, 5.30 am, resisting using air conditioning at night as it "would be intense to sleep with aircon on." INT1, INT7 and HH45 presented the lowest electricity from 8.00 am to 5.00 pm. All three of these households cited rarely using their air conditioning as their homes, despite only INT7 and HH45 being categorised as energy efficient due to the perception that it is unnecessary and their home remaining cool enough for the residents to remain comfortable during summer.

Non-low household size: HH34 consumed the most electricity during the following periods: midnight to 1.00 am, 1.30 am to 7.00 am, 5.30 pm to 6.30 pm, 7.30 pm to 8.30 pm, 9.00 p.m. to 9.30 pm, and 10.30 pm to midnight. This household is all-electric, which explains the increased energy consumption compared to other non-low households. Nighttime use of electricity can be explained given the use of the evaporative cooling unit, which, despite being rarely used only when "it's really hot throughout the night, it will stay on at night and get turned off the next morning." INT18 showed the highest consumption from 6.30 pm to 9.30 pm. The house stays cool by only using evaporative cooling on days over 38°C. Most cooking is done in the gas oven, so the increase in temperature is attributed to the electricity use after work and school in this home of three people.

INT19 showed a higher electricity use from 8.30 am to 4.30 pm. In this household, residents are home during the day despite being retired, one adult works from home, and as the house heats up very quickly on a "normal" summer day, the split system air conditioning is switched on and off by the residents throughout the day based on their perceived conformance level. The units (one in the lounge and two in the study to manage the size of the room) are set at 18 degrees: “we don't run it full-time, we just run it long enough to cool the temperature, and then wait for the heat to build up, and then switch it back on again.” In addition to the air conditioning unit, fans are switched on to “spread cool air” throughout the house. In this household, there is no air conditioning in the bedrooms.

HH28 had the lowest electricity consumption from midnight to early morning. This household uses ducted electric cooling during the day and portable fans when the outdoor temperature reaches 25°C. Room cooling vents are opened and closed across this two-level residence as required. The indoor temperature varies between levels in this story household, with the upstairs rooms hotter than those downstairs. HH32 had the lowest electricity consumption from 6.00 am to 6.30 pm as they preferred not to use air conditioning, as discussed in the preceding section. INT 10 presented low electricity consumption from 9.00 am to 5.00 pm as residents are not home during the day. HH28 and INT12 presented low electricity consumption from 7:00 pm to midnight. Both households only use cooling when it is over 30^{0}C and prefer to use it as little as possible, defaulting to fans if required.

All households use electricity for cooking; however, air conditioning and fans vary based on personal preferences. A review of the qualitative data suggests that the higher electricity consumption in non-low households compared to low households is most likely attributed to differences in the resident's preferred cooling preferences, behaviours and technology choices as the outdoor temperature rises above 25^{0}C. However, low households rely more heavily in summer on air conditioning to create a comfortable indoor air temperature, as reflected in the increase in electricity use in the afternoon when outdoor temperatures rise. This may be attributed to a higher percentage of non-efficient homes in the non-low house category, 30%, compared with 42% in the low household category. No identifiable relationships exist between electricity consumption and daily home occupancy patterns.

Figure 46 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 18^{0}C

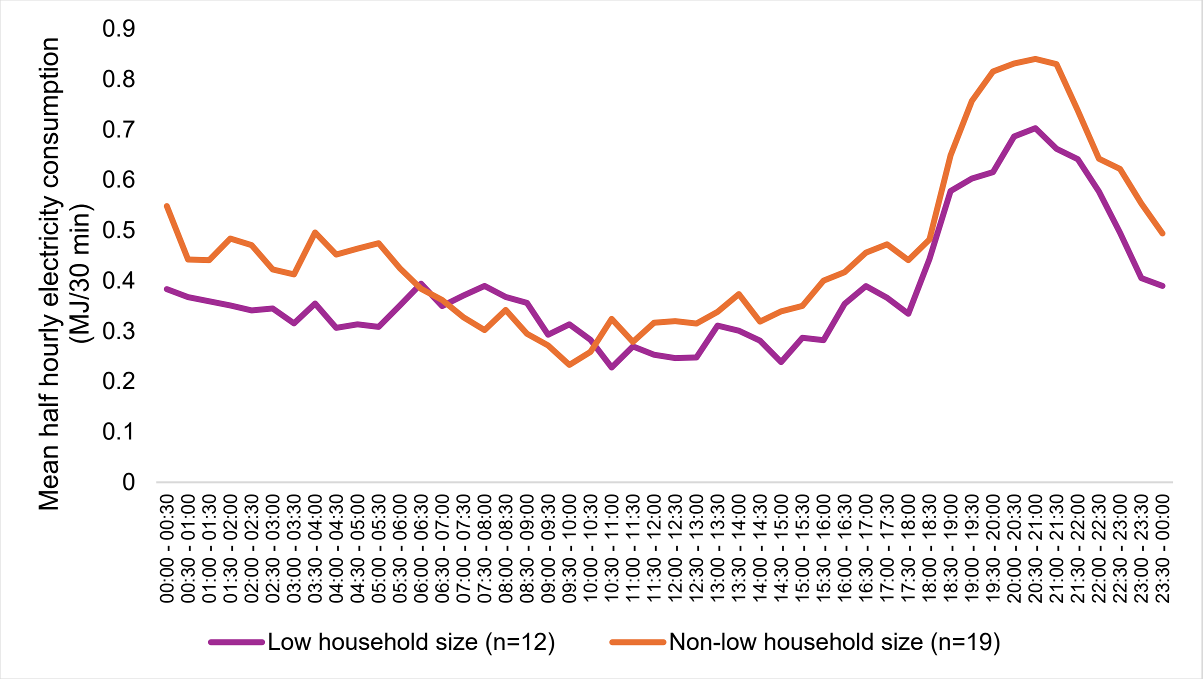
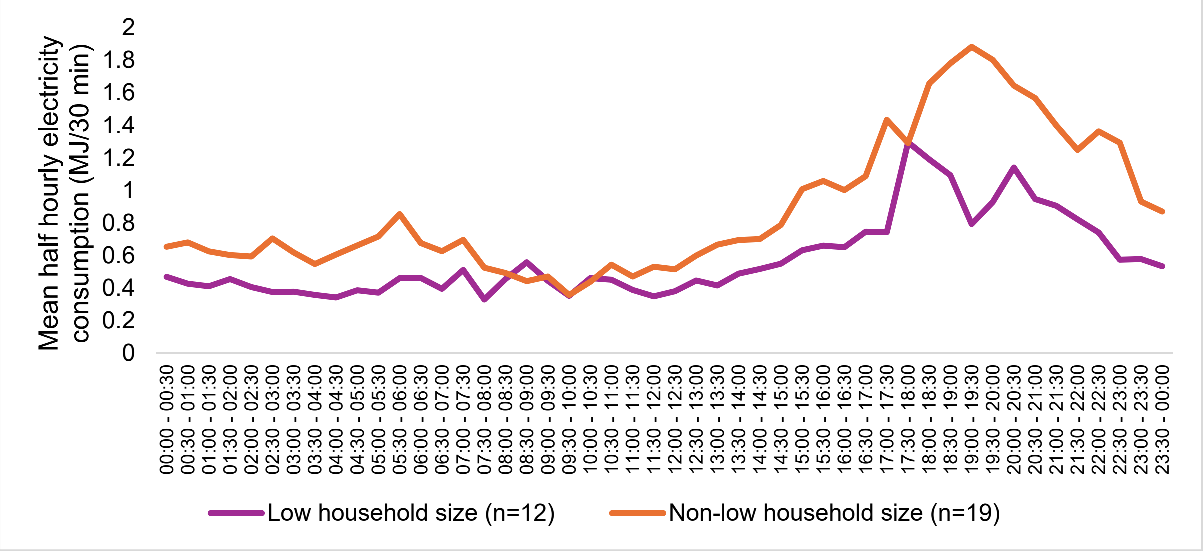


Figure 47 compares the diurnal variations in average half-hourly electricity consumption on days with a daily mean outdoor temperature of 27^{0}C, comparing low household size and non-low household size. Visual analysis showed that there is an increased electricity use in both groups during the evenings on days with daily mean outdoor temperature of 27^{0}C.

Figure 47 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 27^{0}C



5.3 INDOOR TEMPERATURES

This section presents the indoor temperature data for low and non-low household sizes. Living room temperature data was available for 11 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 in summer was higher 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 typical summer days. The maximum living room temperature of the low household size on the warmest days is higher than the daily mean outdoor temperature.

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=11)			Non-low (n=18)		
	Min (°C)	Max (°C)	Range (°C)	Min (°C)	Max (°C)	Range (°C)
15	19	23	4	18	24	6
18 (‘typical’ summer day)	19	27	8	19	27	8
28	20	29	9	21	28	7

The bedroom temperature data was available for seven low household size homes and 15 non-low household size homes. The daily mean bedroom temperature range on the coldest days was same in both the non-low household size homes than in the low household size group (Table 11). Both groups had the same minimum temperatures on the ‘typical’ summer days. However, during the warmest days, the minimum temperature of the low household size group was zero.

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=7)			Non-low (n=15)		
	Min (°C)	Max (°C)	Range (°C)	Min (°C)	Max (°C)	Range (°C)
15	17	21	4	18	22	4
18 (‘typical’ summer day)	19	26	7	19	25	6
28	30	30	0	22	27	5

Figure 48 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 lower than the non-low household size group in the daily mean living room temperatures. Further, the dispersion of the daily mean living room temperatures on days with a daily mean outdoor temperature of 18^{0}C is lower in the low household size group than the non-low household size. Regarding the daily mean bedroom temperatures, the low household size group shows a similar interquartile range (2^{0}C) as the interquartile range of the non-low household size group. However, the dispersion of bedroom temperature in the low household size group is slightly higher than that of homes in the non-low household size group. As shown in Figure 48, the daily mean living room temperatures of both groups are positively skewed to the right.

Figure 48 Box plot for mean indoor temperature on days with a daily mean outdoor temperature of 18^{0}C

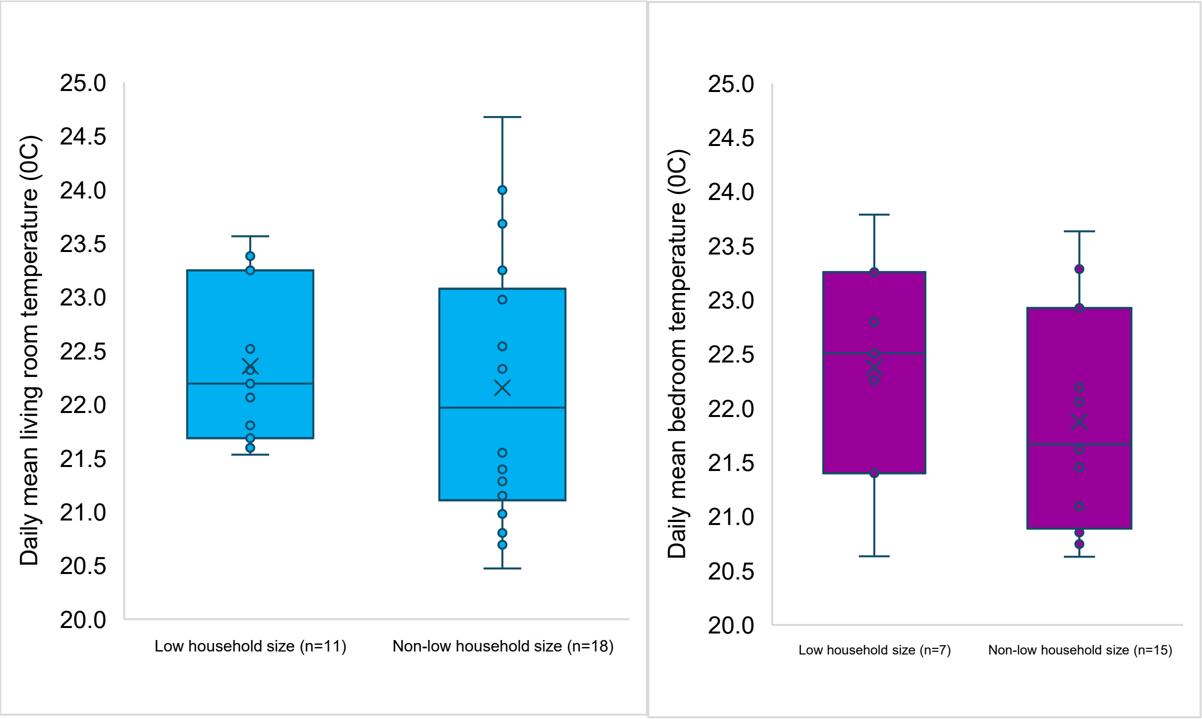
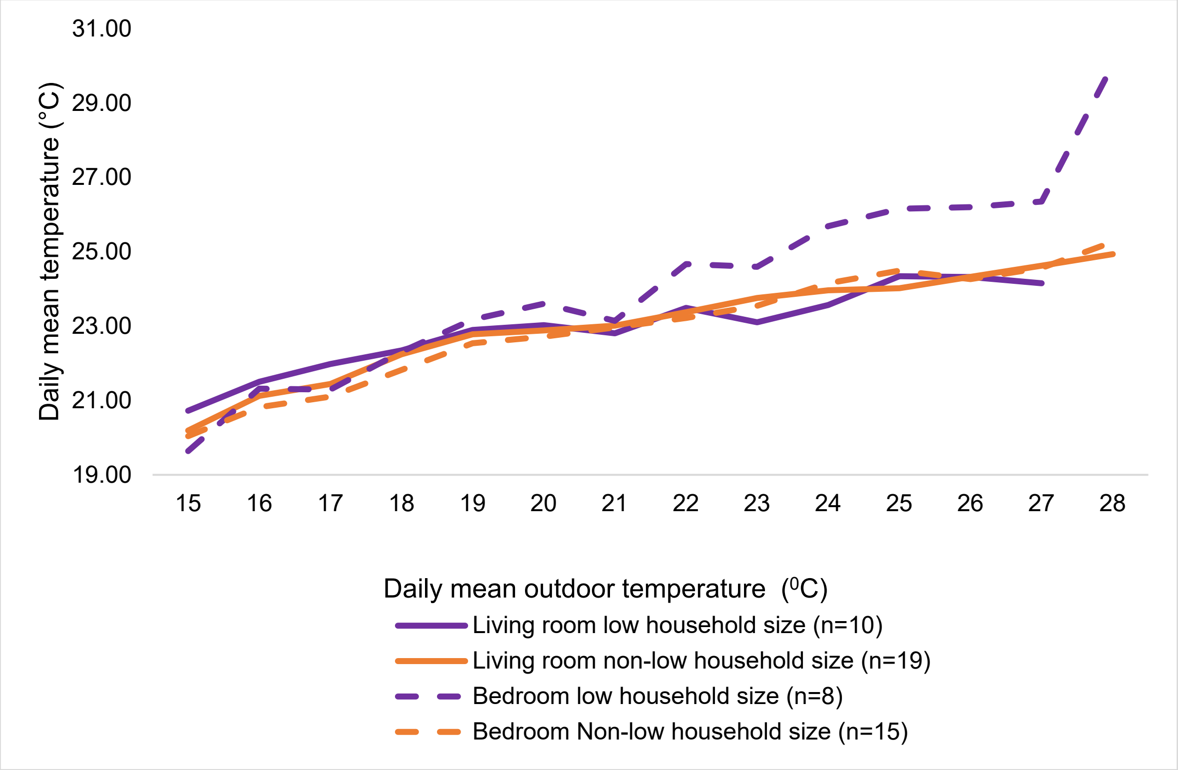


Figure 49 shows the comparison of the average daily mean living room temperatures and bedroom temperatures for the low and non-low household size groups in relation to the daily mean outdoor temperatures. On average, the mean daily living room temperatures and bedroom temperatures in both low and non-low 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 temperature levels 22^{0}C-

24^{0}C and 27^{0}C-28^{0}C. The mean indoor bedroom temperatures in the non-low household size appeared to be lower than those in low household size at all outdoor temperatures. Further, not much difference was observed in the living and bedroom temperatures of both groups at typical summer days when the outdoor mean temperature was 18^{0}C.

Figure 49 Comparison of daily mean indoor temperature at daily mean outdoor temperatures - low/non-low household size



The living room temperatures in low household size group are till noon and evening (after 7.30 pm) than the non-low household size group.

These trends may be explained in relation to cooling behaviours discussed by the residents of these households. Interviews identified that:

Residents of low size households consumed less energy because they had a more conservative approach to the use of mechanical cooling, especially in bedrooms overnight, possibly explaining the increase in room temperature when outdoor temperature increases compared with the living room.

The low and non-low size households have relatively similar living temperatures; however, only 33% of non-low households were energy-efficient homes compared with 44% of the low household participants, possibly explaining the lower average temperature between 22 and 25 degrees outside.

In the low household size group, INT20 had higher mean living room temperatures as this resident avoided turning on the air conditioning, preferring to keep their blinds lower during the day and flushing the hot air out of the house at night when the temperature dropped. Interestingly, this resident is not always at home during the week. INT17's living room temperature peaked from 5.00 pm to 8.00 pm, which can be explained by a lack of insulation and no air conditioning, allowing the home to heat up during the day. HH22 and INT7 had lower living room temperatures in the low household size group, possibly resulting from air conditioning use during the day.

HH40 had the highest mean living room temperatures of the non-low household size group during typical summer days, as this resident had no air conditioning. HH39 had lower mean living room temperatures than the low household size group during typical summer days despite not being at home or using the air conditioning unit, relying on the sea breeze to cool the home, described as “pretty cool” most of the time.

The bedroom temperatures in both groups drop overnight until about 8.00 am. The mean bedroom temperatures of both groups rise during the day and afternoon until they peak in the evening around 6.00 pm. The low household size group has a slightly higher bedroom temperature than the non-low household group throughout the day.

HH29 and HH22 had higher mean bedroom temperatures of the low household size group throughout the day during typical summer days. Residents commented that bedrooms were hotter than the living room because they were located on the second storey of the homes. HH45 had a peak in the evening on typical summer days. INT 16 and INT4 had lower mean bedroom temperatures of the low household size group during typical summer days. Both homes were energy-efficient brick homes on a concrete slab with heavy curtains.

