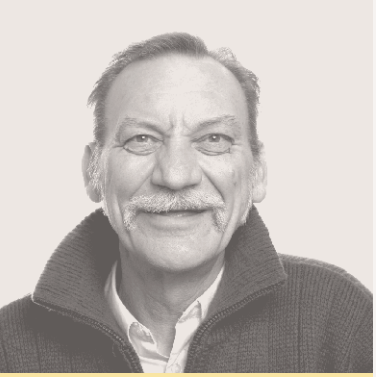

Australian Government
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GET BILL SMART

DETAILED STUDY REPORT

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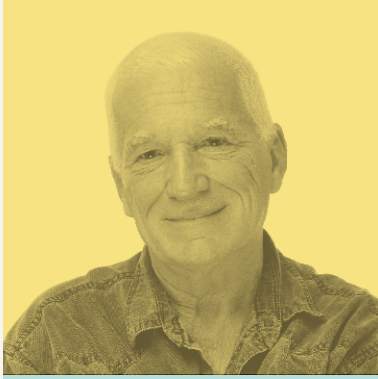

GET BILL SMART

DETAILED STUDY REPORT

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This activity received funding from the Australian Government. The views expressed herein are not necessarily the views of the Commonwealth of Australia, and the Commonwealth does not accept responsibility for any information or advice contained herein.

Please note: There were time constraints that restricted report development. There is more we could say. If interested, please contact the authors to discuss the report and its underlying data further.

This report also uses stock photography rather than photos of actual participants.

Graphic design by Poco People, Hobart.

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1. Introduction

This report, The Detailed Study, provides in-depth examination of participant households and the change that occurred for these households after Get Bill Smart (GBS) program involvement. The report presents the methods and findings from qualitative and quantitative detailed research conducted with 51 of the households involved in the broader GBS project. The aim of The Detailed Study is to gain further insight into energy efficiency and thermal comfort behaviours through more nuanced understanding of the conditions that householders experience, the changes (outcomes) that occur over the GBS study period, key influences affecting those changes, and trade-offs made between energy use and comfort.

The Detailed Study enhances understanding of:

- home energy consumption and energy efficiency change outcomes
- home thermal comfort management and performance changes
- housing conditions participants live with that influence their thermal comfort and energy consumption
- affordability related to energy use and thermal comfort
- health and wellbeing and its relationship to energy use and thermal comfort
- trade-offs participants make when there is an opportunity for comfort improvement or energy saving
- comparative effects of GBS support approaches, and
- the context of low income householders and how it affects energy use, energy efficiency and thermal comfort in the home.

This is one of four reports produced on Get Bill Smart activities and outcomes. The other three are:

1. The Bulk Study
2. Cost benefit analysis, and
3. Organisational report.

These four reports make up the majority of the final report submitted for the Get Bill Smart project. The Detailed Study contributes to the GBS objectives of: comparing outcomes of the approaches and support activities trialled; understanding how a community capacity approach can assist energy efficiency; understanding key processes and determinants that lead to energy and comfort changes; and understanding how energy and comfort outcomes are utilised by low income householders. Overall GBS is working to advance understanding of energy use and thermal performance to improve the design of support activities for application in Tasmania and Australia.

Participants in GBS are divided into four approaches:

1. In-home education and upgrades (EDUG)
2. Community capacity building (CCB)
3. In-home education and upgrades and community capacity building (EDUG+CCB)
4. Representative group (the no activity, baseline comparative group) (REP)

Essentially in these four groups GBS tested two key approaches to energy efficiency support: Community capacity building with local energy champions, and in-home education and upgrades supported by expert sustainability assessors. The 51 households who participated in this detail part of the study were drawn from all four GBS approach groups in roughly equal numbers so that differences in the approaches could be compared.

Research methods used for the Detailed Study were both qualitative and quantitative. As Foulds et al. (2013: 627) have previously observed, the use of both types of data "provides the depth required to reflect suitably on data collection, theoretical application and analysis-related issues". Change outcomes are examined by comparing key indicators before GBS energy efficiency activities and again after the activities, and through comparisons between the GBS approach groups. The quantitative data collection involved monitoring of household's electrical consumption and temperatures inside and outside the house, over a 15-month period. The electricity and temperature monitoring period was across two winters in order to establish 'before' and 'after' periods of cold weather. The qualitative methods involved before and after interviews with householders in addition to the surveys conducted across all GBS households. Electricity billing data, gathered for all participants in GBS, is also referred to in this report.

Detailed study findings are presented in two ways: as individual case studies and as comparative (summative) analysis. Each participant household is described in an individual case study. Each case study describes key characteristics of the participant household, the physical house conditions relevant to the energy/comfort focus, outcomes of the energy efficiency support activities; key influences that affected those outcomes; critical contextual and community considerations; and key domestic considerations within the household. The richness of information presented in this way, while not statistically significant, allows examination of varied cases and reveals critical dynamics (differences) in experiences house to house.

A case-based approach, such as we have used, has recently been applied by Gram-Hassen (2010) to understand variation in residential heat comfort practices and energy use across households. By pulling together quantitative aspects of the home with personalised dwelling experiences we are able, as Ellsworth-Krebs et al. (2015, 100) suggest, to "adopt the home (and all the baggage the term comes with) as the focus for investigation, highlighting an appreciation for the socio-technical nature of domestic energy demand".

Comparative summary analyses identify outcomes for different approach groups and outcomes according to key indicators. Comparisons are presented in tables with interpretation. These comparisons:

- illuminate influential relationships between housing/heater performance and electricity use/comfort outcomes
- present outcomes of the four different GBS approaches, and
- assist, in conjunction with case study analysis, to develop overall detail study findings.

In order to compare cases, the Detailed Study includes only the detailed participants that took part in the main study proper and were part of one of the four approaches described above. 'Energy Champion' (EC) households are not reported here. The 12 EC households took part in similar research processes to detailed participants but, due to program delays at the outset of the project, the monitoring period for the ECs was a non-winter period. Hence, quality data regarding heating could not be collected from the EC household group. The 12 EC households became a very valuable testing ground for detailed research processes. Understanding from researching champion households was fed back into the research processes for the detailed study.

In this report we present all stages of the detailed study by first outlining methods used for quantitative and qualitative data collection and combined analysis; then presenting detailed case studies and comparative analyses; and, finally, presenting a discussion of findings and conclusions.

2. Detailed data collection and analysis methods

This section outlines the methods used to collect, process and analyse data for the detailed component of the Get Bill Smart project. Both qualitative and quantitative data collection methods were used, in a mixed-method approach in order to construct more detailed understanding of: (i) home thermal and energy performance (before and after support activities in homes); (ii) the contributions to change in home thermal and energy performance outcomes; and (iii) people's knowledge and practices around managing energy and comfort in the home.

The detailed study was conducted with 51 households. The 51 households who participated in this detail part of the study were drawn from all four GBS approach groups in roughly equal numbers so that differences in the approaches could be thoroughly investigated. Over the investigation period numbers in various approaches did shift somewhat because of house moves and the length of monitoring periods for people who moved (EDUG 12 households, CCB 16 households, EDUG + CCB 11 households, and REP 12 households). These participant households were involved in the detailed research process between May 2014 and late September 2015. Data for the detailed component of the study was collected via multiple data collection tools, namely:

- semi structured longitudinal interviews with householders (one before GBS support activities and one afterwards)
- logging of household electricity use and the thermal performance of houses through sensors placed in the homes (placed in the home at the 'before' visit and removed at the 'after' visit)
- an interim check-in and sensor-swap visit
- observations of physical housing features affecting thermal performance and energy use (during 'before' visits), and
- surveys before and after GBS support activities.

The analysis is conducted using a before/after overlay so that we can ascertain one year's cold period activity with the next year's cold period activity.

2.1 Ethics and privacy guidelines

The research team obtained ethics approval for the project from the University of Tasmania's Social Science Human Research Ethics Network (Tasmania) through application H0013682. After an Expression of Interest was received from an applicant and their suitability for GBS had been established, applicants were provided with a package of forms. This pack included the GBS (UTAS Human Ethics) Information Sheet, the UTAS Human Ethics Consent Form, the Federal Government Privacy Form, Landlord Consent Form, Billing Data Form and Permission to Use Photos Form. Once these forms had been returned, participants were then formally accepted into the program and allocated into the four different research groups. SLT were often the main contact with landlords and assisted to gain landlord permissions. Detailed Study participants were contacted by UTAS and researchers arranged to visit the home, install the data loggers, conduct the interview and, if the survey had not been returned, make sure it was done.