In the non-low household size group, INT13, HH32, and HH44 had the higher mean bedroom temperatures throughout the day. These three households did not believe Melbourne summers got hot and used their air conditioning only when the temperature outside reached the high thirties. Residents of these households were all CALD families with an Indian background.INT22 had the highest from noon to late evening. INT8 and temperatures HH39, and HH43 had lower mean bedroom temperatures (non-CALD homes). INT8 and INT43 use their air conditioning overnight to cool their bedrooms, while INT39 cools the bedroom passively by opening a window to allow in the sea breeze.

In the non-low household size group, the bedroom temperatures appear to be lower than the living room at all times throughout the day. However, in the low household size group the bedroom temperature is bit higher overnight and 2.00 pm and 8.30 pm.

Figure 50 present the diurnal variations of mean living room and bedroom temperature on ‘typical’ summer days with a daily mean outdoor temperature of 18°C in low and non-low household size groups respectively. The living room temperatures in both groups drop overnight until about 7.00 am. The mean living room temperatures of both groups rise during the day and afternoon until they peak in the evening around 6.00 pm. The living room temperatures in low household size group are till noon and evening (after 7.30 pm) than the non-low household size group.

These trends may be explained in relation to cooling behaviours discussed by the residents of these households. Interviews identified that:

Residents of low size households consumed less energy because they had a more conservative approach to the use of mechanical cooling, especially in bedrooms overnight, possibly explaining the increase in room temperature when outdoor temperature increases compared with the living room.

The low and non-low size households have relatively similar living temperatures; however, only 33% of non-low households were energy-efficient homes compared with 44% of the low household participants, possibly explaining the lower average temperature between 22 and 25 degrees outside.

In the low household size group, INT20 had higher mean living room temperatures as this resident avoided turning on the air conditioning, preferring to keep their blinds lower during the day and flushing the hot air out of the house at night when the temperature dropped. Interestingly, this resident is not always at home during the week. INT17’s living room temperature peaked from 5.00 pm to 8.00 pm, which can be explained by a lack of insulation and no air conditioning, allowing the home to heat up during the day. HH22 and INT7 had lower living room temperatures in the low household size group, possibly resulting from air conditioning use during the day.

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The bedroom temperatures in both groups drop overnight until about 8.00 am. The mean bedroom temperatures of both groups rise during the day and afternoon until they peak in the evening around 6.00 pm. The low household size group has a slightly higher bedroom temperature than the non-low household group throughout the day.

HH29 and HH22 had higher mean bedroom temperatures of the low household size group throughout the day during typical summer days. Residents commented that bedrooms were hotter than the living room because they were located on the second storey of the homes. HH45 had a peak in the evening on typical summer days. INT 16 and INT4 had lower mean bedroom temperatures of the low household size group during typical summer days. Both homes were energy-efficient brick homes on a concrete slab with heavy curtains.

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In the non-low household size group, the bedroom temperatures appear to be lower than the living room at all times throughout the day. However, in the low household size group the bedroom temperature is bit higher overnight and 2.00 pm and 8.30 pm.

Figure 50 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 18^{0}C

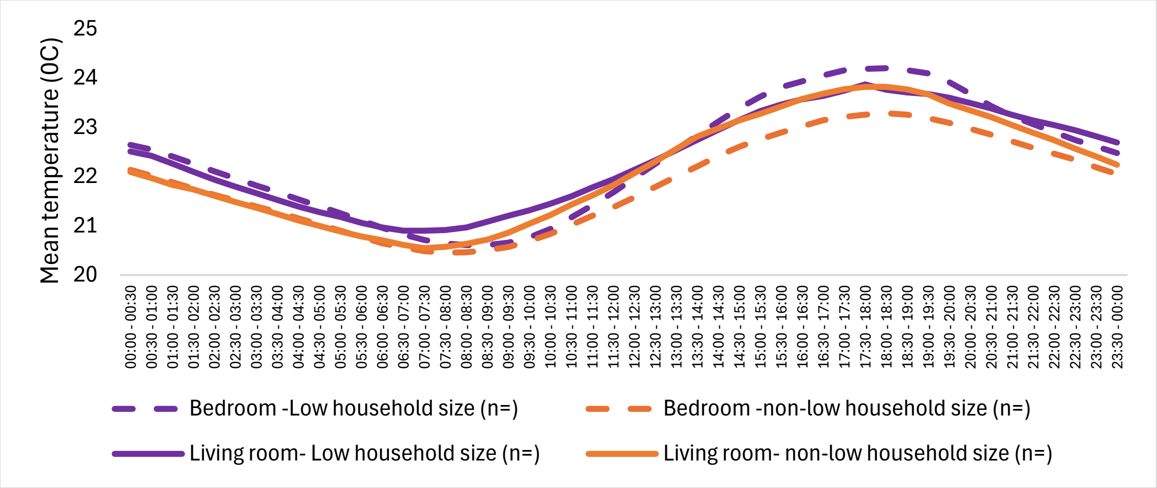
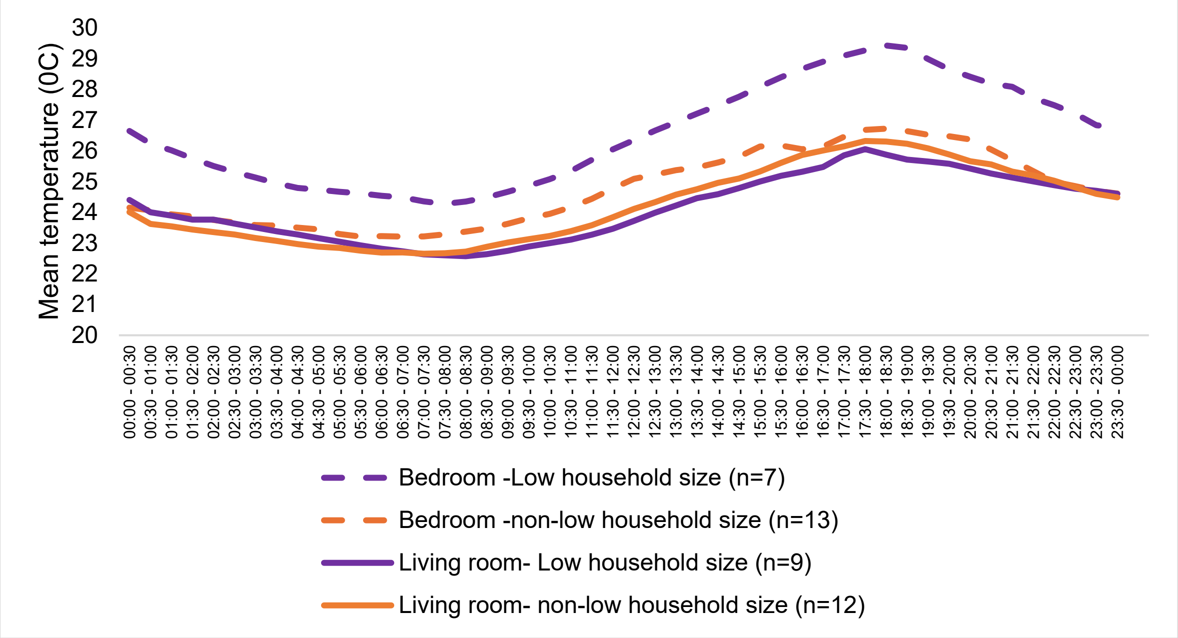


Figure 51 compares the diurnal variations in average half-hourly indoor temperatures on days with a daily mean outdoor temperature of 27^{0}C, comparing low and non-low households. Visual analysis showed that there is an increased bedroom temperatures of the two groups. There’s an approximately 4^{0}C difference between the living room temperature and bedroom temperature of the low household size group in the evening on days with daily mean outdoor temperature of 27^{0}C.

Figure 51 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 27⁰C



5.4 SUMMARY

The number of residents in a household influences the amount of gas consumed to generate hot water and cook. However, the efficiency of gas hot water systems also contributes to the consumption of gas. For instance, a large household with a solar-powered gas booster hot water system may consume less gas than a small household with a traditional gas storage unit. Additionally, households transitioning to electric appliances tend to exhibit lower gas consumption patterns.

Regardless of household size, the type of appliances used can affect gas consumption. Gas usage often peaks in the mornings and evenings when residents prepare for the day, leading to increased demand for hot water and cooking. Many households in this study utilised gas stovetops for cooking, contributing to overall gas consumption. Generally, as the number of residents in a household increases, so does the gas consumption for cooking. However, not all residents with gas cooktops use them regularly; some prefer electric appliances, such as rice cookers or air fryers, specifically chosen to reduce gas usage for moral or practical reasons. For example, one mother and her disabled daughter actively aimed to lower the home's indoor temperature, which led them to use the gas stovetop less frequently.

Low household sizes generally lead to lower total electricity consumption compared with larger ones. Interestingly, the minimum daily energy consumption was greater in lower household sizes than in larger ones; however, the maximum consumption was higher in non-low households. On a typical summer day, the maximum gas consumption was the same for both demographics, with very similar average values. This leads to the conclusion that household size is not a good determinate of electricity consumption compared with gas.

In non-low household sizes, there was a more extensive range of consumption for both cool and hot summer days, contributing to electricity consumption because of the use of mechanical cooling. There was a significant temperature difference between households' living areas and bedrooms, especially those with bedrooms on a second storey. Participants in the low household demographic were generally conscious about not using mechanical air conditioning, tolerating or enjoying warmer indoor temperatures, and often defaulting to passive cooling methods, such as closing blinds and opening windows in the evening. This behaviour was reflected in the total amount of electricity consumed against outdoor temperatures. Non-low households consumed significantly more electricity as outdoor temperatures increased from the mid to high 20s.

Interestingly, residential occupancy did not always correlate with energy consumption. Some households with residents at home all day during the week resulted in lower energy consumption than those whose residents were absent during the 9 to 5 workday. This difference in daily living temperatures between low and non-low households could reflect more energy-efficient homes. Households with the lowest energy consumption actively chose not to air-condition their homes. Most household energy use involves electric ovens and cooking appliances, indicating that cooking is not a major contributor to electricity usage compared to cooling, which plays a major role in determining overall electricity consumption.

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 31 homes (7 low income, 13 mid income and 11 high income) for the summer period. As shown in Table 12, the range of daily mean total gas consumption of the high-income group is low in the coldest, 'typical' summer day and the warmest temperatures. The range of daily mean total gas consumption is high on the coldest and 'typical' summer days and the warmest days in the mid income group. Low income and high-income households present zero gas consumption as a minimum during 'typical' summer days. The average gas consumption on the 'typical' summer days was the same (28 MJ/day) in the low-income and high-income group. The average gas consumption on the coldest days was higher in the low-income group. The average gas consumption on the warmest days was high in the high-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=13)				High income (n=11)			
	Min	Ave.	Max	Range	Min	Ave.	Max	Range	Min	Ave.	Max	Range
15	10	100	261	251	1	78	342	341	1	36	124	123
18 ('typical' summer day)	0	28	119	119	0	44	177	177	0	28	104	104
28	4	40	58	54	4	38	73	69	25	46	65	40

Figure 52 presents box plots comparing the daily mean total gas consumption between the groups on days with a daily mean outdoor temperature of 18^0C. Gas consumption data of 31 homes (7 low income, 14 mid income and 10 high income) for summer months was considered for the box plot. The interquartile range of the high income group (42MJ) is higher than the low income (35MJ) and mid income group (34MJ). 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 median daily mean gas consumption is low in the high-income group than the low- and mid-income groups. HH29 (10MJ) had the lowest daily mean gas consumption and HH34 (75 MJ) had the highest daily mean gas consumption of the low-income homes. HH45 (4MJ) had the lowest daily mean gas consumption and HH40 (82 MJ) had the highest daily mean gas consumption of the mid income homes. INT7 (2MJ) had the lowest daily mean gas consumption and HH43 (58MJ) had the highest daily mean gas consumption of the high-income homes.

Figure 52 Box plot for mean gas usage on days with a daily mean outdoor temperature of 18^{0}C

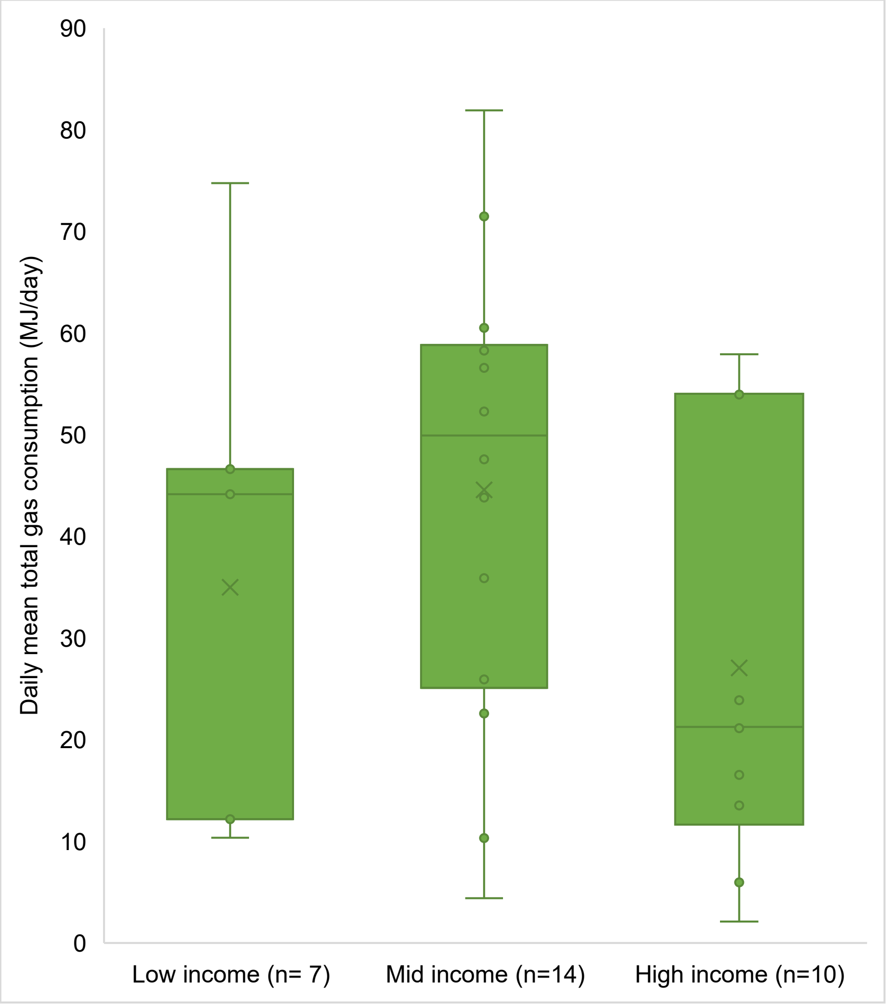
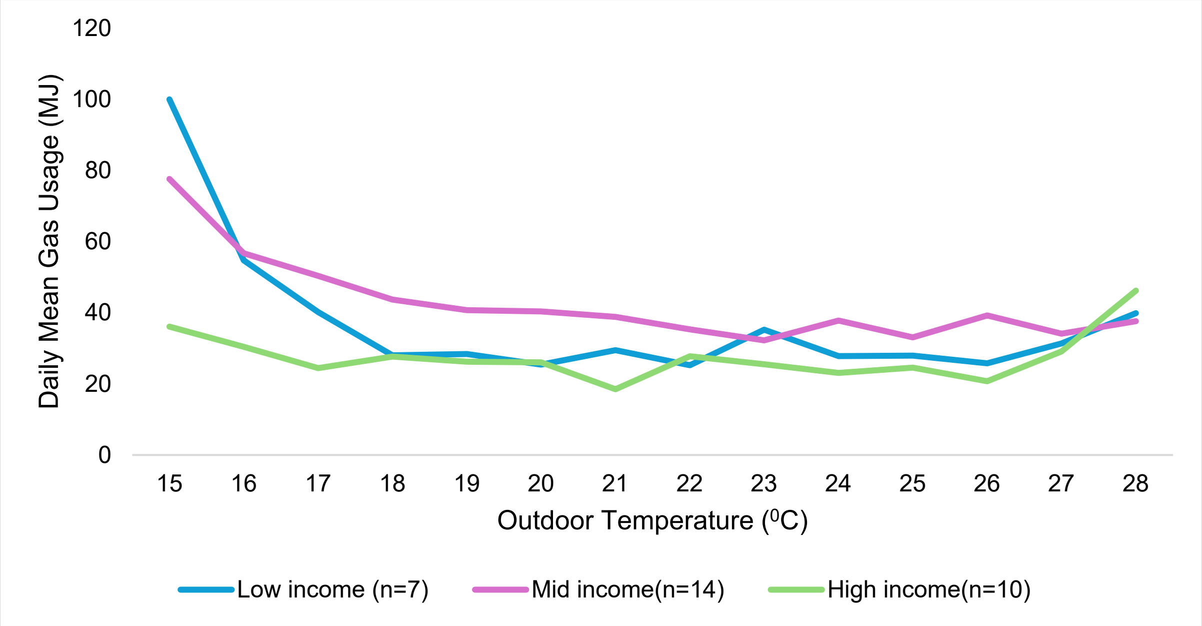


Figure 53 shows the comparison of the daily mean total gas consumption for the low, mid and high-income groups in relation to the daily mean outdoor temperatures. On average, the daily mean total gas consumption in low, mid and high-income groups presented a negative association with the mean outdoor temperatures. The visual analysis of the graph suggests that the daily mean total gas consumption in the high-income homes was lower at daily mean outdoor temperatures 15-27^{0}C. However, the gas usage increases at 27 – 28^{0}C outdoor temperature levels but this result should be interpreted with caution due to the comparatively low number of data points at the high end of the outdoor temperature range. The difference in gas use in low income and mid income homes are low at colder summer temperature and warmer temperatures. Low-income homes had a higher use of gas at colder temperatures. The mid income group showed a higher use of gas 16-22^{0}C and 24-27^{0}C.