2.2 Household data Collection timeline

UTAS researchers and data consultants (the researchers) visited each participant house three times. At initial visits (in May to July 2014) electricity and temperature logging equipment was installed, house observations were conducted and 'before' interviews were held. Interim visits (held in February 2015) provided an opportunity to check logging equipment, collect and replace temperature/humidity loggers that were full of data and helped to maintain contact with participants. At the interim visit checks were made on changes to appliances and their use; and, notes were made about relevant changes to household practices or the changes to the fabric of the house itself. At final visits (in August and September 2015) logging equipment was removed, changes to appliances and their uses were noted, 'after' interviews were conducted, participants were thanked and final vouchers were given. An electrician accompanied the researchers

to the initial and final visits to houses in order to install and then remove electricity loggers in/from meter boards.

Figure 1: Timing of research activities for the Get Bill Smart Project shows the process of data collection over time.

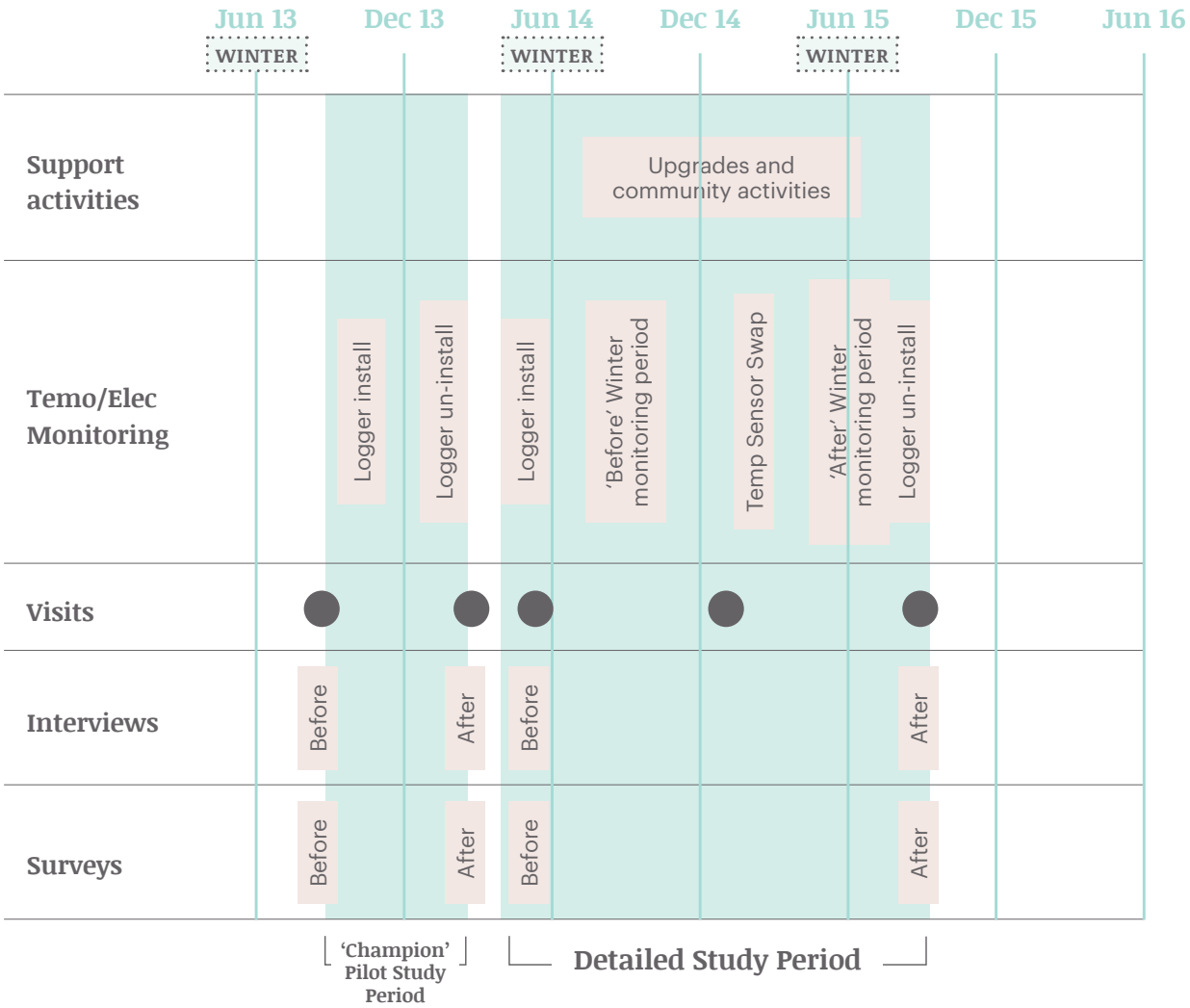


Figure 1: Timing of research activities for the Get Bill Smart Project

Standard information sheets and consent forms were provided to participants as per GBS ethics and Australian Government privacy requirements. In addition, information sheets about the logging equipment were given out at initial visits to Detailed Study participants. These sheets provided explanations of the equipment, what it was recording and contact numbers for researchers.

Grocery vouchers played an important role in the GBS project. Vouchers were given to participants as they completed key stages of the research. Extra vouchers were given to detail participants (more than were given to bulk study participants) to compensate them for the extra time involved in participation and for looking after the-home logging equipment. As with bulk participants, participants in the detailed study received different amounts of vouchers depending on the GBS approach they were part of. For further information on vouchers see the Get Bill Smart Final Report Overview.

2.3 Quantitative data logging and processing

Quantitative logging, data processing and analysis were undertaken for all households in the Detailed Study group. Quantitative data collected included temperature, humidity and electricity use, providing the opportunity for calculation of changes occurring over the life of the GBS project. Electricity billing information was also collected from the electricity power supplier.

Data logging processes were trialled in the houses of the community champions involved in GBS before roll out into detail participant houses. Problems with logging technology and processes identified during the champion logging phase were corrected before the roll out of loggers in detail households (Sustainable Living Tasmania, University of Tasmania et al. 2013). The collected temperature and electricity data allowed the research team to calculate average winter temperature changes (°C); average winter heating power consumption (kWh/day); average winter heating efficiency (°C/kWh/day); and, other significant thermal and electrical use changes in each house.

At each household, during initial consultation with the householders about logger installation, researchers were able to learn more about how each participant's home functioned – for example which rooms were coldest, whether children were likely to pull out power cords, which beds had electric blankets and which heaters were never used. This process built on insights gathered through the interviews and home observations, facilitating discussions about how the home functioned technically and socially.

Logging periods began when loggers were installed into a house and were recorded as finished when loggers were removed. This means that every house has different overall logging periods. Logging periods for electrical and temperature/humidity loggers *within* any given house were the same. Periods over which logging occurred in each house are listed in Table 1. Logging periods generally lasted for about 14 or 15 months, but some logging periods were shorter because households moved. Loggers were removed early when participants moved out of a house. Three houses who moved took part again in their new residences. Table 2 outlines the participant houses that had shorter logging periods.

Table 1: Logging periods in detail houses

House	Start logging	End Logging	House	Start logging	End Logging
GBS013	4/06/2014	31/08/2015	GBS093	10/06/2014	9/09/2015
GBS014	20/05/2014	31/08/2015	GBS094	10/06/2014	9/09/2015
GBS015	26/05/2014	7/09/2015	GBS097	19/06/2014	9/09/2015
GBS016	20/05/2014	2/09/2015	GBS098	2/06/2014	9/09/2015
GBS018	19/05/2014	31/08/2015	GBS099	28/05/2014	8/09/2015
GBS019	19/05/2014	2/09/2015	GBS100	2/06/2014	8/09/2015
GBS021	19/05/2014	1/09/2015	GBS110	2/06/2014	6/09/2015
GBS022	26/05/2014	2/09/2015	GBS113	4/07/2014	8/09/2015
GBS023	16/06/2014	1/09/2015	GBS131	12/06/2014	25/09/2015
GBS026	26/05/2014	6/10/2014	GBS135	12/06/2014	21/09/2015
GBS028	23/06/2014	7/09/2015	GBS140	16/06/2014	1/09/2015
GBS029	23/06/2014	1/09/2015	GBS144	30/05/2014	7/09/2015
GBS036	29/05/2014	1/09/2015	GBS148	4/06/2014	24/08/2015
GBS037	16/06/2014	2/09/2015	GBS156	3/06/2014	24/08/2015
GBS040	25/06/2014	8/09/2015	GBS157	10/07/2014	2/09/2015
GBS041	24/06/2014	9/09/2015	GBS159	27/05/2014	31/08/2015
GBS044	1/07/2014	3/02/2015	GBS161	23/06/2014	31/08/2015