Figure 53 Comparison of daily mean total gas consumption at daily mean outdoor temperatures - low/mid/high annual income



Among low income households, Figure 53 shows the highest use of gas was when the outdoor mean temperatures were lowest. More specifically, the daily mean gas use is above 40MJ when the mean outdoor temperature is between 15-17^{0}C. Between 18^{0}C to 28 ^{0}C, the daily mean gas use does not reach 40MJ, ranging between 22MJ and 38MJ. INT 5, INT 9 and HH34 in the low income group had high gas use in the early morning. These homes were not rated as energy efficienct, had single glazed windows and always had someone home. Despite it being summer, the high gas use could be explained by heating cold homes in the morning. For example, INT 5 stated: *'But the summers have been so weird in Melbourne. I got my gas bill yesterday and it was so cold right up until December, up until Christmas'*. These houses (INT 5, INT 9 and HH34) all had gas storage hot water systems, which also contributed, as INT 9 expained: *'Well, our gas bills are certainly higher than our electricity bills, but that includes the fact that the water heating is also gas, and the heating is also gas.'* Figure 54 shows that gas use amongst low income groups is lowest between 1.00 pm and 6.00 pm. During this period, some households that were higher in gas use are from the archetype entrenched in gas (e.g. INT16) with many gas appliances.

Middle income groups also had higher daily mean gas use at colder outside daily mean temperatures. Again households with gas heating (e.g. HH44) has a higher gas use in the early morning, as well as gas hot water systems in larger households (e.g. INT14 was a six-person home with high early morning gas use). Similar to low income groups, there was less gas use between 1.00 pm to 6.00 pm. The peaks in the evening can be expected with greater occupancy within the homes at these times. In some cases, these peaks could be more pronounced as households tried to reduce their gas use to only when they really needed it. INT19 explained: *'gas prices have gone up dramatically as well, so we thought we'll cut back on as much use of gas as possible.'* This highlights that gas costs were still a consideration amongst middle income groups.

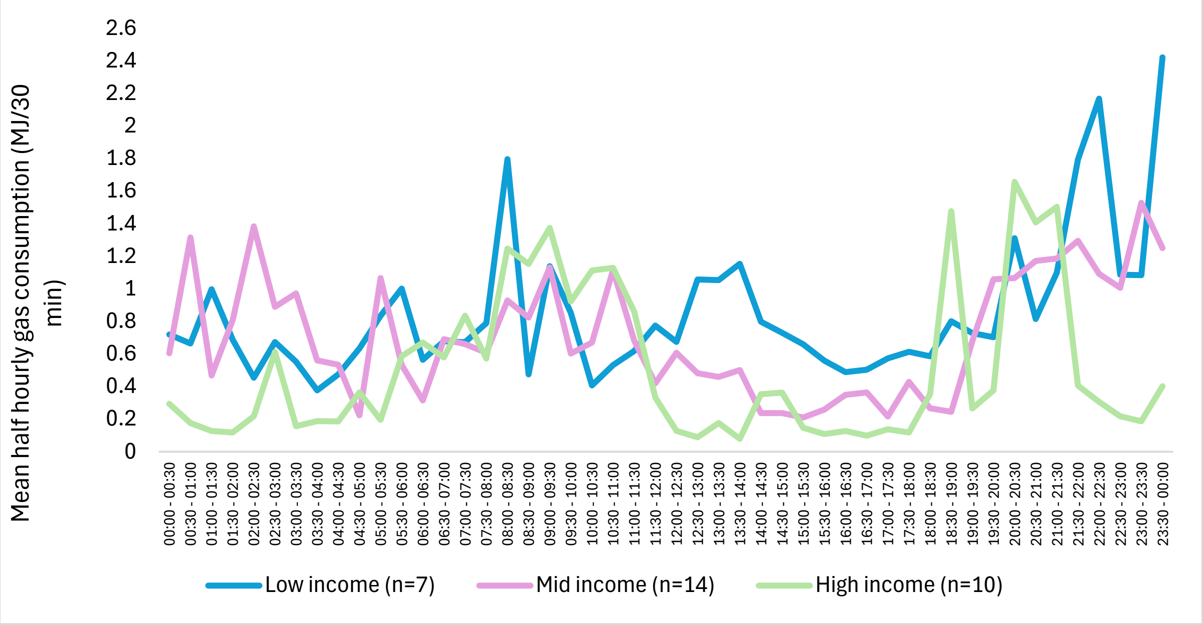
Within high income households, Figure 54 shows less gas use in comparison to middle and low income groups. In some cases, such as INT 10 which showed high gas use from 6.30 am to 8.00 am, and then again, between 6.00 pm to 11.30 pm was because: *'usually, business hours there's nobody home'*. Low gas use homes in the high income group were monitoring or moving away from gas. For example, they expressed they wanted to *'get rid of gas'* (INT18) or kept '*an eye on the meter readings... because recently there was a leak [while they were on vacation] where we ended up paying a thousand dollars for gas.*' (INT13)

Figure 54 compares the diurnal variations in average half-hourly gas consumption on 'typical' summer days of low, mid and high income homes. Figure 55 shows the 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 27^{0}C.

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 lthe mid income group rises in the morning from 4.30 am to 10.30 am and drops in the afternoon. The gas use of low income group drops overnight, increase around 3.00 am – 4.00 am and again drops from 4.30 am 5.30 am. Then it rises from 5.00 am and drops around 7.00 am. The gas use of the low income group was lowest from 8.30 am to 11.30 am. The gas use to the high income group drops over night and increase in the morning from 5.00 am 9.30 am. The low income and mid income groups shows pronoinece peaks in the evening than the high income group.

Figure 54 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 18^{0}C

Figure 55 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 27^{0}C



6.2 ELECTRICITY USAGE

This section presents the electricity consumption data with respect to household income categories. Electricity data of 31 homes (7 low income, 13 mid income and 11 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 mid income group. However, the range of daily mean total electricity consumption on 'typical' summer day was higher in the high-income group. During the warmest temperature, the range of daily mean total electricity consumption was higher in the low-income group. High-income and mid income households have lower average electricity consumption on 'typical' summer day compared to low-income households. The maximum average electricity consumption on 'typical' summer day and the warmest day is the same (63 MJ/day) in the low-income group.

The highest total daily electricity consumption in the low-income group (102 MJ) was presented at HH34 when the daily mean outdoor temperature was 21^{0}C. HH34 is a seven-person household with solar panels. This household reported that there was high electricity use at times when solar production was low or none. It could be explained by their *'spa which is running electricity all the time keeping it hot.'* The lowest daily total electricity consumption in low-income group was presented at HH29 (7 MJ) when the daily mean outdoor temperature was 22^{0}C. There were two adults living within this brick veneer home with no air-conditioning. Instead, they relied on cooling methods that did not use power, such as opening windows at night.

In the middle income group, the highest total daily electricity consumption (195 MJ) was presented at INT14 when the daily mean outdoor temperature was 26 ^{0}C. This high reading was despite having solar panels. It could perhaps be explained by the size of the household (a six-person household with four pets) with a large evaporative cooling system on a hot day. The lowest daily total electricity consumption was presented at INT4 (4 MJ) when the daily mean outdoor temperature was 18^{0}C. This middle income home has a 3.5KW solar system and used power in the day when there was solar providing '*free energy and running the system cools the house down.*' They also had consideration for energy efficient appliances (INT4): '*We'd heard that the more modern air conditioners with inverters were much more efficient, and they really are.*'

In the high-income group, the highest total daily electricity consumption (77 MJ) was presented at INT18 when the daily mean outdoor temperature was 27^{0}C. This household included three adults who worked from home and were about to install a central heating and cooling system '*that's going to take a lot of power.*' The longer-term plan was to have a 10KW solar system to reduce the cost of heating and cooling. The lowest daily total electricity consumption was presented at HH28 (3 MJ) when the daily mean outdoor temperature was 17^{0}C. This four-person and one pet household explained they had high electricity bills in summer when using their ducted air-conditioning. However, that it needs to be at least 25 degrees in the house before they would consider turning it on. The low reading (3MJ) on a mean outdoor day temperature of 17^{0}C suggests their cooling system, and any other high-energy use appliances, were not used on this day.

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=11)			
	Min	Ave.	Max	Range	Min	Ave.	Max	Range	Min	Ave.	Max	Range
15	11	21	36	25	5	26	128	123	4	21	57	53
18 ('typical' summer day)	9	19	63	54	4	24	61	57	3	17	63	60
28	8	44	63	55	16	36	50	34	6	32	49	43

Figure 56 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 18^{0}C. The interquartile range (IQR) of the low-income group (5MJ/day) is lower than the mid income (20MJ/day) and high-income group (16MJ/day). There is one outlier in the low-income group with 46 MJ/day, which is HH34 which has considerably higher electricity use than others in this income group. As previously noted, this households practise of having a spa heated to 37/38 degrees 24 hours a day could explain this outlier. The upper limit and lower limit value of the low-income group appears to be the same as the upper boundary and lower boundary of the interquartile range. Therefore, the low-income group appears to have a lower spread of mean electricity consumption than those for homes in the mid and high-income groups. This could be due to lower number of homes (7) in the low-income group. Mid-income homes display the greatest variability in electricity usage, as seen in the wide IQR and whiskers. The mid income group also has a higher median (22MJ/day) than the low and high-income groups. High-income households also show variability, but slightly less than mid-income households. HH34 has the highest electricity use in the low income households and INT1 and HH29 have the lowest electricity consumption in the low income households. INT6 has the highest electricity consumption in the mid income households and INT4, HH45 and INT20 have the lowest electricity consumption in the mid income households. INT17 had the highest electricity consumption in the high income households and HH28 has the lowest electricity consumption in the high income households.

Figure 56 Box plot for mean electricity usage on days with a daily mean outdoor temperature of 18^{0}C

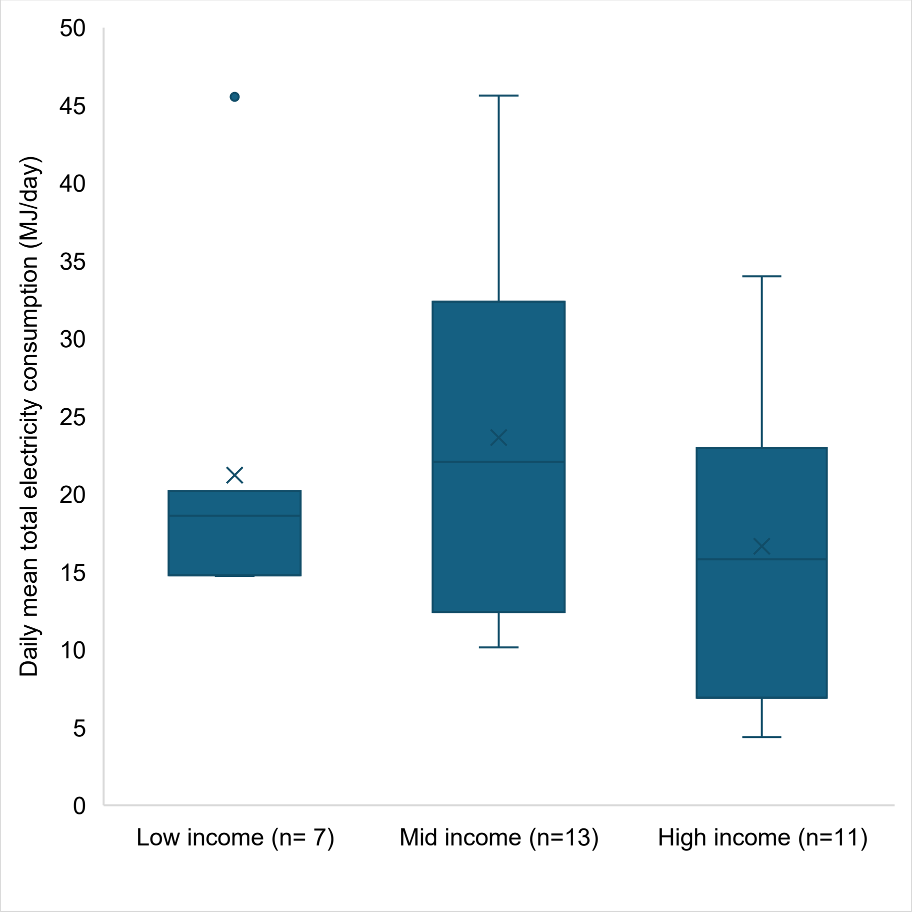


Figure 57 compares the daily mean total electricity consumption for the low, mid and high-income groups in relation to the daily mean outdoor temperatures. On average, the daily mean total electricity consumption in low, mid and high-income groups presented a positive association with the mean outdoor temperatures. The visual analysis of the graph reveals that the daily mean total electricity consumption in the mid income households is higher across all mean outdoor temperatures than the low- and high-income households. The high-income households have the lowest daily mean total electricity consumption from 15-23°C. The low-income households have the lowest daily mean total electricity consumption from 23 -27°C. At the warmest temperature daily mean total electricity consumption of the low-income homes rise, the total electricity consumption of the mid-income homes decreased at mean outdoor temperatures 26 -28°C. The difference in daily mean total electricity consumption of the three groups is low on the colder days than the warmer days. However, not much difference in daily mean total electricity consumption of the low income and mid income homes can be observed mean outdoor temperatures 15-27°C.

Figure 57 Comparison of daily mean total electricity consumption at daily mean outdoor temperatures – low/mid/high income

Figure 58 compares the diurnal variations in average half-hourly electricity consumption on 'typical' summer 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 evening. The higher evening peak is visible from 7.30 pm to 9.30 pm in low income groups, 6.30 pm to 10.30 pm in mid income groups and 6.30 pm to 10.00 pm in high income groups. The average electricity consumption appears to be higher in the low income group than in the mid and high income group early morning 1.00 am to 7.00 am and 6.00 pm to 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 8.00 am- 6.00 pm. The high income group's average electricity consumption appears to be lower than the low and mid income groups 1.00 am to 8.30 am and 4.00 pm to midnight.

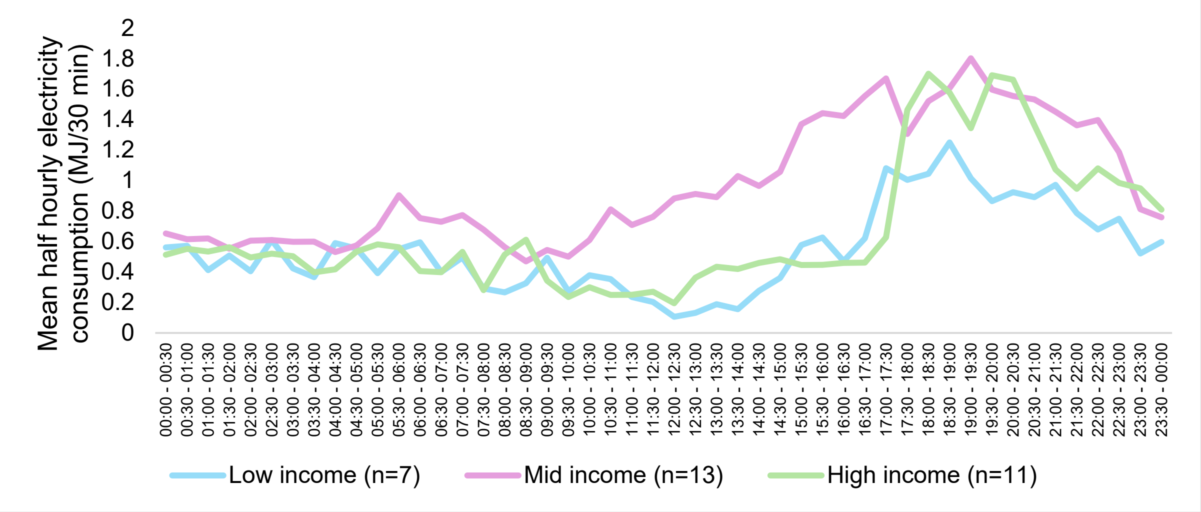
In low-income homes, HH34 had the highest electricity consumption during the following time periods: 1.00 am - 7.00 am, 10.30 am – 11.00 am and 3.00 pm to midnight. This is likely explained by the consistent spa use as previously noted. INT16 had the highest electricity use from 11.00 am to 3.00 pm. However, INT 16 electricity consumption was low from midnight to 5.30 am. This two-adult detached home was well-insulated. There was no air conditioner in the bedroom, but a 'costly' unit operating during the day. INT2 had a peak in consumption from 8.00 am to 8.30 am. This was a single person household with a retired occupier that spent lots of time at home. The household had solar panels which could explain the early morning peak consumption before higher solar outputs during the day reduced consumption from the grid. INT 1 had the lowest electricity consumption from 7.30 am to 6.00 pm. This 2015 two-person home was rated six-stars, but has since been retrofitted with solar panels, double glazing, LED lighting and energy efficient appliances. Their pet fish are in a tank with a water pump run on solar power. They also reported their home to be highly insulated: *'we found that the insulation in the house is really very good and so I would say that in the six years that we've lived here we've probably turned on the evaporative cooler only – less than ten times*.' They have also adopted practices, such as use of shuttering, ceiling fans and planting techniques to try to keep the temperature within the home as constant as possible.

Within middle income homes, INT19 showed a higher electricity use 8.30 am to 4.30 pm. This three-person home (and two pets) was constructed in 1970, with 14 solar panels added 15 years ago. Retired, there was always someone home. They explained that they used to have difficulty cooling their home: '*when the house gets hot, generally if we have two consecutive days of heat, it takes at least two days for the heat to dissipate'*. They installed split systems as: *'the house gets so hot during the summer'*. In their home office they even had two split systems installed as one was not enough. INT 14 showed a higher electricity use 6.30 pm to 8.00 pm. Within this detached home with solar panels, the two-adults and four-children residing were mostly home in the evening. INT3 showed a higher electricity use 8.00 pm to 11.00 pm. This was despite trying to use solar panel power to cook when possible. This detached home constructed in 1995 was occupied by three adults and two pets. They were mostly out during the weekdays, and at home in the evenings and weekends. INT20 showed a low electricity use 8.00 pm to 6.00 am. This detached home was lived in by a single person and a pet. There is a split system in the bedroom but the occupant *'could count on less than one hand the number of times I've even turned it on*.' Instead, their preference was to run a portable fan at night if too hot and uncomfortable to sleep. Lastly, HH45 (2 adults) and HH41 (2 adults, kid and pet) had low electricity use 7.00 am to 6.00 pm. Both homes were brick veneer, had wall and roof insulation, solar panels, LEDs and almost always had someone there.

In high-income homes (INT17) showed a higher electricity use in the morning 5.30 am to noon and 2.00 pm to 6.00 pm. There were two adults within this detached home and always someone there. They undertook cost analysis for the installation of appliances but did not precisely investigate ongoing costs beyond whether the appliance was efficient or not. The occupants did track their usage using the Powerpal app but had no solar panels on the property. INT18 showed the highest consumption from 6.00 pm to midnight. This three adult and child household was moving to an all-electric home. HH32 and INT13 had lower electricity consumption from 7.00 am to 6.00 pm. Both detached homes had solar panels, with HH32 reporting a large solar system of 21 panels. They explained in combination with split systems this was *'cost-effective'* and were also conscious to reduce usage, commenting that '*some people just waste too much money on lighting and having unnecessary things on*.'

Figure 58 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 18^{0}C

Figure 59 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 27^{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 six low income, 12 mid income and 11 high income homes. The range of daily mean living room temperatures on the coldest days, was low in the low income group. However, the range was the same in both mid and high income group. The range of daily mean living room temperatures on the 'typical' summer days was low in the low income group. However, the range was the same in both mid and high income group. On the warmest days, the range were bigger in the low income group than in the mid income and high income group (Table 14). The low income and mid income groups had the same maximum daily mean living room temperatures on the 'typical' summer days and the warmest days. On the warmest days, the range of the mid 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 28°C being present at only HH29 in the low-income group.

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=6)			Mid income (n=12)			High income (n=11)		
	Min (°C)	Max (°C)	Range (°C)	Min (°C)	Max (°C)	Range (°C)	Min (°C)	Max (°C)	Range (°C)
15	19	22	3	18	23	5	19	24	5
18 (‘typical’ summer day)	20	27	7	19	27	8	19	27	8
28	20	27	7	27	27	0	21	25	4

As shown in Table 15, the bedroom temperature data was available for four low income homes, nine mid income and nine high income homes. The daily mean bedroom temperature range on the coldest days was low in low income homes. However, the range of daily mean bedroom temperatures of the low income group was higher than the mid and high income groups on the typical summer days. The daily mean bedroom temperature range on the 'typical' summer 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 4°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=4)			Mid income (n=9)			High income (n=9)		
	Min (°C)	Max (°C)	Range (°C)	Min (°C)	Max (°C)	Range (°C)	Min (°C)	Max (°C)	Range (°C)
15	18	21	3	17	22	5	18	22	4
18 (‘typical’ summer day)	19	26	7	19	25	6	19	25	6
28	30	30	0	27	27	0	22	26	4

Figure 60 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 18^{0}C. The interquartile range of the low income group is lower than the mid income and high income groups. The interquartile range of the high income group (2.3^{0}C)s is slightly higher than the mid income group (1.8^{0}C). Further, the dispersion of the daily mean living room temperatures on days with a daily mean outdoor temperature of 18^{0}C is higher in the mid income group than the low and high income groups. The daily mean living room temperatures of the three groups appear to be positively skewed. INT5 had the lowest daily mean living room temperature (21.5^{0}C) in the low income group. INT1 had the highest daily mean living room temperature (23.2^{0}C) of the low income group. HH40 had the highest daily mean living room temperature (24.7^{0}C) in the mid income group and HH39 had the lowest daily mean temperature (20.5^{0}C) in the mid income group. INT12 had the highest daily mean living room temperature (24^{0}C) in the high income group and HH28 had lowest daily mean living room temperature (20.7^{0}C) in the high income group.

With regards to the daily mean bedroom temperatures, the low income group has a higher interquartile range (2.8⁰C) than mid and high income groups. Furthermore, the dispersion of bedroom temperature is also high in the low income group. The daily mean bedroom temperatures of low, mid and high income homes appear to be right (positively) skewed. and HH34 had the lowest daily mean bedroom temperature (20.6⁰C) in the low income group. HH44 had the highest daily mean bedroom temperature (23.3⁰C) in the mid income group and HH39 had the lowest daily mean bedroom temperature (20.6⁰C) in the mid income group. INT13 had the highest daily mean bedroom temperature (23.6⁰C) in the high income group and HH43 had the lowest daily mean bedroom temperature (20.7⁰C) in the high income group.

Figure 60 Box plot for mean indoor temperature on days with a daily mean outdoor temperature of 18⁰C

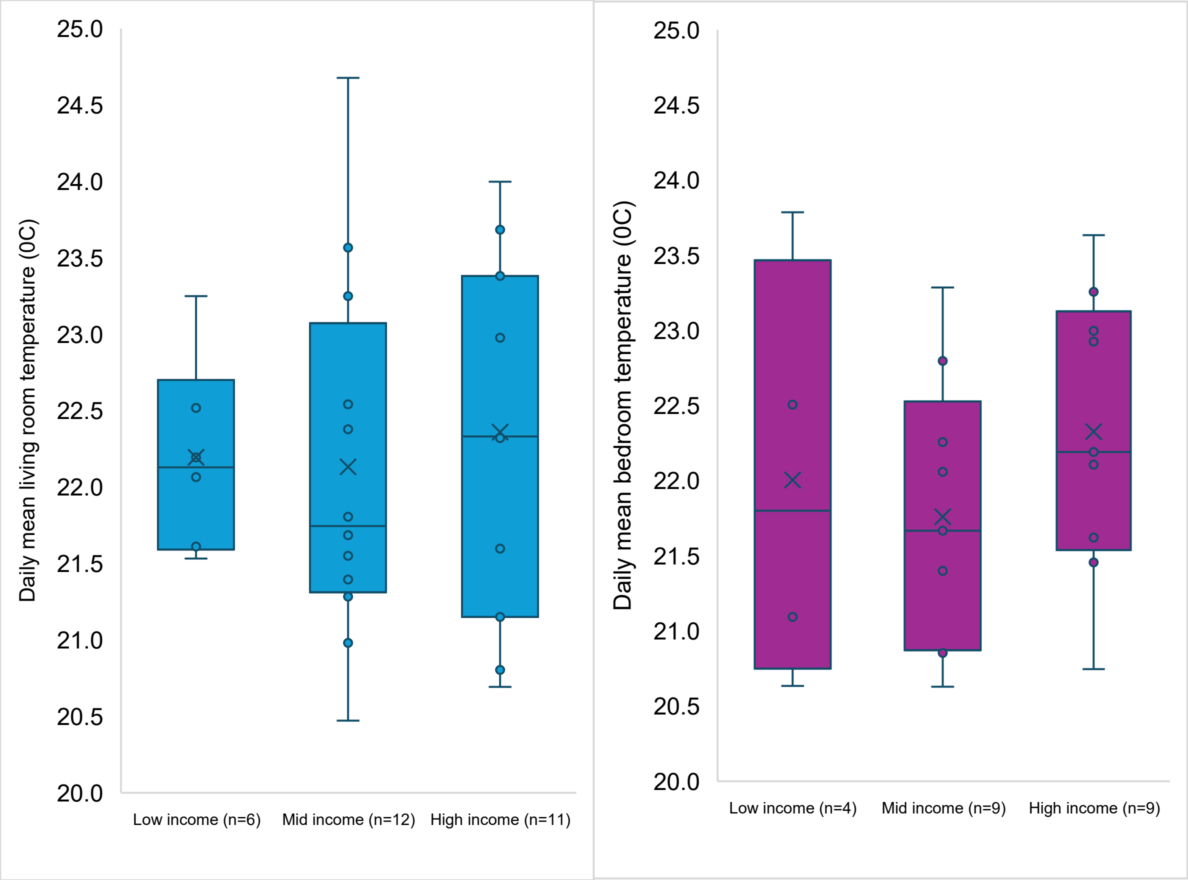


Figure 61 shows the comparison of the average daily mean living room temperatures and bedroom temperatures for the low, mid, and high income groups in relation to the daily mean outdoor temperatures. On average, the mean daily living room temperatures and bedroom temperatures in both low, mid and high 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 when the mean outdoor temperature 17⁰C, 22⁰C and 25⁰C. Further, the difference in the mean indoor living room temperatures of the low and mid income groups is less on warmer days (except at 28⁰C) and 17⁰C -19⁰C on the colder days. There is little difference in the mean indoor bedroom temperatures of the low, mid and high-income groups at colder temperatures. The bedroom temperatures of the low income group were slightly higher than the high income and mid income groups at warmer temperatures.

Figure 61 Comparison of daily mean indoor temperature at daily mean outdoor temperatures - low/mid/high income groups

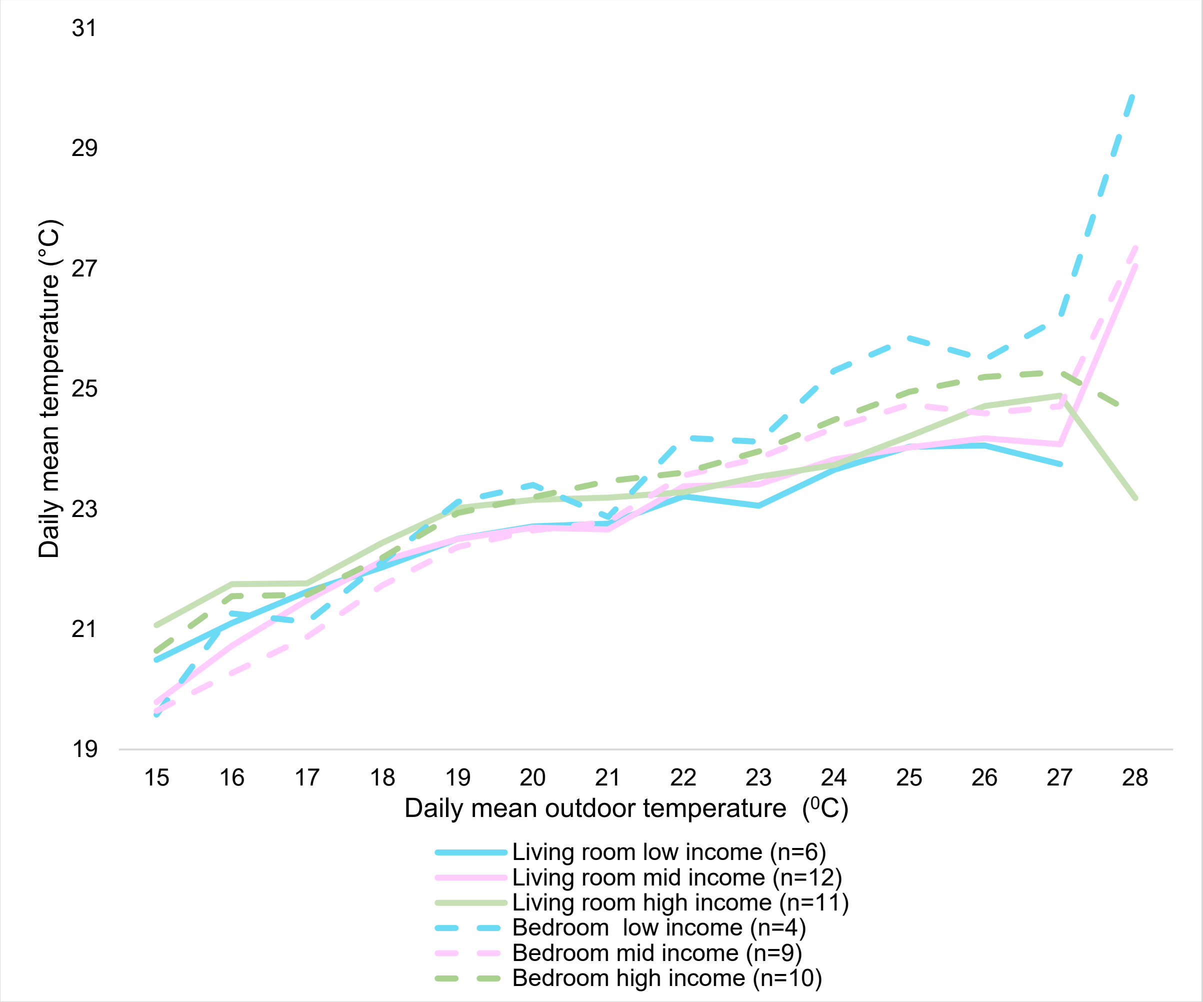


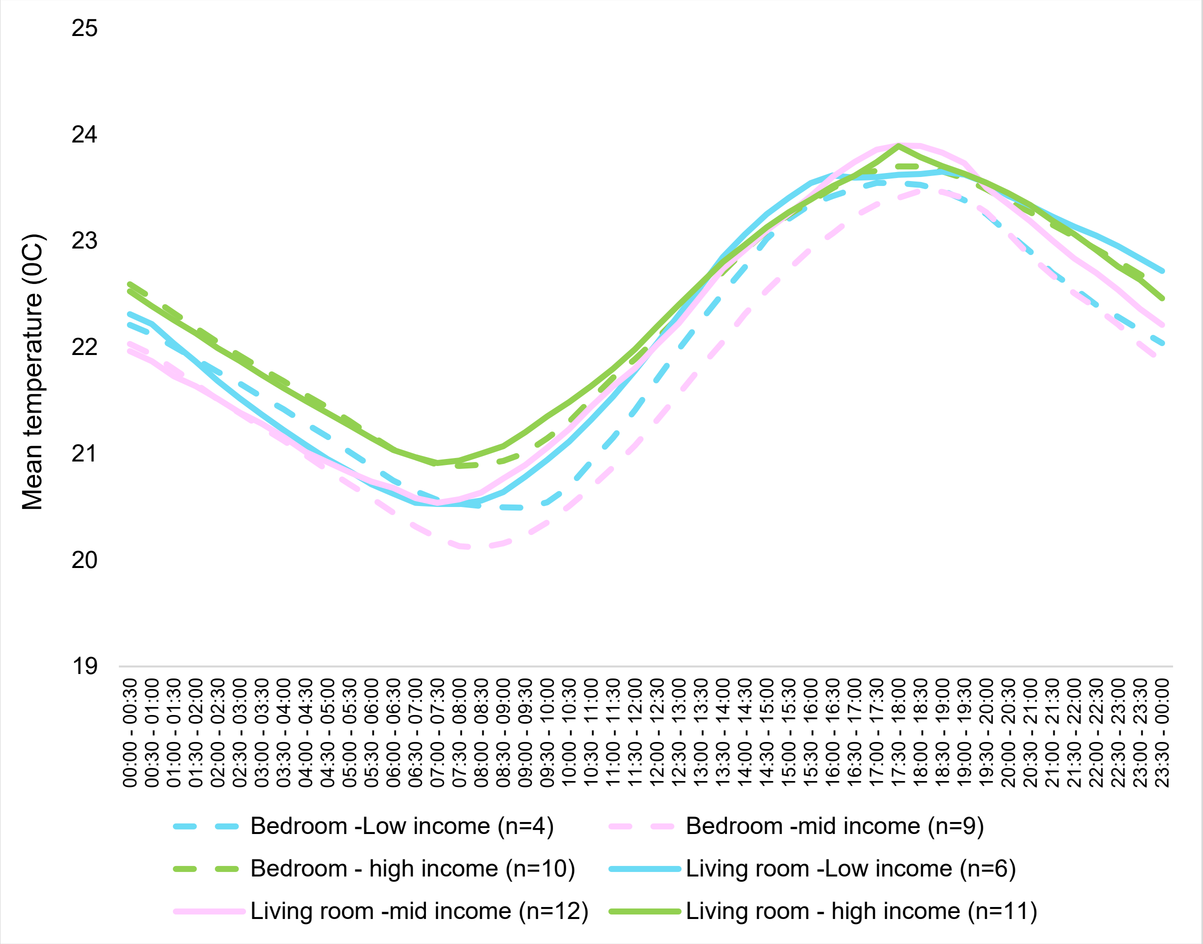
Figure 62 present the diurnal variations of mean living room and bedroom temperature on 'typical' September days with a daily mean outdoor temperature of 18°C in low, mid and high-income groups respectively. The living room temperatures in the three groups drop overnight until about 7.00 am. The mean living room temperatures of low, mid and high-income groups rise during the day and afternoon until they peak in the evening around 6.00 pm. The mean living room temperatures of the high-income group are higher than the low- and mid-income group till the afternoon. The mid income group has higher mean living room temperature during the peak in the evening than the low- and high-income homes.

It can be observed within Figure 62 that temperatures remain within one degree in bedrooms and living rooms across the groups, until over 23^{0}C daily mean outdoor temperatures. After this point, the biggest difference in trend between bedroom and living room is within the low-income groups. At a 27^{0}C daily mean outdoor temperature, there is a difference in daily mean temperature of 23.7^{0}C in the living room and 26.2^{0}C in the bedroom. This then spikes to over 30^{0}C in the bedroom at a 28^{0}C daily mean outdoor temperature. INT1 had higher mean living room temperatures of the low-income households during typical summer days. This household has an evaporative ducted cooling throughout the home including all four bedrooms. However, they used ceiling fans to cool at night, or waited for the cool-change and opened windows. They also showed a preference for using electrical appliances when they had solar power. INT 5 had a lower living room temperatures of the low-income households during typical summer days. This household had an 35-40 year old air-conditioner in their living room that they rarely used (2-3 times per summer). Instead, they opt for blinds, shutters and ceiling fans to keep the room 'reasonably cool'.

The bedroom temperatures in the three groups drop overnight until about 7.30 am - 9.00 am. The mean bedroom temperatures of low, mid and high-income groups rise during the day and afternoon until they peak in the evening around 6.00 pm. Overall, the mean bedroom temperatures of the high-income group are higher than the low- and mid-income group throughout the day. The mean bedroom temperatures of the mid-income group are lower than the mid and high-income group throughout the day.