GBS045	19/06/2014	8/09/2015	GBS166	25/06/2014	1/09/2015
GBS046	11/06/2014	8/09/2015	GBS168	18/06/2014	4/09/2015
GBS047	4/07/2014	25/06/2015	GBS172	20/06/2014	15/12/2014
GBS052	24/06/2014	8/09/2015	GBS175	30/05/2014	2/09/2015
GBS078	9/07/2014	9/09/2015	GBS268	10/07/2014	7/09/2015
GBS088	26/06/2014	24/09/2015	GBS724	22/06/2015	21/09/2015
GBS089	18/06/2014	3/02/2015	GBS725	3/06/2015	21/09/2015
GBS090	28/05/2014	4/09/2015	GBS726	17/12/2014	25/09/2015
GBS091	26/06/2014	15/12/2014			

Table 2: Shorter logging periods (participants who moved house)

GBS no	Reason for shorter logging period	Data logging	Data still viable?
GBS026	Moved interstate so no longer lived in the monitored residence.	26/5/14 – 24/9/14 approx 4 months	Yes. Was in GH, no upgrades group so can use for comparative purposes. Also made personal changes which provide good example.
GBS089	Moved house, still in area. Agreed to be involved in new house (became GBS725).	18/6/14 – 3/2/15 approx 7.5 months	Yes. Was in CVR no upgrades group so no home visit and community activity was already underway. Can use cold period of 2014 for control and comparative purposes.
GBS172	Moved out of area.	20/6/14 – 17/12/14 approx 6 months	Yes. Was in CVR no upgrades group. Can use for control and comparative purposes.
GBS044	Moved house, still in area. Agreed to be involved in new house (became GBS724).	1/7/14 – 3/2/15 approx 7 months	Yes. Reasonable length of time. After home upgrade has no winter. Useful as comparison with performance in new house.
GBS047	Participant moved out of area (as rental that was in was mouldy).	4/7/14 – 24/6/15 approx 11.5 months	Yes. Reasonable length of monitoring with cold weather measured after upgrade.
GBS091	Moved house. Still in area. Agreed to be involved in new house (became GBS726).	26/6/14 – 12/12/14 approx 5.5 months	Yes. Cold periods of time recorded. Can compare this with the data from new house.
GBS724	Moved house. Was a participant in another house (GBS044). Was offered an upgrade in this house. Moved to a more comfortable and less energy hungry house so didn't have an upgrade.	22/6/15 – 21/9/15 approx 3 months	Yes. Periods of cold data collected. Compare against performance of old house.

GBS725	Moved house. Was a participant in another house (GBS089). Went into the upgrade group (there were more short term data sets and one removal in that group).	25/6/15 – 21/9/15 approx 3 months	Yes. Have period of cold weather data logged. Compare against performance of old house.
GBS726	Moved house. Was a participant in another house (GBS091). Went into the upgrade group (there were more short term data sets and one removal in that group). Was in the upgrade group previously. House they moved into had been in the GBS study as GBS 172 with different occupant. The house had been a no upgrade group house when was GBS172.	17/12/14 – 25/9/15 approx 9 months	Yes. Have a good length of logged data. Can compare with GBS172 if needed.

2.3.1 Thermal Logging

Temperature and humidity (thermal) data were recorded using stand-alone USB Lascar USB 2+ Temperature and Humidity loggers, which recorded in situ at 30-minute intervals[1] over the full data collection period. Typically, two (sometimes three) loggers were positioned internally and one was positioned externally, in order to get a comparison of ambient temperature for each house.

Placement of thermal loggers required some consultation with the householders. Householders were shown the loggers before they were installed and their purpose(s) were explained. Householders then consulted with researchers as to the best places to position devices. Typically, one was placed in the main living area, sometimes this was a kitchen or dining area. A second logger was then placed in a bedroom. Internal loggers were positioned carefully so as to get the most reliable reading of the indoor air temperature for the room. They were positioned away from the direct effect of heating devices, away from external walls, and so they would not receive direct sunlight. An attempt was made to position loggers at the same height above the ground in all internal locations to provide consistency of readings. Loggers were fixed in position using double sided sticking foam. External thermal loggers were positioned such that they did not receive direct sunlight and were mounted in PVC piping (with both pipe ends open) for protection and to ensure more controlled and consistent readings. External loggers were mounted in various accessible positions such as under eaves, on sheds, and on top of meter boxes in porches.

The data capacity of the temperature/humidity loggers meant that they were filled with data before the end of the monitoring period and so were removed and replaced at the interim home visits. Loggers were removed (taken out of houses) at final visits. Downloading this data was reasonably straightforward. Temperature/humidity loggers were directly downloaded onto a field laptop during interim visits wherever possible, or at the first convenient chance after visits. Data viability could not be checked while logging was in process so data was checked as soon as data was downloaded. An example of the raw collected data from one of the loggers is shown in Figure 2. Most loggers installed in homes successfully recorded data. Out of all the temperature/humidity loggers used (300 or more over the study), only four loggers failed (a success rate of over 99%). In every case the failure was due to a faulty battery (despite all having fresh batteries inserted just before installation). Three of the failed loggers were in outside positions and one was internal.

1 In Milestone 3 we reported using temperature sensors at 5 minute intervals during monitoring of the champion households. Such a short interval filled the loggers' storage capacity quickly which meant downloads of the lascar usbs (and visits to the houses) had to be more frequent. Upon review, five-minute intervals did not offer any extra benefits for analysis so sensors were set to 30-minute recording intervals (the only other available setting). The 30 minute recording interval was proposed in the original GBS data plans and was therefore in line with original data clarity commitments (Sustainable Living Tasmania et al 2013).

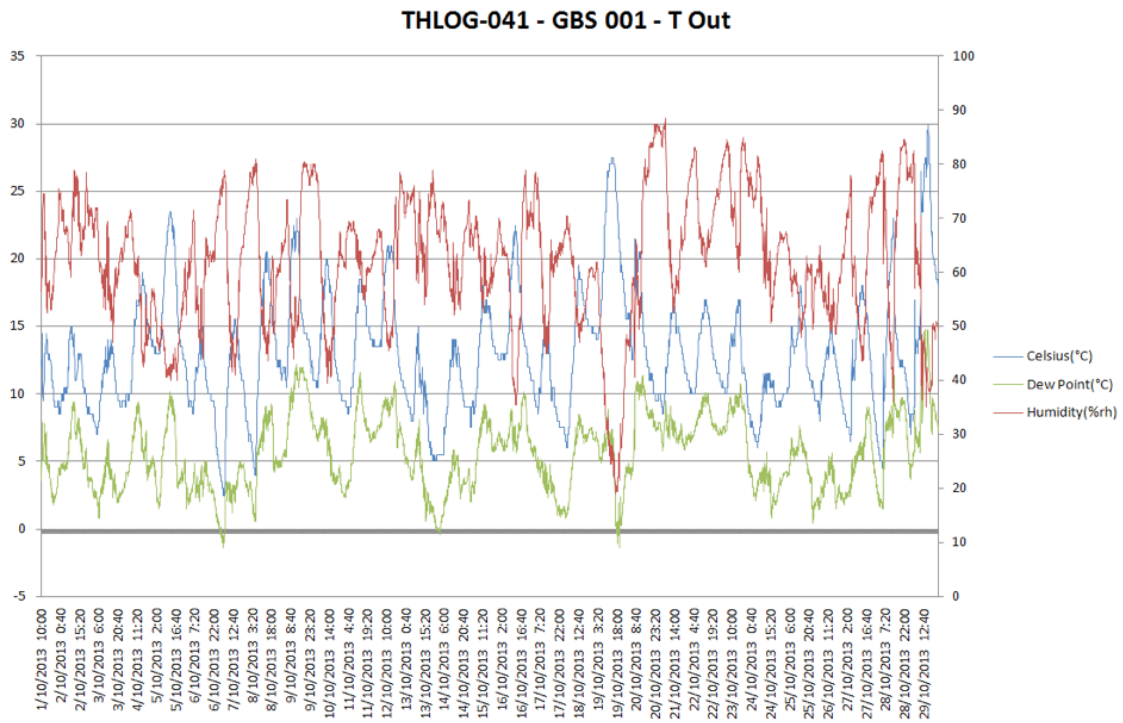


Figure 2: Example of graphed raw data from temperature/humidity data loggers

2.3.2 Electricity Logging

Electricity was logged by sensors in the house that fed data to a remote collection point via a router. Loggers were installed at the first ('before') home visit and were taken out at the final ('after'). Hardwired and plug in sensors were used to log electricity use. Hardwired circuits were monitored by installing hardwired sensors onto the circuits within the house's electrical meter board. Plug in heating appliances were monitored with the use of a sensor that was positioned (plugged-in) between the appliance and the power outlet. Both of these sensor types were wireless and sent data at approx. 5 second intervals to a centrally located router (the Billion sg6200nxl) installed in the house[2]. A 3G modem was attached to the router which uploaded the data to a web-based data collection portal. Figure 3 shows the equipment installed for electrical logging. The number of sensors installed in a house depended on the number of wired in circuits and plug-in heating devices that were in use in the household.