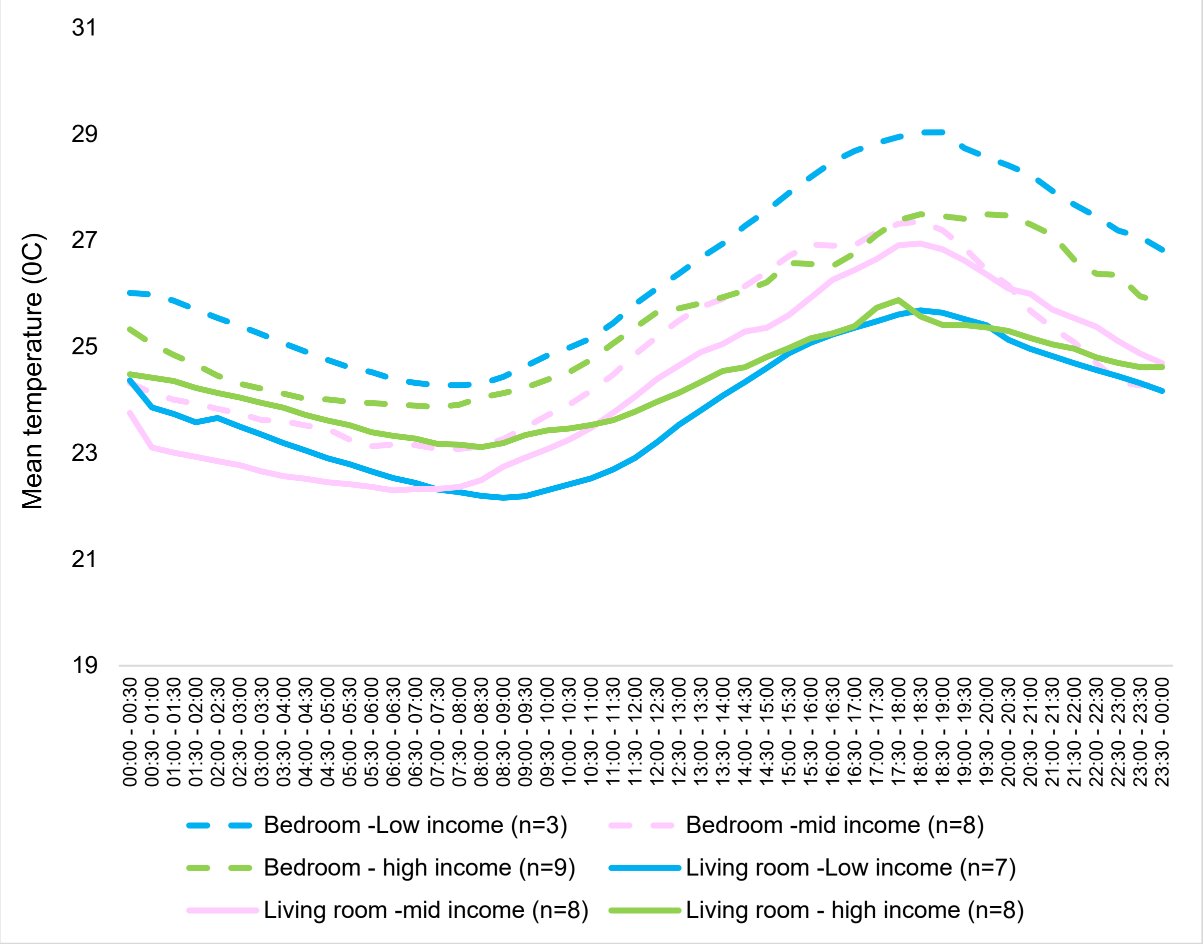
Figure 62 illustrates the variation in temperatures across groups on days with a daily mean outdoor temperature of 18 degrees. It can be observed at any point during the day there is minimal and insignificant differences, with bedroom and living room temperatures across groups falling within one degree at any given time. Details of the very slightly higher or lower households are highlighted below:

Figure 62 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 18^{0}C



HH29 had the highest mean bedroom temperatures of the low-income group throughout the day during typical summer days. HH44 had the highest mean bedroom temperatures of the mid-income group throughout the day during typical summer days. HH45 had a peak in the evening on typical summer days. INT13 and HH22 had higher mean bedroom temperatures of the high-income group throughout the day during typical summer days. INT16 had lower mean bedroom temperatures of the low-income group during typical summer days from morning to evening. HH39 had lower mean bedroom temperatures of the mid-income group during typical summer days. However, INT15 had lower mean bedroom temperatures in the evening. HH43 had lower mean bedroom temperatures of the high-income group during typical summer days.

Figure 63 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 27^{0}C



6.4 SUMMARY

In summary, the cost of gas and electricity use was a consideration across all the income groups (low, middle and high). The results found evidence that despite having a higher income, high-income households used the least gas. Some also monitored gas consumption and considered moving away from gas due to increased prices. Households with the highest use of gas, typically had gas heating and hot water systems. Despite being summer, the higher gas use suggests that households were perhaps heating homes on cooler summer mornings and evenings. Electricity use also showed high-income groups using the least energy, with the lowest households having solar panels combined with energy efficient electric appliances. Despite having higher income, they still reported household practises that reduced power consumption if deemed unnecessary (e.g. turning lights off). In both the low and middle-income groups, there were households that had solar panels but still high electricity use. This suggests the household practices, as well as solar panels, can be significant. For example, the choice to constantly heat a spa to 37/38^{0}C all year round in one household.

The mean half-hourly indoor temperature in low, mid and high income groups on days with a daily mean outdoor temperature of 18^{0}C showed insignificant differences in both bedroom and living room temperatures. These rooms (at all times) were within a 1 ^{0}C range, which suggests that on days with an outdoor mean temperature of 18 ^{0}C, income has no significant bearing on room temperature. Where differences became apparent was at higher outdoor temperatures. It is not until over 23^{0}C daily mean outdoor temperatures that more varied differences can be observed. These become clearer especially in the low-income group at a 27^{0}C daily mean outdoor temperature, where there is a difference in daily mean temperature of 23.7 ^{0}C in the living room and 26.2 ^{0}C in the bedroom. This then spikes to over 30 degrees in the bedroom at a 28^{0}C daily mean outdoor temperature. In some low-income homes, they had air-conditioning within these rooms, but chose instead to use cheaper operating alternatives, such as fans, blinds and shuttering.

7 Cultural and linguistic diversity – CALD and non-CALD

This section presents summer results for 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 households. Gas data was available for 31 homes (12 CALD and 19 non-CALD household) for December 2023 to February 2024.

As shown in Table 16, average daily mean total gas consumption decreases with increasing daily mean outdoor temperature for both CALD and non-CALD households. There is one exception – non-CALD households at a daily mean outdoor temperature of 28^0C. This is discussed further below in relation to Figure 65.

Comparing CALD and non-CALD data, the average, maximum and range of daily mean total gas consumption of non-CALD homes is much higher than the CALD homes on the coldest days. For 'typical' summer days, the range of daily mean total gas consumption of the CALD homes is higher than the non-CALD homes although the average gas consumption is lower. on the warmest days the average, maximum and range of daily mean total gas consumption of non-CALD homes is again much higher than the CALD homes. Both groups present the same minimum on the coldest days and typical summer days with some households using no gas on those days.

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=12)				Non-CALD (n=19)			
	Min	Ave.	Max	Range	Min	Ave.	Max	Range
15	1	53	234	233	1	84	342	341
18 ('typical' summer day)	0	33	177	177	0	37	139	139
28	4	23	48	44	58	64	73	15

Figure 64 presents box plots comparing the daily mean total gas consumption between the groups on days with a daily mean outdoor temperature of 18^0C. Gas consumption data of 31 homes (12 CALD and 19 non-CALD) for the summer months was considered for the box plot. The interquartile range of the CALD group (45 MJ) is higher than the non-CALD group (33 MJ). Further, the CALD group also showed a higher dispersion of mean gas consumption than the non-CALD group. However, as shown in the box plot, the median daily mean gas consumption was less in the CALD group than the non-CALD group. Both groups of data appear to be right skewed.

Further investigation based on qualitative data shows that factors related to CALD status are not driving the differences in the results. HH45 had the lowest daily mean gas consumption and HH40 had the highest daily mean gas consumption of the CALD homes. The families who lived in these homes were very similar demographically and their homes were of similar construction. The key difference appears to be their attitude towards energy use. HH45 falls into the 'moving to all electric – multiple benefits' archetype meaning that they had adopted practices at home leading to lower gas usage whereas HH40 is 'entrenched in gas' and paid less attention to energy use practices.

INT7 had the lowest daily mean gas consumption and HH34 had the highest daily mean gas consumption of the non-CALD homes. Again, these homes were very similar (brick veneer of a similar size and energy rating) although INT7 had a solar hot water system and HH34 relied on a gas storage system. The key difference was in how the homes are occupied. INT7 was a sole occupier retiree whereas HH34 was a high energy using household of 7 people.

Figure 64 Box plot for mean gas usage on days with a daily mean outdoor temperature of 18^{0}C

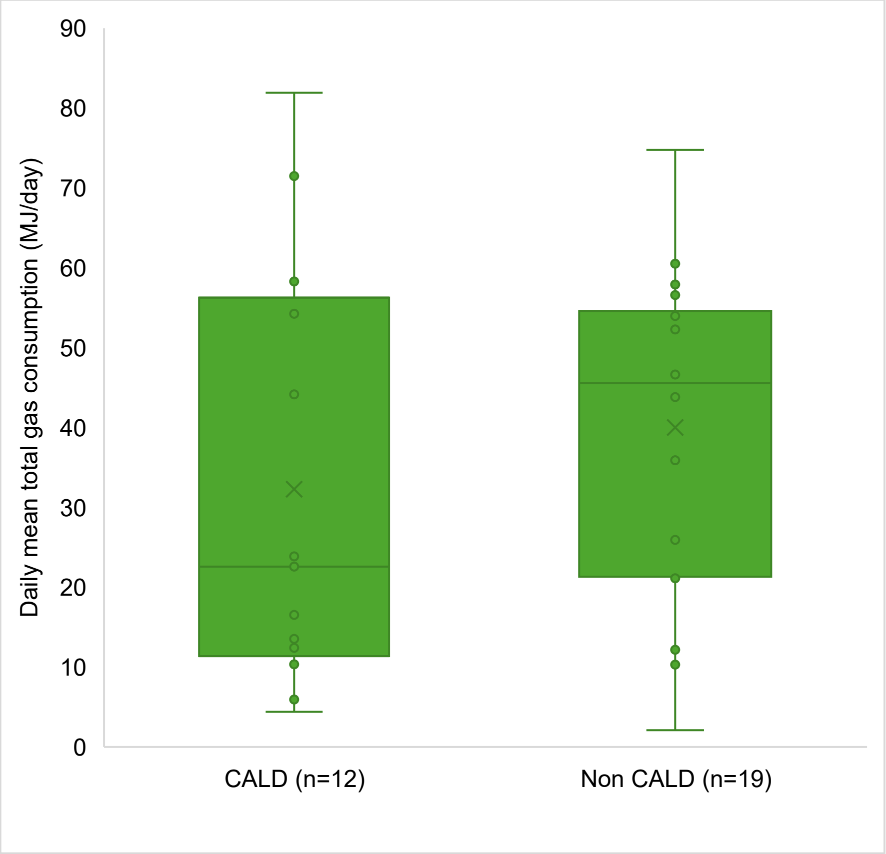
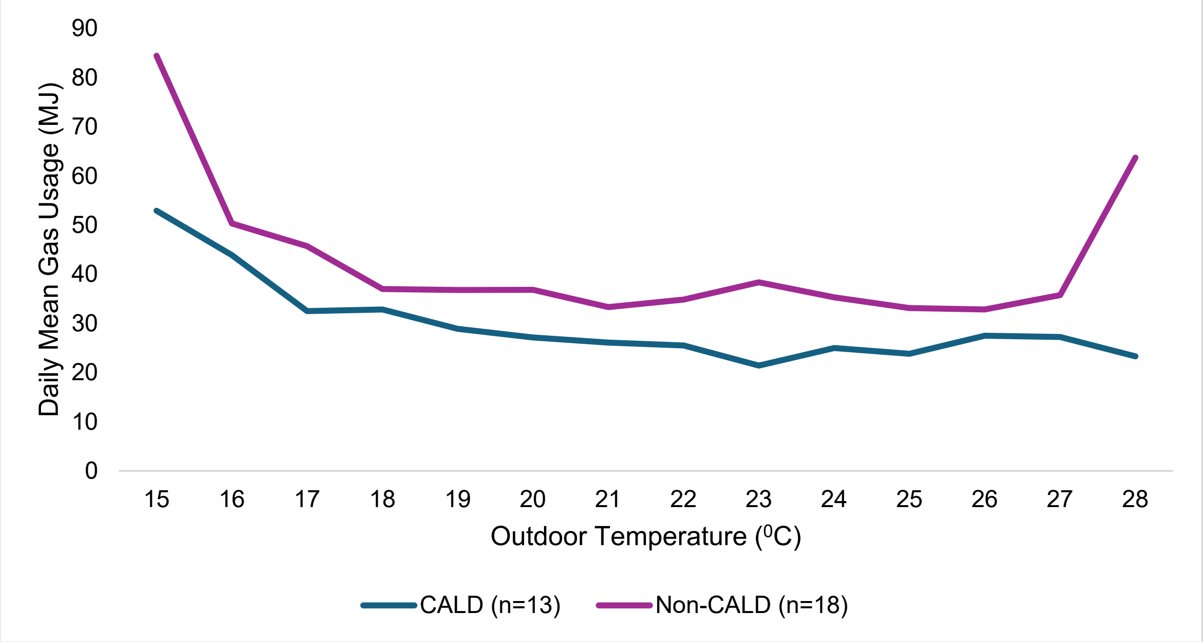


Figure 65 shows the comparison of the daily mean total gas consumption for the CALD and non-CALD groups in relation to the daily mean outdoor temperatures. On average, the daily mean total gas consumption in both CALD and non-CALD groups presented a negative association with the mean outdoor temperatures. The visual analysis of the graph reveals that the daily mean total gas consumption in the CALD homes appeared to have been somewhat lower than those in non-CALD homes across all outdoor temperature levels. These trends are similar to those seen during the winter (see interim Report 33, Section 7) although overall gas use is much lower.

There is an unexpected increase in gas usage with outdoor temperature in the non-CALD data at a mean outdoor temperature of 28^{0}C. This mean outdoor temperature is rarely seen in the data and this mean gas usage figure (64 MJ) is driven by gas use in three households (HH34, HH39 and HH43) on a single day. Tracking down reasons for high gas use on a single day is beyond the granularity of the data collected, but it seems likely this was driven by high hot water use for showers. All three households had old gas storage hot water systems and two of the households (HH34 and HH39) included 4 or more adults.

Figure 65 Comparison of daily mean total gas consumption at daily mean outdoor temperatures - CALD/non-CALD



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 6.00 am to 11.30 am and drops in the afternoon. The average gas consumption of the CALD homes gradually rises from 5.30 pm until it peaks at 8.30 pm in the evening. The average gas consumption of the non-CALD homes gradually rises from 6.30 pm until it peaks at 9.30 pm in the evening. The evening peak in both CALD and non-CALD groups of homes is higher than its morning peak. The average gas consumption of the non-CALD homes are higher than the CALD homes at all times except 2.00 am – 4.30 am, 5.00 am – 6.00 am, and 10.00 am-12.00 pm.

CALD homes INT12, HH44, HH40 have higher use gas consumption in the early mornings. HH35, HH44 and INT12 has pronounced peaks in the morning (10.000 am – 11.00 am). INT16 has higher gas use from 12.30 pm – 3.00 pm. HH40 has higher gas comsumption from 2.30 pm to midnight. Further, CALD homes such as HH42 and HH44 have pronouced peaks in the late evening.

Looking at non-CALD homes, HH34, INT14 and INT5 have higher use gas consumption on the early mornings. HH39, INT14, INT5, INT6, INT9 have peaks in gas use from 5.30 am – 8.30 am. HH34 and INT10 have higher gas use 9.00 am to 10.30 am. HH34 also has higher gas use from noon to 1.30 am. HH43 has higher gas use from 1.00 pm to 4.30pm. INT10 shows pronouced gas use from 6.00 pm to 9.00 pm. INT19 also has higher gas use from 8.00 pm to 10.00 pm. HH34 and INT14 has pronounced gas use from 8.00 pm to 10.30 pm.

For both groups, high gas use is driven by hot water and cooking. It is notable that 12 of the 15 households mentioned as high gas users at some point in the day have gas storage-style hot water systems (the other 3 are gas instant systems). Three of the six CALD households mentioned above (HH40, HH44, INT16) used their gas stovetop cooking facilities often. Eight of the nine non-CALD households (all except INT5) reported that they use their gas stovetop often.

Figure 66 compares the diurnal variations in average half-hourly gas consumption on 'typical' summer 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 6.00 am to 11.30 am and drops in the afternoon. The average gas consumption of the CALD homes gradually rises from 5.30 pm until it peaks at 8.30 pm in the evening. The average gas consumption of the non-CALD homes gradually rises from 6.30 pm until it peaks at 9.30 pm in the evening. The evening peak in both CALD and non-CALD groups of homes is higher than its morning peak. The average gas consumption of the non-CALD homes are higher than the CALD homes at all times except 2.00 am – 4.30 am, 5.00 am – 6.00 am, and 10.00 am-12.00 pm.

CALD homes INT12, HH44, HH40 have higher use gas consumption in the early mornings. HH35, HH44 and INT12 has pronounced peaks in the morning (10.000 am – 11.00 am). INT16 has higher gas use from 12.30 pm – 3.00 pm. HH40 has higher gas comsumption from 2.30 pm to midnight. Further, CALD homes such as HH42 and HH44 have pronouced peaks in the late evening.

Looking at non-CALD homes, HH34, INT14 and INT5 have higher use gas consumption on the early mornings. HH39, INT14, INT5, INT6, INT9 have peaks in gas use from 5.30 am – 8.30 am. HH34 and INT10 have higher gas use 9.00 am to 10.30 am. HH34 also has higher gas use from noon to 1.30 am. HH43 has higher gas use from 1.00 pm to 4.30pm. INT10 shows pronouced gas use from 6.00 pm to 9.00 pm. INT19 also has higher gas use from 8.00 pm to 10.00 pm. HH34 and INT14 has pronounced gas use from 8.00 pm to 10.30 pm.

For both groups, high gas use is driven by hot water and cooking. It is notable that 12 of the 15 households mentioned as high gas users at some point in the day have gas storage-style hot water systems (the other 3 are gas instant systems). Three of the six CALD households mentioned above (HH40, HH44, INT16) used their gas stovetop cooking facilities often. Eight of the nine non-CALD households (all except INT5) reported that they use their gas stovetop often.

Figure 66 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 18^{0}C

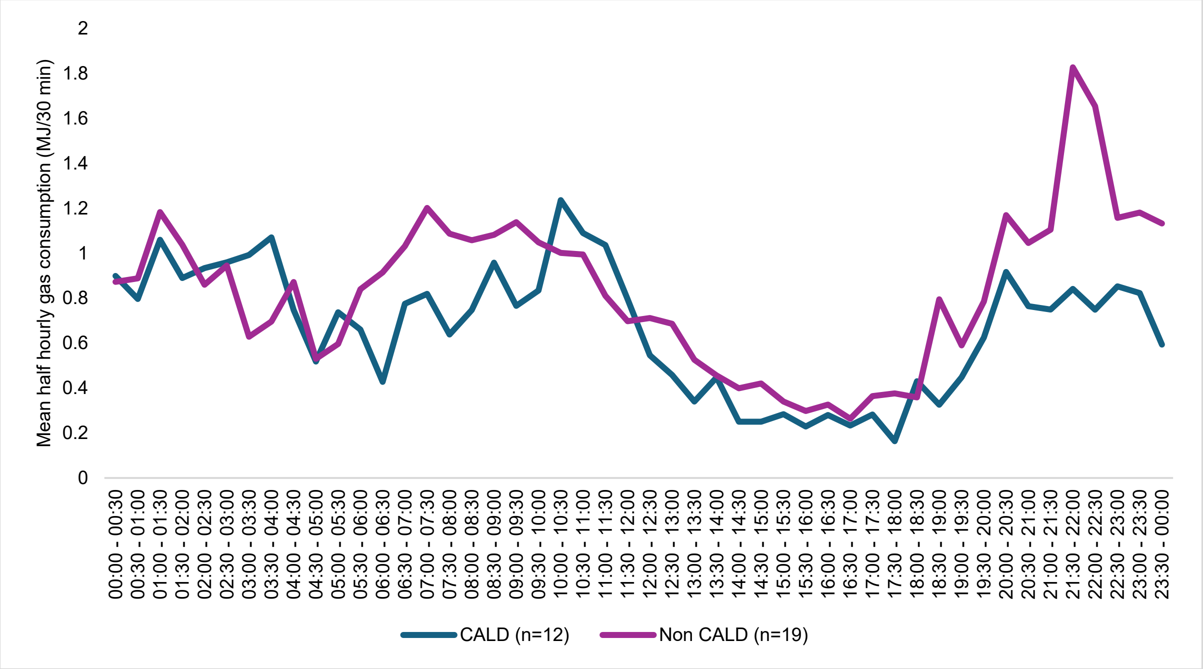
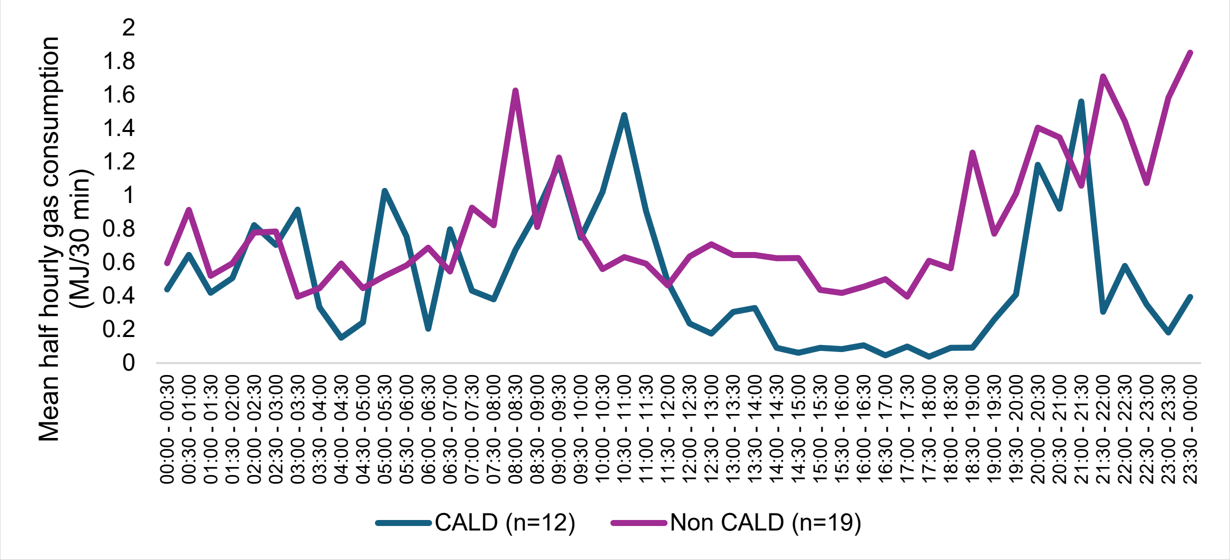


Figure 67 compares the diurnal variations in average half-hourly gas consumption on days with a daily mean outdoor temperature of 27^{0}C, comparing CALD and non-CALD households. Visual analysis shows that there is a slight increase in the gas use in both CALD and non-CALD groups in the morning and in the evening compared to typical summer days. Again, we see that CALD status does not determine gas consumption patterns.

Figure 67 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 27^{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 31 homes (12 CALD and 19 non-CALD) was considered in this analysis.

As shown in Table 17, daily mean total electricity consumption increases with daily mean outdoor temperature for both CALD and non-CALD households and average electricity consumption by non-CALD households was higher than CALD households at all outdoor temperature points. On the coldest days, the non-CALD group shows a higher average electricity consumption than CALD households. Further, the non-CALD group shows significantly more variability in electricity consumption (range 123 MJ/day) at 15°C. On the warmest days the average electricity consumption of the non-CALD group is higher (52 MJ/day) than that of the CALD group (25 MJ/day). However, the range for the non-CALD group is much smaller (22 MJ/day) compared to the CALD group (44 MJ/day). On a 'typical' summer day, both groups show similar minimum consumption (3 MJ/day) but the non-CALD group has a slightly higher average consumption compared to the CALD group. The range of the non-CALD group is slightly higher than that of the CALD group on the 'typical' summer day.

The highest total daily electricity consumption in the CALD household group 100 MJ was presented at HH41 when the daily mean outdoor temperature was 24^{0}C. In the non-CALD group, highest total daily electricity consumption 195 MJ was presented at INT14 when the daily mean outdoor temperature was 26^{0}C Both households had solar panels, but also new recently-installed air conditioning systems in place at the time of interview. Both households are classified as 'energy agnostic' and place highest value on comfort when it comes to energy use decisions, so it seems likely that the high electricity use was driven by overnight use of air conditioning.

The lowest daily total electricity consumption in the CALD group was presented at HH32 (2 MJ) when the daily mean outdoor temperature was 16^{0}C and the lowest daily total electricity consumption was presented at HH28 (3 MJ) when the daily mean outdoor temperature was 17^{0}C. In both cases, this seems to reflect energy use for lighting and household appliances.

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=19)			
	Min	Ave.	Max	Range	Min	Ave.	Max	Range
15	4	16	31	27	5	27	128	123
18 (‘typical’ summer day)	3	17	54	51	3	23	63	60
28	6	25	50	44	41	52	63	22

Figure 68 presents a box plot comparing the daily mean total electricity consumption between the groups on days with a daily mean outdoor temperature of 18^{0}C. The interquartile range of the CALD homes (10 MJ/day) is lower than the non-CALD group (19MJ/day). Further, the median electricity consumption of the CALD group (15 MJ/day) is lower than the non-CALD group (22MJ/day). The non-CALD group shows a higher dispersion of mean electricity consumption than the CALD group. Both distributions are positively skewed.

Figure 68 Box plot for mean electricity usage on days with a daily mean outdoor temperature of 18^{0}C

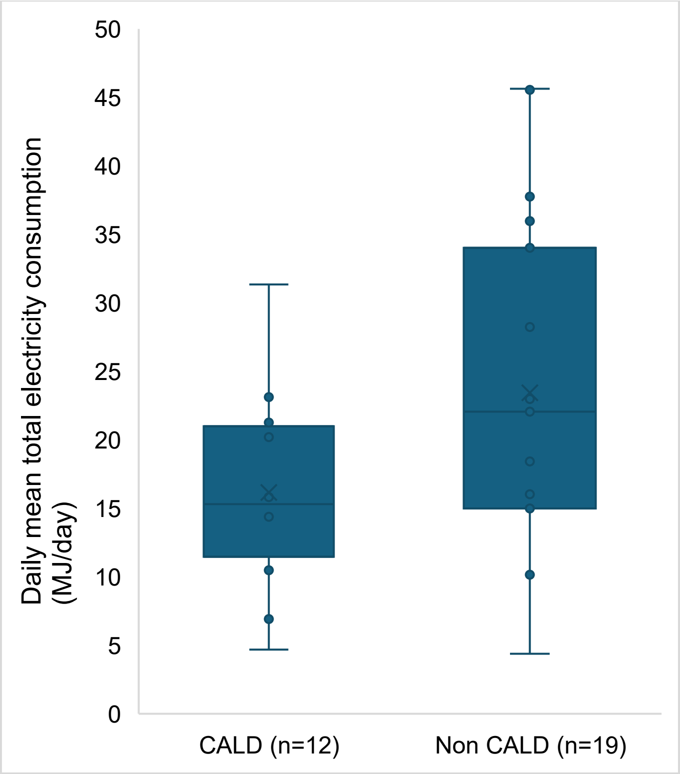


Figure 69 compares the daily mean total electricity consumption for the CALD and non-CALD groups in relation to the daily mean outdoor temperatures. The electricity consumption of the non-CALD group is higher across all temperature ranges compared to the CALD group. It starts relatively flat between 15°C and 20°C, but from 21°C onwards, there is a steady increase, with a spike after 27°C. However, in the CALD group the electricity consumption is more stable, with a slight increase after 22°C. At lower outdoor temperatures (15-20°C), both groups maintain relatively stable electricity consumption.

However, at the warmest temperatures the electricity consumption in the CALD households decreased (after 27°C) whereas the electricity consumption in the non-CALD households increased.

Figure 69 Comparison of daily mean total electricity consumption at daily mean outdoor temperatures - CALD/non-CALD

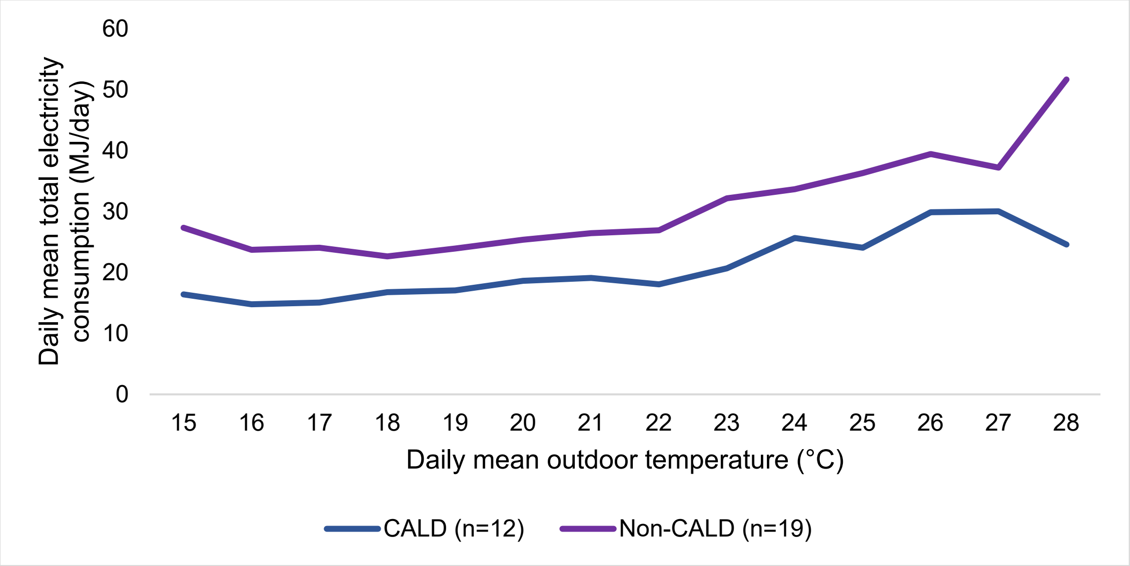


Figure 70 compares the diurnal variations in average half-hourly electricity consumption on 'typical' summer day of the CALD and non-CALD groups. The CALD group consumes less electricity than the non-CALD group throughout the day. There is a decline in the average electricity consumption of both groups in the morning with the CALD group showing a steeper drop around from 4.30 am to 7.30 am. A clear evening peak emerges for both groups, with the average electricity consumption rising sharply from around 5.00 pm, peaking around 8.00 pm. Non-CALD households reach a peak of approximately 0.789 MJ/30 min at around 8.00 pm, whereas CALD households peak slightly lower, around 0.778 MJ/30 min.

CALD home INT18 showed the highest consumption from 6.30 pm to 9.00 pm. This household included 3 adults who were typically in different parts of the house in the evening. They had a reportedly drafty Victorian weatherboard house with solar panels, no battery and an old evaporative air conditioning system which they report ran hard in the warm months because it was not effective at cooling. CALD home HH40 showed a higher average electricity use in the early morning. INT16 and HH44 had the highest electricity use from 10.00 am to 6.00 pm. Householder INT16 was a retiree in a large wooden house with no solar panels who tended to run the air conditioning system all day in the summer. Similarly, householder HH44 was in a property without solar panels and tended to run the air conditioning all day every day in summer.

HH32 and HH45 showed the lowest electricity use in the CALD group from 6.00 am to 6.00 pm. These two households are from the 'moving to all electric – multiple benefits' archetype. Despite having household members largely working from home, their daytime energy use was low because they had solar panels and heavy insulation and actively managed their homes to minimise energy use., INT12 had the lowest electricity use from midnight to early morning and from 7.00 pm to midnight. This household had young children and their lifestyle concentrated energy usage into daylight hours.

In the non-CALD group, HH34 had the highest electricity consumption during the following time periods: 1.00 am 7.00 am, 5.30 pm to 6.30 pm, 7.30 pm to 10.00 pm and 11.30 pm to midnight. Reasons for this household's high energy use are explored in detail in section 4.2.1. INT17 showed a higher electricity use in the morning from 8.00 am to 9.30 am. This was an older house built in 1970 which the householder reported to be very hot and energy inefficient. The have multiple ceiling and portable fans but no fixed air conditioning and no solar panels. INT19 showed a higher electricity use from 9.30 am to 4.30 pm. This householder worked at home during the day and runs two air conditioning units in order to keep his working space cool.

HH28 had the lowest electricity consumption from mid night to early morning and 7.00 pm to midnight. INT7 presented the lowest electricity use from 8.00 am to 5.00 pm. This was a single person household with solar panels and no battery. The property had an old evaporative cooling system, but the householder reported ‘I tend to feel the cold more than the heat. I tend to keep the place a bit warmer than a lot of people would.’ This seems to be reflected in her relatively low summer energy usage.

Figure 70 Comparison of diurnal variations of mean half-hourly electricity consumption in CALD and non-CALD household on days with a daily mean outdoor temperature of 18^{0}C

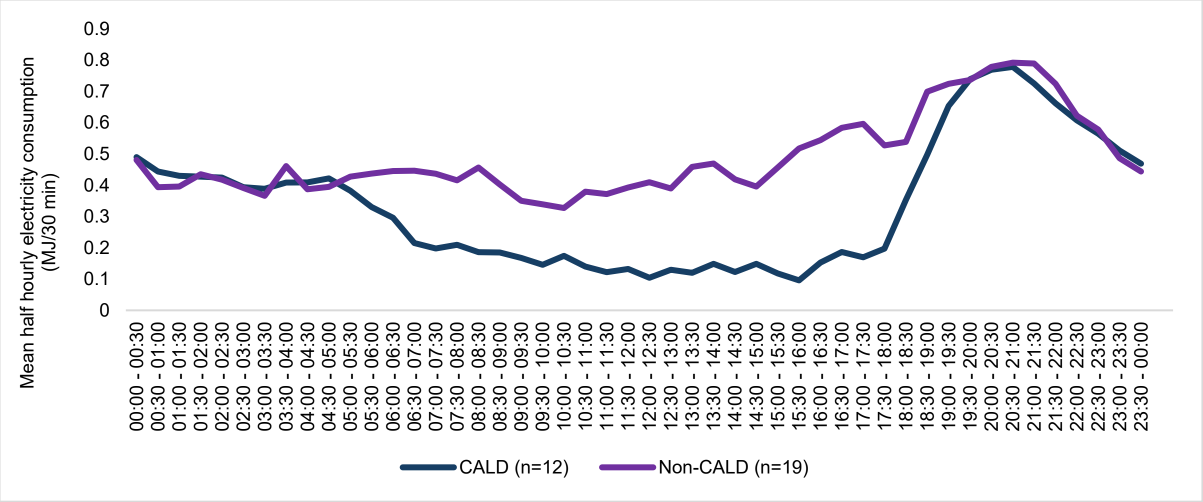
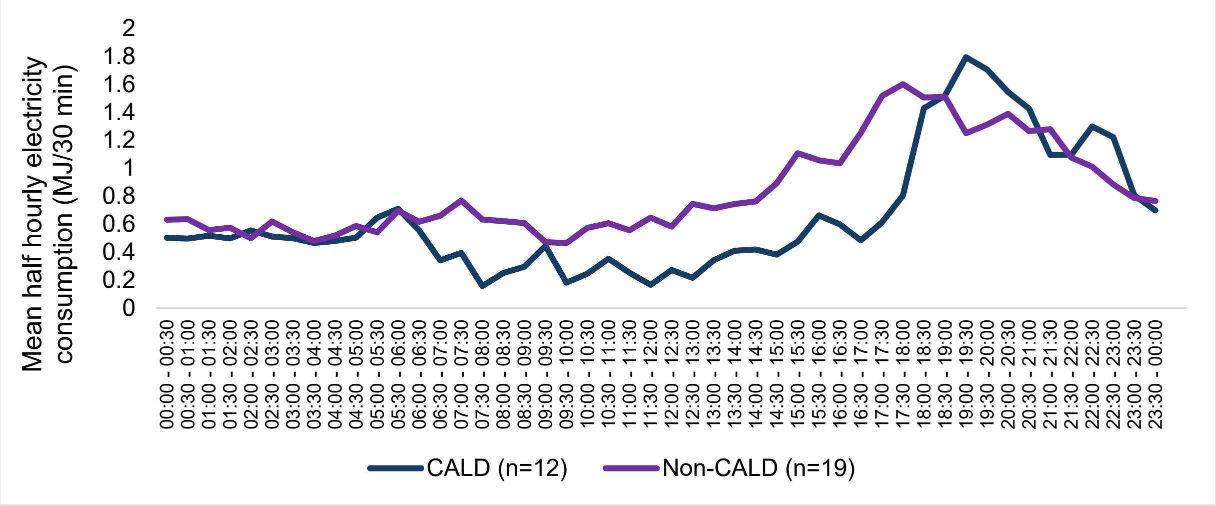


Figure 71 compares the diurnal variations in average half-hourly electricity consumption on days with a daily mean outdoor temperature of 27 ^{0}C, comparing CALD and non-CALD households. Visual analysis showed that there is an increased electricity use in both group on days with daily mean outdoor temperature of 27^{0}C. non-CALD households are still generally the higher energy users although the difference is less pronounced that at lower outdoor temperatures.