2 All houses bar one in the detail group were able to have electricity sensors installed (GBS110). There were no electrical sensors installed GBS110 because there was a lack of space in the meter board for the sensors.

Figure 3: Power Tracker electrical sensing equipment (Reduction Revolution 2016)

The Power Tracker online data collection portal has a web interface through which real-time electricity use can be viewed (Reduction Revolution 2016). An example of the real-time data from the Power Tracker web portal is shown below in Figure 4. Power tracker's web portal gave the research team the opportunity to monitor the system installations in real-time. The online interface was useful to check that data being recorded, but was not used for calculating outcomes and other analysis. Logged electrical data was consequently accessed from Power Tracker in two ways. Aggregated information was accessed, using a power tracker account, from the web either as graphs or as csv files. This web information was aggregated into 10 minute intervals. More detailed, raw information was accessed via data downloads. GBS data consultants downloaded full data sets from Power Tracker once the monitoring period was complete.

The routers could be accessed remotely in order to undertake some maintenance and upgrades. Dropping out of 3G modem connections caused significant trouble with data collection, particularly with households in certain locations in the study. Processes were put in place such that the modems should have automatically re-connected if a disconnection occurred, but sometimes this reconnection did not occur. This was problematic because it meant that the routers could not be accessed remotely and data loss occurred. On the occasion where contact with the router was lost and could not be regained remotely, the research team would contact the householders and ask them to check the router. Sometimes the router had been accidentally unplugged or switched off, in which case the householders could turn it back on. In other cases, where the router was apparently working, the householders were asked to re-start the routers, which would in turn re-set the 3G modem and allow re-connection.

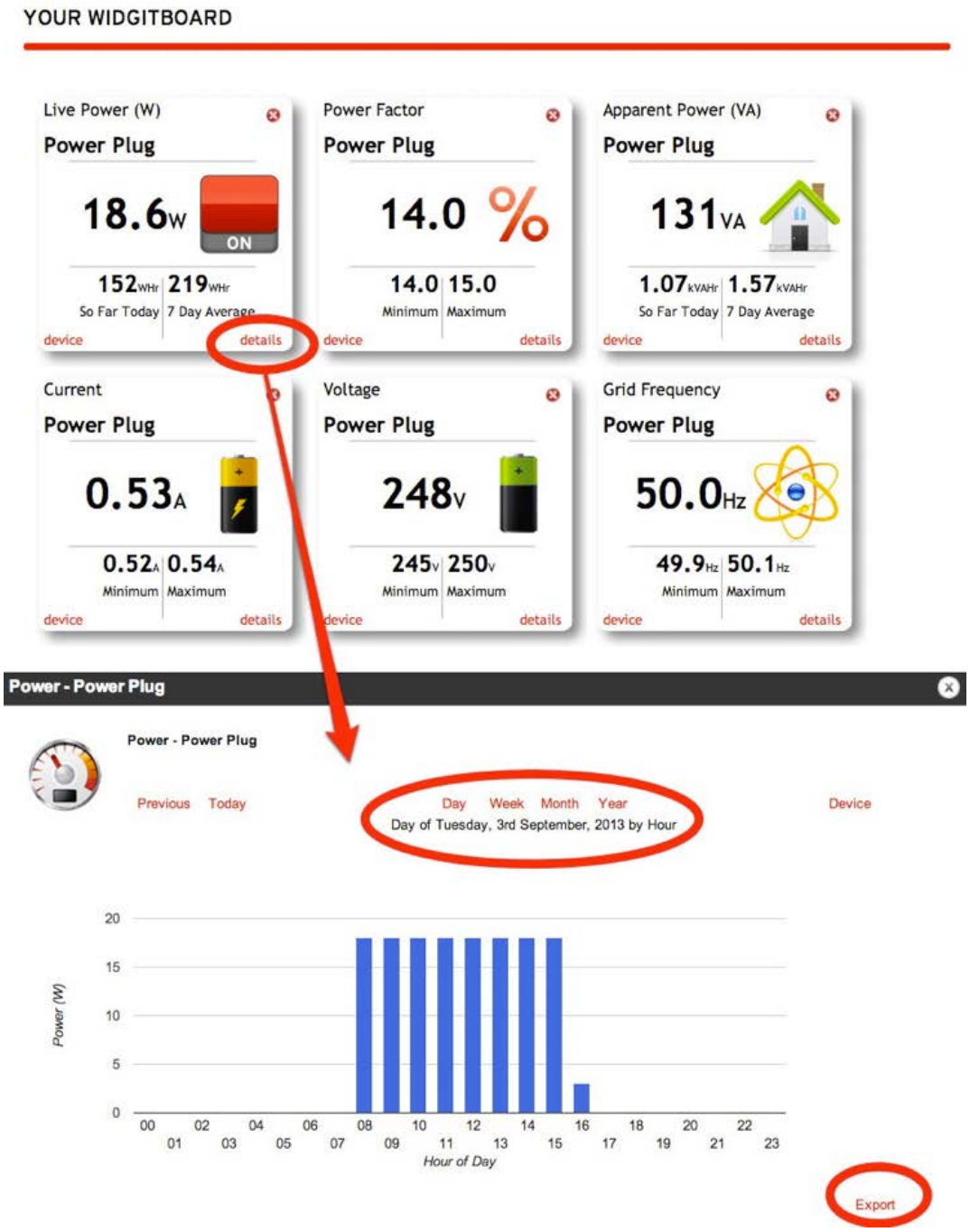


Figure 4: Example of information provided by power tracker portal (Reduction Revolution 2016

Overall electrical logging was successful in isolating key heating devices and electrical circuits. Some issues did occur, in particular:

- In a few cases hard wired heating appliances were not able to be isolated from the general light and power circuits because they were not on their own meter board circuits. For example, 'IXL Tastic' bathroom heater lights.
- Plug in heating appliances were isolated via sensors on plugs to isolate this data from general light and power. From review of the data it appears likely that some households used some heaters at times without using the sensor extension plug.
- Similarly, the use of new appliances in detail houses over the study period was not always recorded because households did not notify us when they began to use them.

2.3.3 Pre-processing logged data

After the electricity and thermal data was logged and downloaded, pre-processing was required before analysis could be conducted. Pre-processing data included downloading sequences, cleaning sequences, setting consistent time sequences and checking integrity.

Electrical data required significant pre-processing effort before it could be analysed. Early conversion of data took place at Power Tracker before it could be downloaded by the GBS team. There were numerous false starts with downloads from Power Tracker. Downloads were difficult in part because of the significant size of data sets. The GBS team liaised with the Power Tracker data mangers to download data in an appropriate format. Liaising took time – by degrees GBS received data in a cleaner format with column definitions clarified. Data files when downloaded contained 4 or 5 key parameters:

- main energy – the cumulative measure of the amount of energy that had passed through the sensor
- active power – the instantaneous power being used by the appliance or circuit
- apparent power
- power factor, and
- negative energy – for circuits that were monitoring PV systems this is the cumulative amount of energy being produced by the PV system.

After receiving correct electrical data, all individual sensor data sets for a given house were amalgamated into one data set. Data was 'padded out' to fill gaps in data. Gaps in data sequences occurred when there were interruptions in data feeds from internet failure and householders accidentally removing routers for periods of time. After padding, before and after periods were then applied to extract sample data. Electrical data was then checked for completeness in the identified before after periods.

Temperature/humidity logger downloads were reasonably straightforward. Data was downloaded directly to computer in CSV format. The length of time houses were monitored and the technology used for temperature and humidity logging meant that each particular location in each particular house had two data sets. Data from two individual loggers used for the same location were amalgamated to give a continuous measure of temperature and humidity over the logging period for that particular sensor location. All temperature/humidity logger data sets for a particular participant house were then amalgamated into one file.

All logger time periods were then cropped so that data sets only contained data logged while the loggers were sitting at participant houses and not data logged during set up, removal and transit to the house. Cropping allowed a consistent time base to be established. The same time base was also used for electrical analysis. The before and after periods were applied as per the electricity data, and then all thermal and electricity data for an individual household was combined into one file.

2.4 Quantitative Analysis methods

After data cleaning, padding, amalgamation and cropping, analysis was conducted on the quantitative data. Before and after (comparative) sampling periods were established and temperature/humidity and electrical data were analysed separately and together.