Figure 71 Comparison of diurnal variations of mean half-hourly electricity consumption in CALD and non-CALD household on days with a daily mean outdoor temperature of 27^{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 13 CALD homes and 16 non-CALD homes. The maximum and minimum daily mean living room temperatures on the coldest days and 'typical' summer days, were the same (or very similar) in both groups. The range of daily mean living room temperatures on the warmest days was bigger in the CALD group than in the non-CALD group (Table 18) because the minimum temperature was lower and the maximum temperature was higher in the CALD group compared to the non-CALD group on the warmest days.

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=13)			Non-CALD (n=16)		
	Min (°C)	Max (°C)	Range (°C)	Min (°C)	Max (°C)	Range (°C)
15	19	24	5	18	23	5
18 ('typical' summer day)	19	27	8	19	27	8
28	21	28	7	23	27	4

As shown in Table 19, the bedroom temperature data was available for 12 CALD homes and 10 non-CALD. The maximum and minimum daily mean living room temperatures on the coldest days and 'typical' summer days, were the same (or very similar) in both groups. The range of daily mean bedroom temperatures on the warmest days was bigger in the CALD group than in the non-CALD group because the minimum temperature was lower and the maximum temperature was higher in the CALD group compared to the non-CALD group on the warmest 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=10)		
	Min (°C)	Max (°C)	Range (°C)	Min (°C)	Max (°C)	Range (°C)
15	18	22	4	17	21	4
18 ('typical' summer day)	19	26	7	19	25	6
28	22	30	8	25	27	2

Figure 72 presents the box plots comparing the daily mean living room and bedroom temperatures between the CALD and non-CALD groups. The interquartile range of both groups are 2^{0}C. Further, the dispersion of the daily mean living room temperatures on days with a daily mean outdoor temperature of 18^{0}C is higher in the CALD group by 1^{0}C than the non-CALD group. The daily mean living room temperatures of CALD and non-CALD homes appeared to be right skewed. HH42 had the lowest daily mean living room temperature (21^{0}C) in the CALD group. This is consistent with their reported recently installed 13 kW solar system that they were using to run the air conditioning extensively, delighting in their expectation of no electricity bills. HH40 had the highest daily mean living room temperature (25^{0}C) on a 'typical' summer day in the CALD group, consistent with the lack of air conditioning in this home.

In the non-CALD group, HH39 had the lowest daily mean living room temperature (20^{0}C) reflecting air conditioner use. INT20 had the highest (24^{0}C) daily mean living room temperature on a 'typical' summer day in the non-CALD group. This householder described managing the temperature in his home largely by controlling solar gain and natural ventilation, seeing air conditioning as 'kind of a last resort' that is never on at night.

With regard to the daily mean bedroom temperatures, both CALD and non-CALD groups have the same interquartile range (1^{0}C). However, the distribution of bedroom temperature of the non-CALD group is smaller than those for homes in the CALD group. The daily mean bedroom temperatures of both groups are right skewed. INT16 and HH42 presented the lowest daily mean bedroom temperature in the CALD homes (21^{0}C). In both cases, this is due to high air conditioning use but for INT 16 this results in high mains electricity use (as described above) whereas for HH42, energy comes from solar panels. HH29 and INT13 had the highest daily mean bedroom temperature (24^{0}C) on a 'typical' summer day in the CALD group. HH29 has no air conditioning installed. INT13 have solar panels installed and tried to limit their electricity usage beyond the capacity of the solar system.

Several non -CALD homes presented the lowest daily mean bedroom temperature (21^{0}C) (INT4, INT8, INT9, INT15, HH39 and HH43), reflecting use of ducted air conditioning in these homes. HH22 had the highest daily mean bedroom temperature (23^{0}C) on a 'typical' summer day in the non CALD group, consistent with the construction of the property – a two story house with bedrooms upstairs and no ducted air conditioning. Local air conditioners can be used at night in the bedrooms, but the temperature can be very high there during the day.

Figure 72 Box plot for mean indoor temperature on days with a daily mean outdoor temperature of 18^{0}C

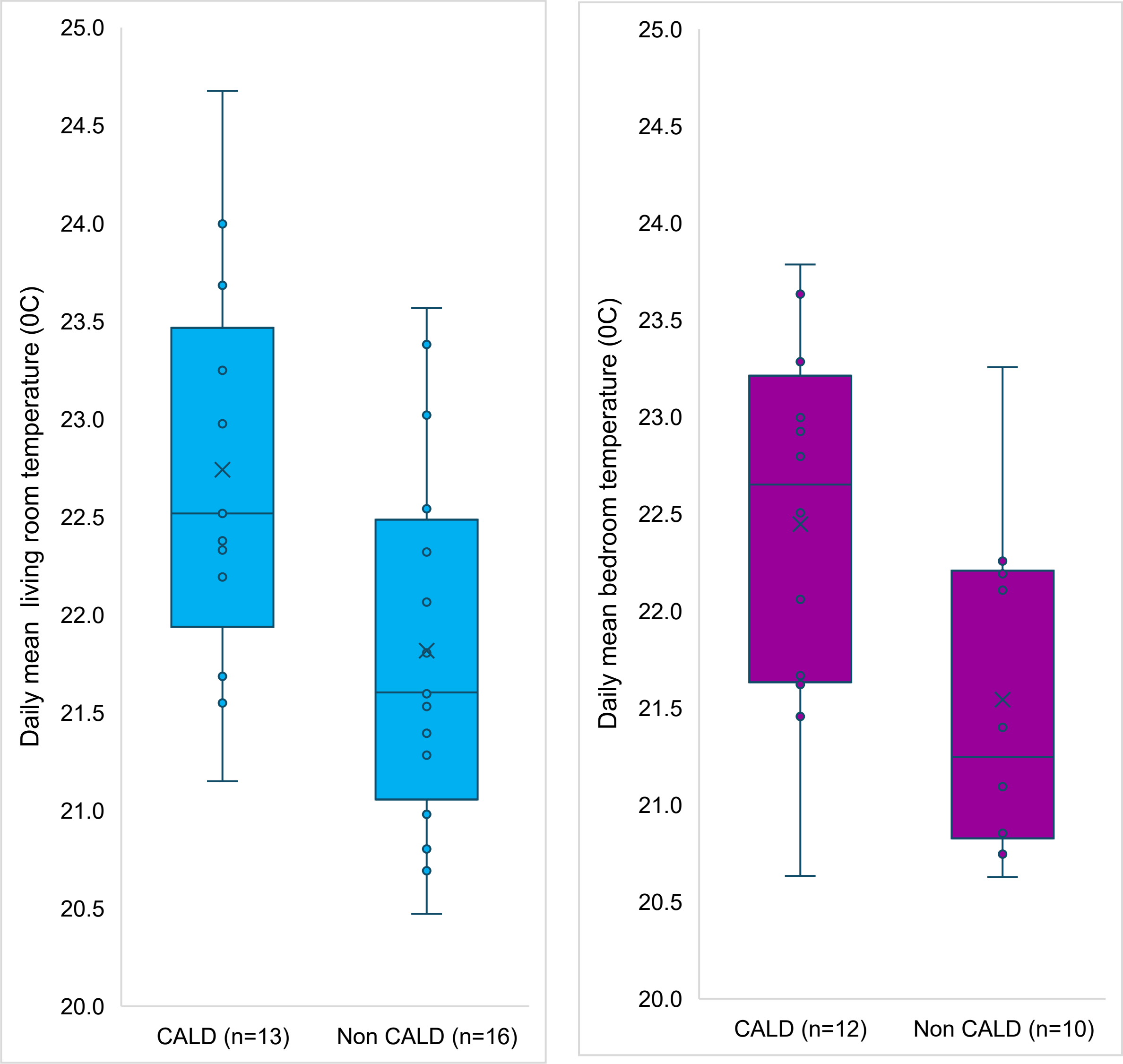


Figure 73 shows the comparison of the average daily mean living room temperatures and bedroom temperatures for the CALD and non-CALD groups in relation to the daily mean outdoor temperatures. On average, the mean daily living room temperatures and bedroom temperatures in both CALD and non-CALD household 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 in warmer temperatures. On average, the mean bedroom temperatures in the CALD homes appeared to be higher than those in non-CALD homes. There is little difference in the mean indoor bedroom temperatures of the non-CALD and CALD from temperature 24-28^{0}C. Bedroom temperatures rise more quickly with outdoor temperature for both groups because bedrooms tend to be unairconditioned during the day and in some properties are upstairs trapping internal heat.

Figure 73 Comparison of daily mean indoor temperature at daily mean outdoor temperatures - CALD/non-CALD household size

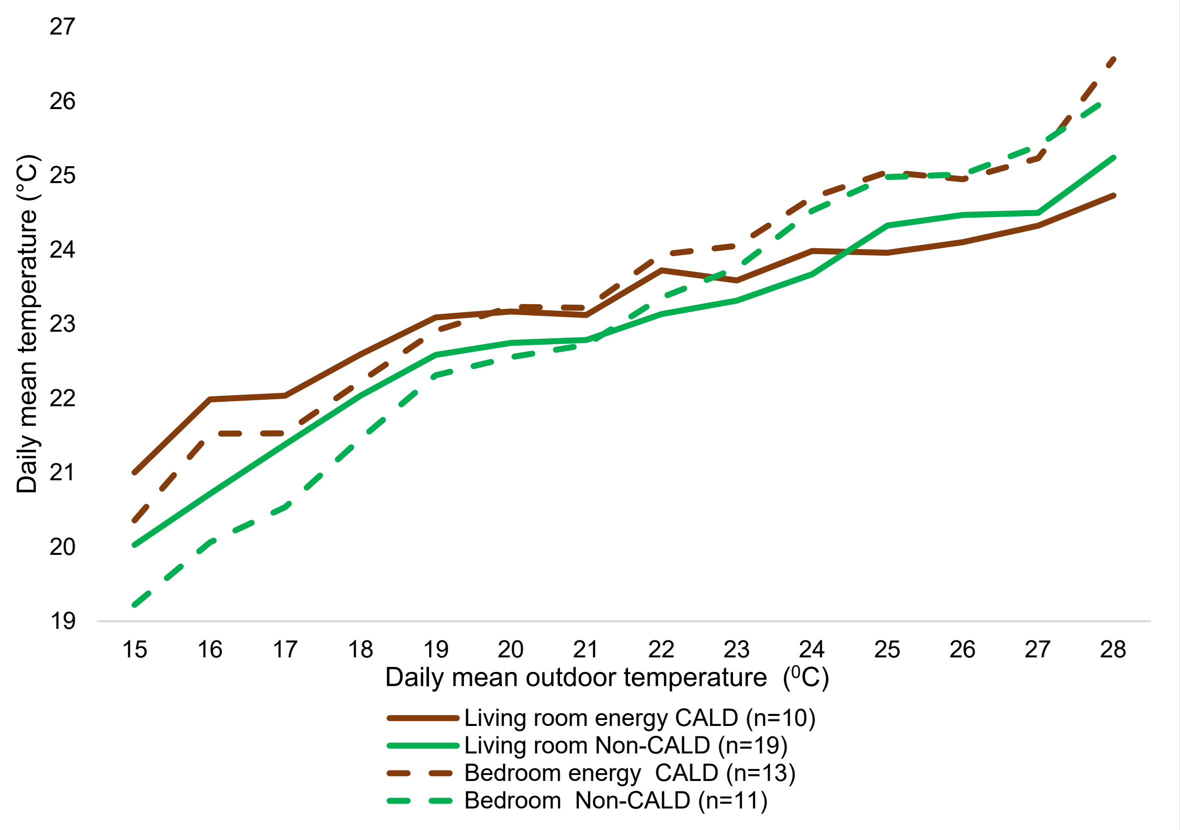


Figure 74 present the diurnal variations of mean living room and bedroom temperature on ‘typical’ September days with a daily mean outdoor temperature of 18°C in CALD and non-CALD groups respectively. Homes in the CALD group tend to be around one degree warner than non-CALD homes.

The living room temperatures in both groups drop overnight until about 7.00 am. The mean living room temperatures of both groups rise during the day and afternoon until they peak in the evening around 6.00 pm.

HH42 and HH45 had the lowest mean living room temperatures of the CALD group during typical summer days. As already described HH42 runs their air conditioning from a new solar system. Consistent with their lack of air conditioning, HH45 only has evaporative cooling but they manage their home closely to keep heat out on the hottest summer days. HH40 had the highest mean living room temperatures of the CALD group during typical summer days due to the lack of air conditioning in this home. HH32 had a higher mean living room temperature from 11.30 am to the evening on typical summer days. This home has cooling installed but it is not used much as the householders felt that ‘Melbourne doesn’t get that hot’.

In the non-CALD group, HH39 had the lower mean living room temperature. INT20 had the higher mean living room temperatures as described above. INT15 and 17 had a peak in the living room temperature 5.00pm to 8.00 pm.

The mean bedroom temperatures of both groups drops over night until about 8.00 am and rise during the day and afternoon until they peak in the evening around 6.00 pm. Overall, the bedroom temperatures of the CALD group are higher than the non-CALD group.

INT16 had lower mean bedroom temperatures in the CALD group throughout the day during typical summer days due to high air conditioning use. HH29 had the highest mean bedroom temperatures of the CALD group throughout the day during typical summer days due to no air conditioning installed. HH45 had a peak in the evening on typical summer days.

In the non-CALD group HH39 and HH43 had the lower mean bedroom temperature and INT20 and HH22 had a higher mean bedroom temperature throughout the day for reasons described earlier.

Figure 74 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 18^{0}C

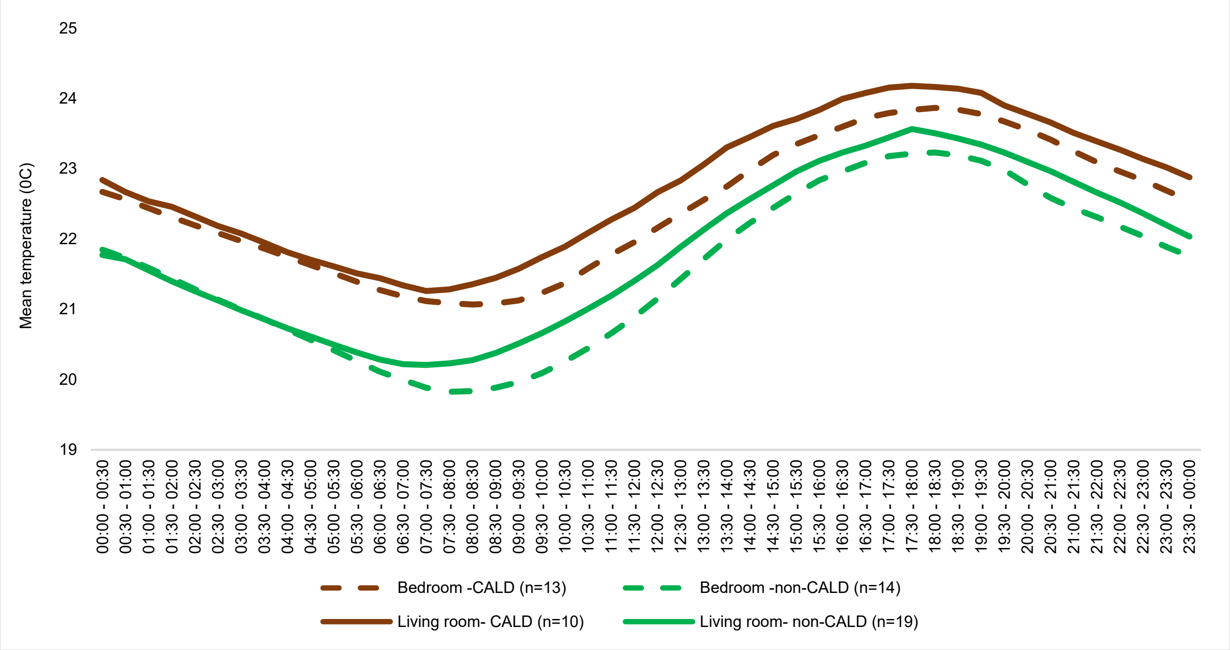
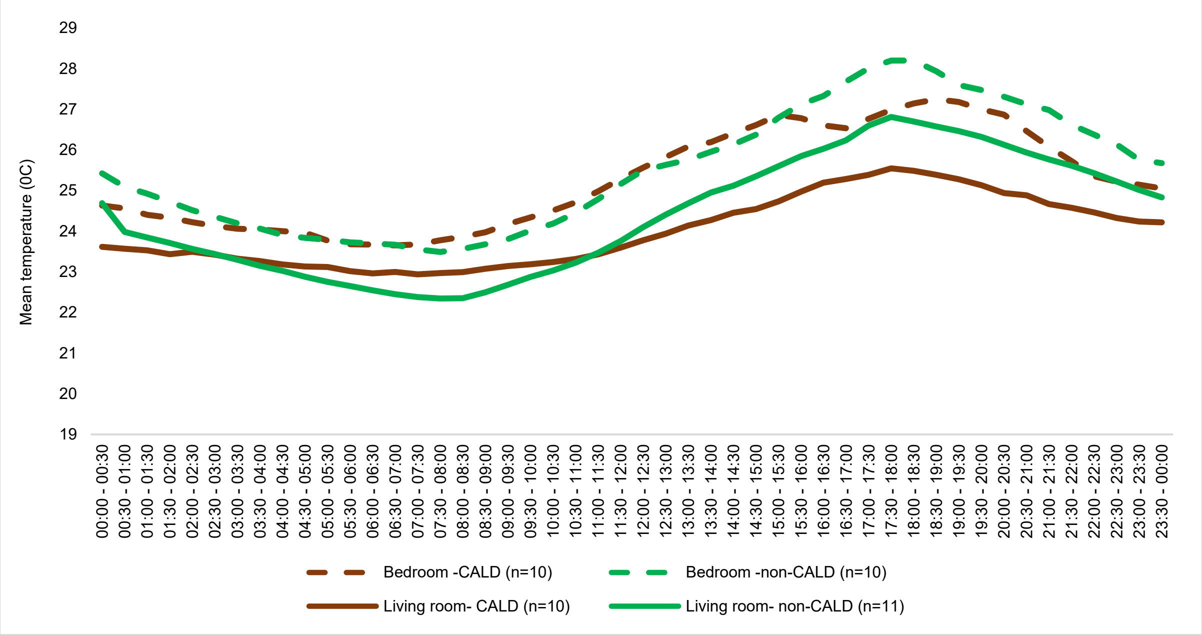


Figure 75 compares the diurnal variations in average half-hourly indoor temperatures on days with a daily mean outdoor temperature of 27^{0}C, comparing CALD and non-CALD households. Visual analysis showed that while the same diurnal variation is seen as on a typical summer day, the overall indoor temperatures are hotter and the difference between CALD and non-CALD households apparent for a typical summer day are no longer seen on the hottest days.

Figure 75 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 27⁰C



7.4 SUMMARY

The CALD status of households is not a strong determinant of their gas usage during summer. Mean daily gas use is slightly lower for CALD households compared to the non-CALD group across all outdoor temperatures. The effect is not strong and review of the qualitative data does not suggest there are cultural factors driving this result.

Both CALD and non-CALD households show morning and evening electricity usage peaks but electricity use for CALD homes is lower on average during the working day. This is seen on a typical summer day and also on the warmest days. The CALD households were younger on average and so are more likely to be away from their homes during the working day. The non-CALD group included more older and retired people who were at home all day. There is also some qualitative data to suggest that CALD households are more heat-tolerant than non-CALD households. For both groups, electricity consumption rises with increasing outdoor temperature. On average non-CALD households use more electricity across all outdoor temperatures.

The indoor temperature data supports the electricity use data showing that on a typical summer day, non-CALD households are slightly cooler than CALD households showing that they are more likely to use air conditioning than CALD households. At higher outdoor temperatures, this difference is no longer apparent showing that on the hottest days, all households use whatever air conditioning facilities and practices that are available to them.

These finding are consistent with the winter data reported in interim report #3 which showed that the CALD group in our sample used more heating (reflected in higher gas use and warmer bedrooms) but showed lower daytime electricity use, perhaps due to the younger age of the group and so more time spent away from the home.

8 Discussion

The following discussion draws upon data and analysis outcomes from both the winter (Interim Report #3) and summer (this report) data and presents it across the four key demographic categories applied in both reports.

8.1 Dwelling type – efficient and non efficient

Whether or not a household has an energy efficient house is a predictor of gas use on average in winter and summer i.e. households with an energy efficient design use less gas on average than those with a non-efficient design. However, there is substantial overlap between the two groups and household practices play a large role in determining gas use and outdoor temperature also plays a role. In winter 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. However in summer, while average gas use was around half for efficient houses compared to non-efficient houses, efficient houses also recorded the highest gas consumption on a typical summer day.

Both groups show a peak in gas use in the evenings during winter 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 in winter. This is exacerbated by the apparent desire for householders with non-efficient homes to heat their houses in winter 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. In summer there tended to be a slight morning and evening gas peak which was less pronounced on 27^0C days compared to 18^0C days.

Whether or not a household has an energy efficient house is also a predictor of electricity use on average in winter and summer and this applies across all outdoor temperatures. Generally speaking, households with high electricity consumption are those that use (mainly) electric heating options in winter, but this is not always the case. The household with the highest gas consumption also shows the highest electricity consumption. In summer average electricity consumption was significantly lower for all outdoor temperature ranges for efficient housing compared to non-efficient housing, with lower minimum and maximum consumption also recorded. Variation in electricity usage during the day follows a similar pattern to gas usage in winter. 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. In summer while electricity consumption is similar for both house types from 11.00 pm to 5.30 am there is a significant reduction in electricity consumption of efficient compared to non-efficient dwellings for the remainder of a typical 18^0C day. For both types electricity consumption sees a slow increase throughout the afternoon which increases more significantly around 3.00 pm with a peak around 9.00 pm. For a 27^0C day the electricity profile is more similar for both types although the efficient dwelling uses less electricity in the middle of the day.

The efficiency of the home design was not a good predictor of indoor temperature.

8.2 Household size – low and non-low household size

While household size is a predictor of gas use on average in both winter and summer i.e. households with fewer people use less gas on average, specific circumstances can have a significant impact. In winter 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 and impact overall gas consumption. 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. This is similar in summer where appliances also influenced outcomes. For example, non-low households with a solar-powered gas booster hot water system generally consuming less gas than a low household size with a traditional gas storage unit.

Additionally, households transitioning to electric appliances tend to exhibit lower gas consumption patterns.

Both groups show a peak in gas use in the evenings in winter 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 in winter. More of these households are working families with a distinct daily routine that the entire household prepares for in the early morning. In winter 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. In summer gas usage often peaks in the mornings and evenings when residents prepare for the day, leading to increased demand for hot water and cooking. On a typical summer day, the maximum gas consumption was the same for both demographics, with very similar average values.

Many households in this study utilised gas stovetops for cooking, contributing to overall gas consumption. Generally, as the number of residents in a household increases, so does the gas consumption for cooking. However, not all residents with gas cooktops use them regularly; some prefer electric appliances, such as rice cookers or air fryers, specifically chosen to reduce gas usage for moral or practical reasons. For example, one mother and her disabled daughter actively aimed to lower the home's indoor temperature, which led them to use the gas stovetop less frequently.

In contrast, overall electricity use is not a function of household size in our sample in winter. Electricity use in winter is dominated by other factors such as use of electric heating or a continuously running a spa heater. Variation in electricity usage in winter during the day follows a similar pattern to gas usage. Both groups show an evening winter 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. In summer the data reveals that low household sizes generally lead to lower total electricity consumption compared with non-low households. However, the minimum daily summer electricity consumption was greater in low household sizes than in non-low ones; however, the maximum consumption was higher in non-low households.

In winter, 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. However, in summer in non-low household sizes, there was a significant temperature difference between households' living areas and bedrooms, especially those with bedrooms on a second storey. Participants in the low household demographic were generally conscious about not using mechanical air conditioning, tolerating or enjoying warmer indoor temperatures, and often defaulting to passive cooling methods, such as closing blinds and opening windows in the evening. This behaviour was reflected in the total amount of electricity consumed against outdoor temperatures. Non-low households consumed significantly more electricity as outdoor temperatures increased from the mid to high 20s.

Interestingly, residential occupancy did not always correlate with energy consumption in summer. Some households with residents at home all day during the week resulted in lower energy consumption than those whose residents were absent during the 9 to 5 workday. This difference in daily living temperatures between low and non-low households could reflect more energy-efficient homes. Households with the lowest energy consumption actively chose not to air-condition their homes. Most household energy use involves electric ovens and cooking appliances, indicating that cooking is not a major contributor to electricity usage compared to cooling, which plays a major role in determining overall electricity consumption.

Household size is not a good determinate of electricity consumption compared with gas.

8.3 Annual income – low, mid, and high

There were mixed outcomes across summer and winter analysis in relation to income and household energy consumption. In winter 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 in winter. 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.

However, in summer the results found that despite having a higher salary, high income groups used the least gas. Some also monitored gas consumption and considered moving away from gas due to increased prices. Households with the highest use of gas, typically had gas heating and hot water systems. Despite being summer, the higher gas use suggests that households were perhaps heating homes on cooler summer mornings and evenings.

On average, the largest users of electricity were the middle income group in winter and the low and middle income groups in summer. In winter low income groups indicated concern about cost and tend to try to use less electricity due to concerns about energy bills. Given that there were low and middle income earners who had solar panels on their dwellings but had high summer electricity consumption it suggests that household practices, as well as solar panels, can be significant. For example, the choice to constantly heat a spa to 37/38^{0}C all year round in one household. All income groups use less electricity as outdoor temperature increases, this relationship is strongest for low income households and weakest for high income households.

For high income households they 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 in both summer and winter. Despite having higher income, they still reported household practises that reduced power consumption if deemed unnecessary (e.g. turning lights off).

Household income was not a good predictor of indoor temperature in winter, with living room temperatures being similar across the different income categories and bedroom temperature being lowest for the middle income category. In summer indoor temperatures across the income groups were within a 1^{0}C range on days with a daily mean outdoor temperature of 18^{0}C in both bedroom and living room temperatures. It is not until over 23-^{0}C daily mean outdoor temperatures that more varied differences can be observed. These become clearer especially in the low-income group at a 27^{0}C daily mean outdoor temperature, where there is a difference in daily mean temperature of 23.7 degrees in the living room and 26.2^{0}C in the bedroom. This then spikes to over 30 ^{0}C in the bedroom at a 28^{0}C daily mean outdoor temperature. In some low-income homes, they had air-conditioning within these rooms, but chose instead to use cheaper operating alternatives, such as fans, blinds and shuttering.

8.4 Cultural and linguistic diversity – CALD and non-CALD

The CALD status of households is not a strong determinant of their gas consumption in winter or summer. However, there are some differences between CALD and non-CALD groups. While the variation is not significant, CALD households tend to use more gas in winter than non-CALD households as the outdoor temperature drops. This may be cultural with some CALD households who come from warmer locations finding Melbourne winters hard and so use high levels of home space heating. This is reflected in higher gas consumption and warmer bedrooms. However, in summer the data does not suggest that there are cultural factors driving the daily gas use which is slightly lower for CALD households compared to the non-CALD group across all outdoor temperatures result. Both CALD and non-CALD households show morning and evening gas winter usage peaks with no major differences.

When it comes to electricity use, non-CALD households show higher use but also more variation in use during winter. For both groups, electricity consumption falls with increasing outdoor temperature suggesting there is not a high reliance on electric heating to provide warmth. In summer, both CALD and non-CALD households show morning and evening electricity usage peaks but electricity use for

CALD homes is lower on average during the working day. This is seen on a typical summer day and also on the warmest days. There is also some qualitative data to suggest that CALD households are more heat-tolerant than non-CALD households. For both groups, electricity consumption rises with increasing outdoor temperature. On average non-CALD households use more electricity across all outdoor temperatures.

The CALD households were younger on average and so are more likely to be away from their homes during the working day. The non-CALD group included more older and retired people who were at home all day. However, this does not seem to explain why there is higher gas consumption for heating in winter and lower electricity consumption in summer.

CALD status is not a good predictor of living room temperature across summer and winter, 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. In summer, the indoor temperature data supports the electricity use data showing that on a typical summer day, non-CALD households are slightly cooler than CALD households showing that they are more likely to use air conditioning than CALD households. At higher outdoor temperatures, this difference is no longer apparent showing that on the hottest days, all households use whatever air conditioning facilities and practices that are available to them.

9 Conclusions and Implications

The objectives of this study were 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.

Implications of the data and analysis will be discussed for these below.

The data found that household consumption of energy was influenced by different factors including efficiency of the dwelling, annual income and CALD households. While non-CALD higher-income households in newer more efficient housing consumed less energy overall there were variances across different characteristics as discussed above. Across all households though there were a range of practices implemented in relation to balancing electricity and gas services. In most instances it was not a question of which energy to use but more about when and how to use each appliance to deliver the expected outcomes, e.g., warmth, cooking, hot water.

Improved thermal performance of housing (i.e., newer housing built to higher minimum regulatory standards) were found to reduce energy consumption for thermal comfort compared to older less efficient housing. However, this was not always the case and occupant practices for heating, cooling and cooking as well as cultural preferences and the efficiencies of the appliances used had a significant role to play in overall energy and thermal comfort outcomes. With changes to the National Construction Code in 2022 increasing minimum performance requirements from 6 Stars to 7 Stars, as well as the inclusion of appliance efficiencies in the Whole of Home tool, this should improve thermal performance and reduce energy consumption for thermal comfort for occupants in new housing moving forward.

However, as the data in this study shows, there will be variances based upon other factors in terms of how this translates in reality. As new housing moves to 7 stars and beyond there may need to be consideration about the range of thermal comfort outcomes that drive overall energy consumption. For example, CALD participants who had come from locations which were generally warmer found themselves using more heating during winter to stay warm. While it might not be possible for the National Construction Code to consider all cultural backgrounds and thermal preferences there may be a need for minimum heating and cooling requirements across a dwelling to allow for individuals to adjust thermal comfort to meet their own needs or to recognise that there may be additional energy consumption for those who want to use additional (e.g. portable) heating and cooling systems. As the climate changes the additional energy requirements for heating and cooling could be significant.

While there have been improvements to minimum performance requirements from new housing there will need to be a focus on retrofit of existing housing as well over coming years. Retrofit can significantly improve thermal performance and reduce energy consumption of existing dwellings. This needs to be considered as part of any wider transition of decarbonising the energy network to ensure it can be delivered efficiently and effectively and to enhance affordability and other benefits for households. Some states like Victoria offer a range of rebates and subsides for replacement of old appliances with more modern energy efficient versions. There are also incentives through this replacement of appliances to transition away from gas although as the data found there is a strong attachment to gas from some households who may not be as willing to shift energy sources. Additionally, households who spoke about updating or replacing appliances typically did so when those appliances stopped working properly, and there was often an urgency to replace the appliance. This meant household would often default to what the tradesperson suggested they replace the appliance with, rather than exploring what the full range of options might be.

As more efficient housing is developed there may be impacts on the types of technology included which could have implications for performance, affordability and overall energy consumption. For example, there may be an opportunity to have smaller heating and cooling units which typically cost less to purchase and may result in less overall energy consumption and therefore lower energy bills. The way technologies are used may also shift, for example with heat pump hot water systems able to heat water when energy prices are lower or when there is onsite generation from renewable energy. Pre-cooling using reverse cycle air conditioners is another idea being explored in Australia to utilise high levels of residential solar. This involves putting on household reverse cycle air conditioners earlier with the aim of smoothing energy impact on the wider grid during hot days.

Increasingly, households are adding solar panels to their dwellings which the data from this study showed help reduce overall energy purchased from the grid. Solar panels can help reduce purchased energy in both summer and winter and help reduce energy bills. There is an increasing number of households in Australia who are installing battery storage systems which could offer further sustainability and affordability benefits in the future, especially as the price of battery storage decreases.

The data shows that there will be ongoing challenges with managing peak energy loads. Energy usages were usually characterised by bi-modal diurnal patterns. In winter the peaks were in the morning and evening and for summer, electricity use tended to build from mid-afternoon until late evening. A transition to future fuels must ensure that this can be delivered, or work towards ways that smooth energy peaks. An alignment of electricity supply and demand may be more critical if there is an ongoing push to electrifying homes. Battery storage is one opportunity where peak energy could be smoothed or shifted to help the wider energy network and reduce energy costs. However, there is also likely a need for households to play a more active role here and change some of their energy practices to better align with a future fuel energy network.

Low-income households have previously been identified as being at higher risk of energy poverty both in terms of affordability but also consuming enough energy to achieve basic levels of thermal comfort and liveability. The data in this study shows that there are challenges for low-income and perhaps mid-income households in terms of their energy consumption and affordability. For example, the winter gas data found that low-income households did not vary their gas consumption as temperature dropped outside, whereas middle- and higher-income households increased their gas consumption. This raises issues around low-income households being able to maintain a safe indoor temperature and potential impacts for health and wellbeing. There will need to be ongoing and increased support to help low-income households in a transition to future fuels to ensure they are not further disadvantaged. This support should not just be around reducing the cost of energy but also helping to improve the performance of their dwellings through retrofit to ensure that improved thermal comfort with less energy input can be achieved. Such assistance may be extended to mid-income households, as they tended to be the highest gas and electricity users in summer. All households, regardless of income, were conscious of saving energy to reduce costs.

With regards to culturally and linguistically diversity, the qualitative data suggested that householders perceived differences in thermal sensitivity between themselves and their Australian friends, which translated into warmer homes in winter and summer. This difference in adaption to the cold or heat seemed to be more pronounced among adults than children. This has implications for forecasting of energy use, as ethnic background can predict energy use patterns in suburbs (Leslie et al. 2022). However, coming from a warmer country of origin may also then translate into higher energy costs, especially in winter. On the other hand, lack of air conditioning or reluctance to use it may also expose adults and children to heat stress, as has been observed in previous work (Hansen et al. 2013). Public awareness and retrofit campaign may find it useful to tailor their measures to the practices of ethnic groups.

The study also suggest that a key vulnerability may be the age of householders. Age was not a criterion used to differentiate between households in this study, however, we suggested that age of householders may explain some of the quantitative outcomes in winter and summer. Age seemed to influence cold tolerance. Being more sensitive to cold seemed to increase heating use and decrease air conditioning, yet energy demand was higher in winter. Older people also seemed to be overrepresented in the low household size group and be negatively affected by a legacy of older, resilient but energy inefficient white good appliances. Low-income older people may, thus, carry the two burdens of increasing energy and living costs. Younger households with children may be equally vulnerable, carrying the double burden of higher mortgage rates and living costs. Measures are needed to reduce the vulnerability of both these population groups.

As we identified earlier in the research, there were a range of different household archetypes in relation to considerations around energy. This included many households that were energy agnostic, and valued energy outcomes rather than the energy carrier. For some though there was a connection to the energy carrier which came out most strongly for gas heating and cooking. Some of this related to cultural or historical ways of heating and cooking, while for others it was that there was an unknown about other technologies or even a dislike for how they operated. This has implications for the decarbonisation approach for housing to ensure that households understand why the transition is occurring and what the implications are for them. The concerns from some households about electrification may also be prevalent for other future fuels. More research would be required to explore that.

10 Next steps and future works

This work is now available for use by FFCRC participants. The raw data on which this analysis is based will also be banked for future reference. Details will be determined as part of the FFCRC transition plan.

11 References

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Leslie GW, Pourkhanali A and Roger G (2022) 'Electricity consumption, ethnic origin and religion', *Energy Economics*, 114, doi:10.1016/j.eneco.2022.106249.

12 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	Not 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 (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
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

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