2.4.1 Identifying comparative before and after periods for quantitative analysis

Key sampling periods were identified according to the individual circumstances of each house and according to the dates GBS support activities were undertaken. Comparative before and after periods were first identified by specifying two periods of time when temperatures were below 18°C – one before interventions took place (but in the logging period) and one period after (but before the end of the overall logging period). Identifying these periods of time was achieved using Bureau of Meteorology (BOM) data from the two closest meteorological stations: Hobart airport and Hobart CBD. After identifying periods of time below 18°C (where the temperature never went over 18°C), the before and after periods were further refined based on the completeness of the electricity data for those periods (and based on start and finish dates of the logging process). Figure 5outlines the steps taken to define before and after periods. The upper temperature limit of 18°C was used because it was the bottom of the comfort zone and guaranteed a period of continuity with no hot days. An average cold(er) temperature could not have been used to define cold periods because temperatures still could have spiked above 18°C. Taking an upper limit temperature approach to defining the cold period meant that temperatures would often be much colder than the 18°C upper limit chosen.

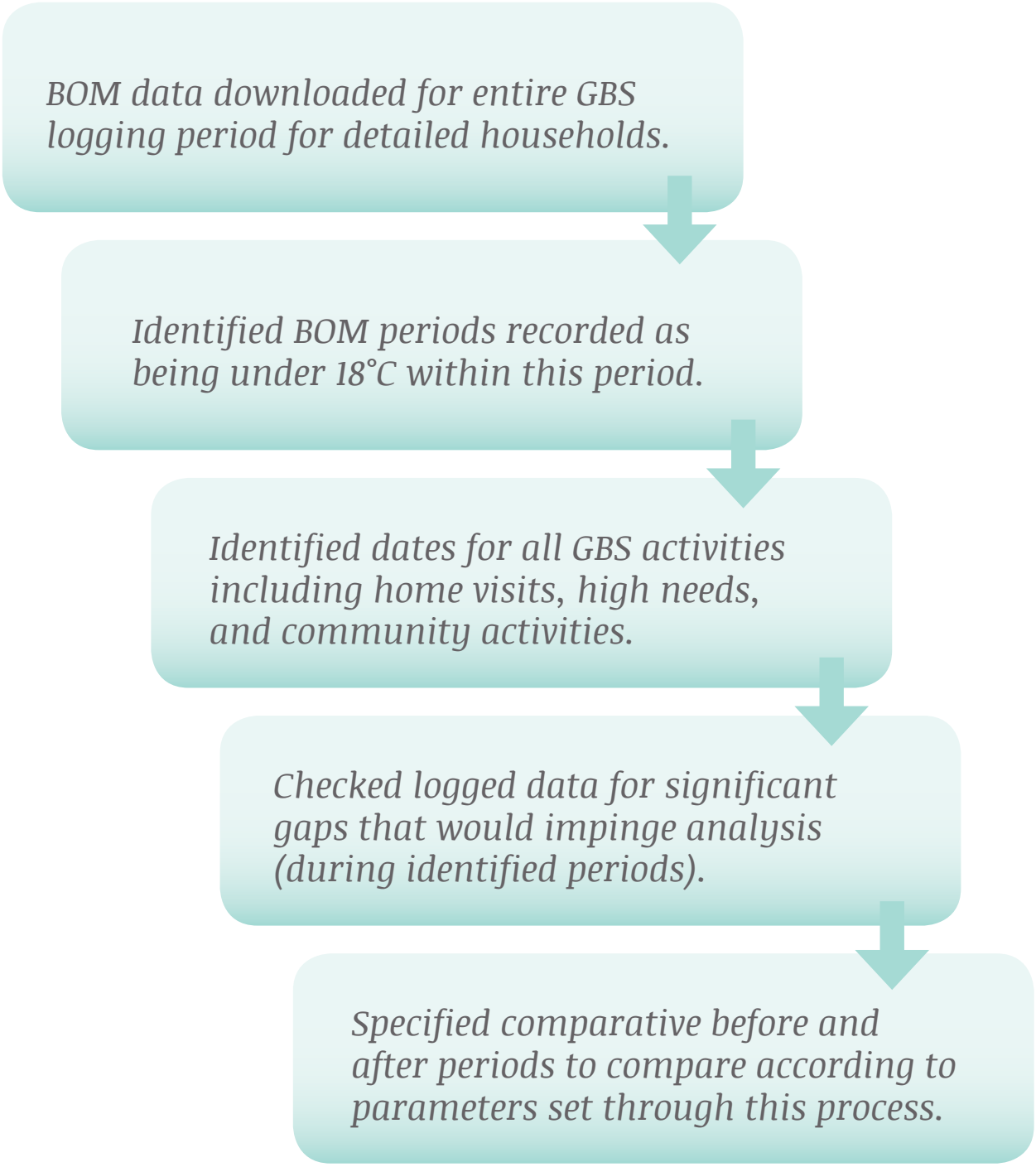


Figure 5: Steps to defining before and after periods.

Table 3 lists the specific before and after periods applied to each participant house.

Table 3: Before and after periods used for analysis

House	Before Period		After period		After Period 2	
	Start date of period	End date of period	Start date of period	End date of period	Start date of period	End date of period
GBS013	5/06/2014	26/08/2014	4/05/2015	20/08/2015		
GBS014	21/05/2014	26/08/2014	4/05/2015	20/08/2015		
GBS015	27/05/2014	26/08/2014	4/05/2015	20/08/2015		
GBS016	21/05/2014	26/08/2014	4/05/2015	20/08/2015		
GBS018	20/05/2014	26/08/2014	4/05/2015	20/08/2015		
GBS019	20/05/2014	26/08/2014	4/05/2015	20/08/2015		
GBS021	20/05/2014	26/08/2014	4/05/2015	20/08/2015		
GBS022	27/05/2014	26/08/2014	4/05/2015	20/08/2015		
GBS023	17/06/2014	26/08/2014	4/05/2015	20/08/2015		
GBS026	27/05/2014	26/08/2014				
GBS028	24/06/2014	26/08/2014	4/05/2015	20/08/2015		
GBS029	24/06/2014	26/08/2014	4/05/2015	20/08/2015		
GBS036	30/05/2014	26/08/2014	4/05/2015	20/08/2015		
GBS037	17/06/2014	26/08/2014	4/05/2015	20/08/2015		
GBS040	26/06/2014	26/08/2014	6/05/2015	6/06/2015	8/06/2015	20/08/2015
GBS041	25/06/2014	26/08/2014	6/05/2015	6/06/2015	8/06/2015	20/08/2015
GBS044	2/07/2014	26/08/2014				
GBS045	20/06/2014	26/08/2014	6/05/2015	6/06/2015	8/06/2015	20/08/2015
GBS046	12/06/2014	26/08/2014	6/05/2015	6/06/2015	8/06/2015	20/08/2015
GBS047	5/07/2014	26/08/2014	6/05/2015	6/06/2015	8/06/2015	24/06/2015
GBS052	25/06/2014	26/08/2014	6/05/2015	6/06/2015	8/06/2015	20/08/2015
GBS078	10/07/2014	26/08/2014	6/05/2015	6/06/2015	8/06/2015	20/08/2015
GBS088	27/06/2014	26/08/2014	6/05/2015	6/06/2015	8/06/2015	20/08/2015
GBS089	19/06/2014	26/08/2014				
GBS090	29/05/2014	26/08/2014	6/05/2015	6/06/2015	8/06/2015	20/08/2015
GBS091	27/05/2014	26/08/2014				
GBS093	11/06/2014	26/08/2014	6/05/2015	6/06/2015	8/06/2015	20/08/2015
GBS094	11/06/2014	26/08/2014	6/05/2015	6/06/2015	8/06/2015	20/08/2015
GBS097	20/06/2014	26/08/2014	6/05/2015	6/06/2015	8/06/2015	20/08/2015
GBS098	3/06/2014	26/08/2014	6/05/2015	6/06/2015	8/06/2015	20/08/2015
GBS099	29/05/2014	26/08/2014	6/05/2015	6/06/2015	8/06/2015	20/08/2015
GBS100	3/06/2014	26/08/2014	6/05/2015	6/06/2015	8/06/2015	20/08/2015

GBS110	3/06/2014	26/08/2014	6/05/2015	6/06/2015	8/06/2015	20/08/2015
GBS113	5/07/2014	26/08/2014	6/05/2015	6/06/2015	8/06/2015	20/08/2015
GBS131	13/06/2014	26/08/2014	6/05/2015	6/06/2015	8/06/2015	20/08/2015
GBS135	13/06/2014	26/08/2014	6/05/2015	6/06/2015	8/06/2015	20/08/2015
GBS140	17/06/2014	26/08/2014	4/05/2015	20/08/2015		
GBS144	31/05/2014	26/08/2014	4/05/2015	20/08/2015		
GBS148	5/06/2014	26/08/2014	4/05/2015	20/08/2015		
GBS156	4/06/2014	26/08/2014	4/05/2015	20/08/2015		
GBS157	11/07/2014	26/08/2014	4/05/2015	20/08/2015		
GBS159	28/05/2014	26/08/2014	4/05/2015	20/08/2015		
GBS161	24/06/2014	26/08/2014	4/05/2015	20/08/2015		
GBS166	26/06/2014	26/08/2014	4/05/2015	20/08/2015		
GBS168	19/06/2014	26/08/2014	6/05/2015	6/06/2015	8/06/2015	20/08/2015
GBS172	21/06/2014	26/08/2014				
GBS175	31/05/2014	26/08/2014	4/05/2015	20/08/2015		
GBS268	11/07/2014	26/08/2014	4/05/2015	20/08/2015		
GBS724	23/06/2015	20/08/2015	22/08/2015	9/09/2015		
GBS725	9/06/2015	12/08/2015	22/08/2015	9/09/2015		
GBS726	9/06/2015	16/08/2015	22/08/2015	9/09/2015		

Table notes:

- Some before and after periods were further refined during analysis due to gaps in electricity data.
- Two separate after periods were defined for the CVR groups because the outdoor temperature went over 18°C for a period of time.

Support activities for home upgrade involved one main visit by the Home Energy Helpers, and for a small number of households involved a second visit for extra (high-needs) upgrades. These upgrades were conducted at various times after the first (before) research visits to the homes. The main home energy visits and high needs visits (where applicable) are treated as a single activity for the majority of analysis. This means that before and after periods sit either side of high needs support activities. Actual interventions for each house are listed (specified) in the case studies for each participant house. High needs upgrades are also listed there.

2.4.2 Individual Electricity Use Analysis

Initial electricity use analysis used data from the before and after periods to sum up overall energy consumption and provide average per day consumption for:

- total household electricity consumption
- total household electrical heating consumption
- hard-wired heating consumption
- plug-in heating consumption
- overall light and power consumption including plug-in heating
- light and power consumption without plug-in heating
- hot water consumption
- photovoltaic production (where applicable).

A comparison was made on all of these parameters of the average daily consumption in the before and after periods.

2.4.3 Individual Temperature/humidity

Temperature/humidity data from each house were used to show typical thermal performance for any given house. Initial analysis of temperature and humidity identified:

- average temperatures experienced over the defined before and after periods (°C) in the various rooms monitored
- average outdoor temperature at the house during the before and after periods
- difference between inside outside temperatures (ΔT)
- difference in ΔT between the before and after period, and
- time spent within the defined 18-24°C comfort zone and the difference in time within comfort zone between the before and after periods.

Initial analysis provided a picture of the thermal performance of each house and understanding of physiological comfort/discomfort experienced by householders in winter before compared to after GBS activities.

In selected cases that showed problems with humidity, before and after humidity data was reviewed using graphical analysis of the thermal data. Graphed humidity data identified the significance of reported moisture and mould problems and highlighted how often dew point may have been reached inside homes. Householders were also asked about moisture and mould in the homes and this qualitative self-reported information was considered when assessing humidity or dew point issues in homes.

Comfort zones were defined to be between 18-24°C after reviewing international standards and local research on comfort zones (Ranson 1988; Roaf, Crichton et al. 2005; Watson 2013).

2.4.4 Combined temperature and electrical analysis

Combined temperature and electrical analysis provided the opportunity to understand house performance further and to examine heating efficiency. Combined analysis of the thermal performance and the electrical use showed overall efficiency and provided a means for summarising quantitative outcomes. Further, this combined analysis supported integrated analysis with the qualitative data.

The measure of heating efficiency was derived using average winter temperature difference between inside and outside ΔT (°C) and average winter heating power consumption (kWh/day) to identify average winter heating efficiency (°C-hours/kW/day). The change in this heating efficiency measure between the before and after periods was then compared. Summaries of combined temperature and electrical analysis steps follow.

Steps for Heating Efficiency Analysis

1. Identify two periods before/after energy efficiency upgrade date that were similar in temperature (max temp less than 18°C).
2. Determine average ΔT for each of the before and after periods (°C).
3. Determine total average daily heating energy consumption during those periods (kWh/day).
4. Calculate heating efficiency (°C-hours/kWh/day).
5. Calculate changes to heating efficiency before/after intervention date (%).

Steps for Comfort Zone Analysis

1. Determine % of time within the 18-24°C for before and after periods
2. Determine change in % between the before and after periods.
3. Determine comfort zone heating efficiency % time/kWh
4. Determine change in comfort zone heating efficiency between the before and after periods.

Data presented in case studies in results tables and in graphs describe temperature and electricity data generated through using the steps described above. Note that where heating is provided by non-electric sources such as gas or wood fire, the heat delivered by these sources is not picked up by electricity consumption and hence the heating efficiency ratio is not comparable. The heating efficiency ratio also tends to vary widely depending on the absolute amount of heating being used. Small amounts of heating will tend to deliver a bigger heating efficiency ratio, but very cold temperatures within the house. Hence heating efficiency can be of use as an indicator when comparing between houses, with the understanding of these limitations and when considered in relation to the other indicators such as overall heating use and thermal comfort ratings.

2.5 Qualitative data collection

Qualitative forms of data collection and then analysis enable researchers to relate to participant contexts, perceptions, opinions and details of their situations otherwise unattainable or unmeasurable via other means. Qualitative data for the detailed report involved: longitudinal semi-structured interviews with householder participants; house observations; surveys and interim conversations at sensor swap-overs.

2.5.1 Interviews

Longitudinal semi-structured interviews were conducted with all detailed households to gather in-depth qualitative information. Interviews were conducted in homes at initial 'before' and final 'after' home visits. Notes from conversations were also taken at interim home visits as sensors were swapped.

Collecting the participants and stakeholders' experiences and opinions through interviews was seen as a critical element of data collection because it engaged with the nuance of everyday life that informs how people use energy and manage comfort (Crosbie and Baker 2010; Watson 2013). Interview data allowed exploration of participant and stakeholder opinions, perspectives and experiences and allowed richer understanding of the dynamic 'terrain' of an issue. Examination of in-depth narratives provided through interviews allowed researchers to understand the dynamics and variability between houses, common themes across houses, and uncover inaccessible information or unrecognised impacts and influences.

Interviews followed a schedule, but were semi structured so that householders were able to raise issues that they felt were important and that may not have been anticipated by the interviewers. This avoided researchers having to guess or presume outcomes prior to data collection. Interviewers made efforts to ensure they were respectful and receptive during interviews and that they provided background for the research, the questions and themselves. The looser structure and the efforts made to engage respectfully allowed participants to have some control over their contributions. In most cases this allowed householders to better trust researchers, creating space for sharing of information, mutual examination of the topic and mutual construction of knowledge which ensured maximum possible learning was taken away from interviews.

Interviews were recorded with permission from participants. Notes were also taken in case of a poor quality recording or if participants did not want to be recorded. Only one household chose not to be recorded and have notes taken instead during their interviews.

In interviews participants were invited to talk about:

- experiences of the GBS energy efficiency upgrades/interventions and community activities
- perceived indoor thermal performance (summer and winter)
- ways thermal comfort was managed and heating practices
- effects of discomfort
- energy use practices
- effects of 'high' energy bills (relatively speaking)
- changes participants had and were planning to make to their home
- barriers stopping participants making changes
- assessment of the outcomes of GBS activities
- choices made between thermal comfort, affordability and other housing needs when energy use reduced (trade-offs)
- social networks involved or influencing their energy efficient upgrade and practice change activity, and
- Perceived influences (if there is any) of the community capacity-building activities.

All recorded interviews were transcribed and notes taken were stored for analysis.

2.5.2 Housing observations

Observations of physical house conditions were recorded in order to identify key physical characteristics of houses that influenced energy use and comfort performance and to ascertain the general physical housing conditions and thermal performance participants lived with. Before the initial household visit, the researchers examined Google Earth satellite and 'Street View' images of the houses in order to record information about the surroundings, and to get an initial idea of the orientation and construction of the house. Researchers observed physical house conditions at initial 'before' household visits via a checklist and documented conditions with photos. Observed information was also gathered via discussions about logger positioning in homes and during interviews.

Housing observations were made of various aspects of the house, for example:

- orientation of house and windows
- building materials – walls, floors, roofs, glazing
- hot water and heater type
- heating system types and locations
- window frames
- window coverings
- lighting types
- floor coverings
- air vents, and
- access to sunlight and obstructions in the surroundings.

Observations took the form of checklists, descriptions, counts categorisations, drawings, photos, diagrams, and measurements. To gather this data, researchers looked around (the inside and outside of) houses with the householder. During the process of these observations, householders were able to discuss various parts of the home, explaining the quirks of the physical dwelling and the social interactions that took place with and within the structure. For example, walking into wind-blown parts of houses allowed participants to point out the prevailing wind directions and the windows or doors most affected by draughts. Observations were also collated as loggers were installed. The researcher installing loggers, for example, talked to participants about cold bedrooms, heater types and house layouts and contributes this information to the observation set. This parallel collection of observations meant that researchers limited the time they spent in the householders' personal space. Key house observations have been integrated into the case studies with assessments made of house performance based on these observations.

2.5.3 Surveys

Surveys were given to all householders involved in the project, including those taking part in the detailed study. Surveys are being used to build a baseline and to compare across the GBS approaches. Surveys asked participants about:

- occupant numbers
- occupant age groups, education and employment
- dwelling features, including heating and hot water systems
- home energy efficiency measures undertaken and changes for comfort
- prevalence of moisture and mould in their home
- indoor comfort levels
- their concerns about energy consumption and costs, and
- their views of the local community.

Survey design and questions are further outlined in the Bulk Study description of methods. The survey data contributed to the detail cases providing information on: house ownership, occupants, bedrooms, house structure and materials, confidence of the householders in sourcing energy efficiency information, confidence about community connections, moisture and mould and draught accounts, and changes listed as having been made to the home.

2.6 Qualitative analysis

Qualitative analysis is conducted to generate in-depth descriptive information on the householders living circumstances, householder practices, constraints and needs which are helpful when interpreting the figures derived from quantitative processes. Qualitative data allows examination of the dynamics of situations and the variability of outcomes.

Qualitative analysis extracts key themes, descriptors, context, trends, and comparisons from the details of specific cases in the form of narratives, comments and researcher observations gathered during interviews and surveys. Data for analysis is contributed in the form of voice recorded interviews, researchers' notes and transcriptions, survey content descriptions and comments, and researcher observations.

2.6.1 Interviews

Before and after interview transcripts provide in-depth narratives from participants. Transcripts were reviewed in NVIVO analysis software by researchers. Multiple reviews of each transcript were conducted to identify layers of findings, in particular: content descriptors; participant opinions, perspectives and experiences; key thematic dynamics and patterns; and narratives.

Extracting content helps to build a basic (descriptive) picture of a participant's situation. For example, content was extracted about what jobs people did, who they connected with in

the community, changes in occupants, and lists of changes made to the house. Content from interviews often paralleled and complimented data collected in surveys. Content from interviews added to survey information by providing a richer, less static understanding of content.

Participant opinions, perspectives and experiences shared by participants helped researchers understand comfort practices and energy use and what households do in reaction to their comfort and energy situations. This data provides us with understanding of contextual information, value bases, attitudes, priorities and daily household practices allowing us to discern drivers and barriers to making energy and comfort.

Multiple points can be taken from each comment made. People might provide comments that highlight not only a daily practice but the reasons they undertake that practice. For example, 'I open up the house in the morning even though we are cold. Gerry hates it but I don't see how else to deal with the crying windows'. This comment informs researchers about daily household practices and household micro-politics. Aligned with this, people may communicate explicitly or implicitly. Implicit communications are examined as well.

Transcripts are also examined to identify key thematic dynamics and patterns. For example, after reading the transcripts we identified that habits of householders around animals in houses can play an important role in the level of thermal comfort of participants and that teenagers in various houses repeatedly spent a lot of time in the shower using a lot of hot water. Thematic understanding such as this helps build understanding of key issues being examined.

Text and term searches were also conducted in NVIVO software by researchers to examine specific data and concepts. Using an iterative and emergent process of examining findings has highlighted critical issues of context, situation, capacity, influences, and outcomes from the community capacity building process.

2.6.2 Observations and free form survey answers

Housing observations and written (as opposed to ticked) survey answers also provided qualitative data in the form of: content, contextual information, participant values, opinions, perspectives. Despite the collected qualitative data being in various formats, such as lists, photos, notes, and short text answers, they are able to be 'read' and reviewed in the same ways that transcripts are. As information is considered, absorbed and synthesised from these sources, key content and descriptors, key themes and key trends emerge which are then considered in conjunction with all other data sources.

2.7 Combined quantitative and qualitative analysis

In order to ensure we paint a picture that includes in depth and contextual aspects of GBS outcomes, qualitative and quantitative data are analysed together and findings are presented as an integrated whole in detail cases studies. Temperature and energy consumption data is compared with interviews, survey data and house observations to identify commonalities, trends and variations. By combining the data into case studies we present an integrated analysis that shows comfort and energy outcomes with connections made to overall household contexts, behaviours and routines, wellbeing and affordability thereby examining underlying issues and barriers that affect thermal and energy performance in the home.

Key stages for combining data and conducting overall analysis were:

1. Gather qualitative and quantitative data.
2. Analyse quantitative data (for a participant).
3. Analyse qualitative data (for same participant).
4. With knowledge of participant's qualitative data, review participant's thermal and energy data. Note key changes in logged data, key changes reported by participants, trends and patterns emerging, anomalies and useful themes.
5. Develop case study profile. Include observation and survey data.
6. Add key bill outcomes, check against case study data.
7. Revisit qualitative transcripts to further contextualise cases.
8. Develop findings for participant's case.
9. Identification of key themes emerging from the individual case study to use in synthesis of overall findings.

Importantly, the combined analysis was conducted by data consultants and the qualitative data researchers in conjunction, ensuring that understanding gathered from both sources were integrated and informed the overall synthesis of findings.

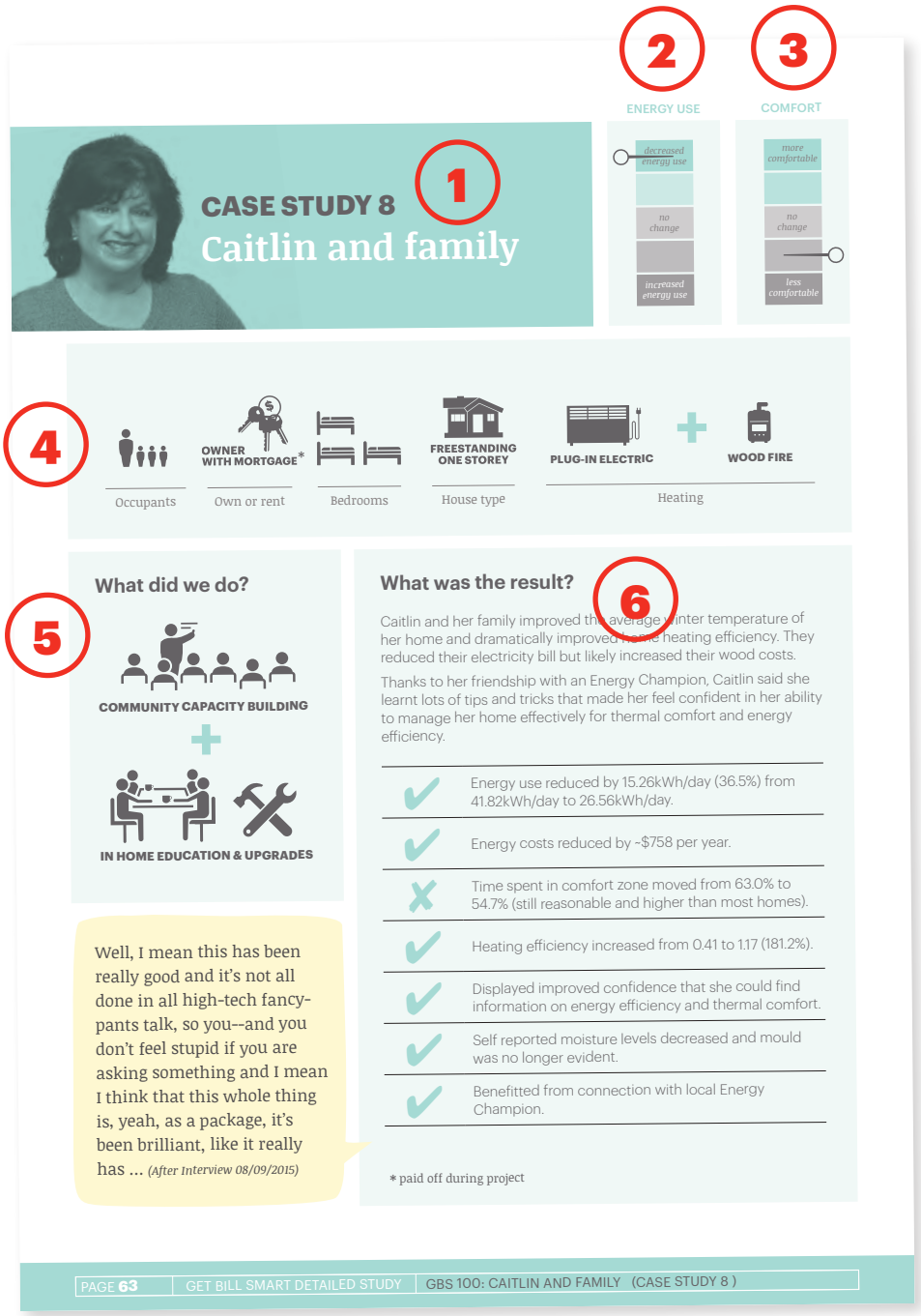
2.7.1 Methods for outcomes and assessments in cases

Cases are presented in two lengths – long with extensive description, short with one overall description. There are at least three long cases studies per approach group.

On the following page is an example front page of a case study (Figure 6), with key elements numbered, these numbers correlate with explanatory text below the image. These key elements are described on the subsequent pages, along with other subject headings used to present the findings in the case studies.

The methods used to develop descriptions and ratings in the case studies in this report are described here under headings used in the case studies.

Figure 6: example of first page of case study



1. Case Study Title

Each Detailed Study participant household has a case study in this report. Each household has been assigned a case study number. This is different from the GBS reference number that references all 504 households in the GBS project. All householders who participated in the research are provided with an alias. Other household members are described generically. Most often either one or two adults per house provided information to GBS.

2. Energy Use increase/decrease

This gives an indicator as to overall energy use outcome for each household. The use change between before and after data is rated on a five level scale from 'increased energy use' through to 'no change' and 'decreased energy use 'This rating is generated by reviewing the energy use changes quantified by electricity monitoring data and also from energy bill comparisons.

3. Comfort increase/decrease

This gives an indicator as to overall thermal comfort outcome for each household. The comfort change between before and after data is rated on a 5 level scale from 'less comfortable' through 'no change' to 'more comfortable'. This rating is developed by reviewing the comfort ratings participants gave in surveys, the comments made about comfort in interviews and the time in comfort zone data generated from thermal logging data. It is important to note that this is relative change. A household that has greatly increased comfort levels is not necessarily a warm house.

4. House and Household Characteristics

This section notes a series of household characteristics through a series of icons.

- Occupants: this is the number of occupants (adults and children) living in the house through the majority of the GBS study (changes to occupancy that occurred during the study are noted in the text)
- Household tenure: whether the house is owned with or without a mortgage, or rented.
- Bedrooms: the number of bedrooms in the house are depicted as beds.
- House types: describes whether the house is freestanding, or conjoined, and one or two storey.
- Heating: describes the two main types of heating used in the house. Images describe plug-in electric, hard-wired electric resistance, hard-wired heat pump, wood fires and gas heaters.

5. What did we do?

This section notes the GBS approaches this participant household was involved with. If the participant household received an in home education and upgrade visits, the image is presented here. If the household was in the community where community capacity building was rolled out the community capacity building icon is shown. Note that being within the community that received capacity building activities, does not necessarily mean that the participants attended capacity building activities. Attendance at capacity building events is noted further down in the body of the case study.

6. What was the result

This section presents a brief summary of the outcomes of the GBS project for the household. The first five of these indicators are the same for each case study:

- Daily energy use
- Energy costs
- Time in comfort zone
- Heating efficiency, and
- Confidence of householders in sourcing energy efficiency information.

Two additional indicators are provided to highlight specific aspects that may be relevant for individual cases. For each indicator, a tick or a cross represents a positive or negative change in regard to that parameter. A tilde (~) is used to show that something is unclear or borderline.

Existing physical conditions of the house:

House descriptors and ratings are listed in the case study to provide a picture of existing physical housing conditions as they relate to thermal comfort and energy use. Various key building elements are rated according to the following system:

Rating descriptor	Meaning
VERY POOR	Thermal performance/ performance is extremely poor and is clearly **far below** current energy efficiency standards in the Building Code of Australia.
POOR	Thermal performance/ performance is poor and **still significantly below** current energy efficiency standards in the Building Code of Australia for new builds and renovations.
NEAR STANDARD	Thermal performance/ performance is **below** current energy efficiency standards in the Building Code of Australia for new builds and renovations.
TO STANDARD	Thermal performance/ performance **meets** current (or very recent) energy efficiency standards in the Building Code of Australia for new builds and renovations.
ABOVE STANDARD	Thermal performance/ performance **exceeds** current (or very recent) energy efficiency standards in the Building Code of Australia for new builds and renovations.

Most thermal performance of existing housing observed in the GBS project was within the VERY POOR, POOR and NEAR STANDARD categories, which is why there are three lower than standard categories. Features that are rated as TO STANDARD and ABOVE STANDARD have features which meet (or could) contribute to current 5 and /or 6 star thermal resistance standards.

Changes to home

In this section we describe two types of changes that may have occurred to the house or household in the intervening time between the before and after data collection periods. For households who received home upgrade visits cases list the specific upgrades that were undertaken. For all household cases also list other changes that are unrelated to the GBS project. Changes may have related to occupant numbers of have been physical or behavioural in nature.

Energy and comfort

In this section tables are presented that summarise the quantitative energy and comfort data collected from the households. The data used here shows peak cold weather energy use.

The table showing average daily energy use and heating efficiency during winter conditions contains parameters defined as follows:

- *T31 Heating (plug in heating)* = all plug in heater energy recorded for the given (before or after) period presented as average kWh/day consumption.
- *T41 Heating (hard wired heating)* = all hard wired heater energy recorded for the given (before or after) period presented as average kWh/day consumption.
- *Total heating* = the total heating energy recorded for the given (before or after) period presented as average kWh/day consumption.
- *Other light and power* = light and power energy use, with plug in heating energy removed, for the given (before or after) period presented as average kWh/day consumption.
- *Hot water* = Total hot water heating energy recorded for the given (before or after) period is presented as average kWh/day consumption.
- *Total household electricity* = Combines hardwired and plug-in electricity consumption for the whole house. The total energy recorded for the given (before or after) period presented as average kWh/day consumption.
- *House heating efficiency* = cumulative degree-hours above outdoor temperature based on the average of measured rooms in the house over the given (before or after) period, divided by the heater electricity consumption for the house over the (before or after) period. This is described as a ratio (degree-hours/kwh/day). Notes that where heating is provided by non-electric sources such as gas or wood fire, the

heat delivered by these sources is not picked up by electricity consumption and hence the heating efficiency ratio is not comparable.

- *Before* = the before period as defined in method description 'Identifying comparative before and after periods for quantitative analysis'.
- *After* = the after period as defined in method description 'Identifying comparative before and after periods for quantitative analysis'.
- *Change (electricity use)* = Change between before and after average use per day, expressed as an absolute amount in kWh/day and as a percentage (%). A negative % means that there was a reduction in use. A positive % means there was an increase in use.
- *Change (in heating efficiency)* = the difference between the before and after heating efficiency expressed as an absolute amount and as a percentage. A negative % means that the heating is less efficient in the *after* period, and a positive % means that the heating is more efficient in the *after* period (%). Note when comparing heating efficiencies that heating efficiency is the product of the building shell thermal resistance and electrical heating choices and technology in each individual house.

The table showing average daily temperatures and time in comfort zone during winter conditions contains parameters defined as follows:

- *Living Temp* = average temperature (°C) in the living room in the before and after periods and the difference between the two periods.
- *Bedroom Temp* = Average temperature (°C) in the bedroom in the before and after periods and the difference between the two periods.
- *Outdoor Temp* = Average temperature (°C) in measured outside at the house, in the before and after periods and the difference between the two periods.
- *Avg out/in temp diff* = the difference between outdoor temperature and the average indoor temperature in the before and after periods and change in this difference between the two periods.
- *% time in comfort zone* = percentage of time spent in comfort zone between 18°C and 24°C in the before and after periods and the difference between the two periods.

Graphs showing example before and after temperature/humidity energy

Longer length case studies also show example temperature and electricity performance graphs of typical winter weeks (see Figure 7 below for an example). These graphs show energy use compared to temperatures over a chosen example week from the before and a chosen example week from the after period. The graphical analysis allows different energy use consumption practices to be analysed along with the impact of these practices on temperatures within the house. These examples also provide a visual representation of the absolute temperatures being maintained with the house, the difference between outdoor and indoor temperatures and the times when temperatures are within the comfort zone.

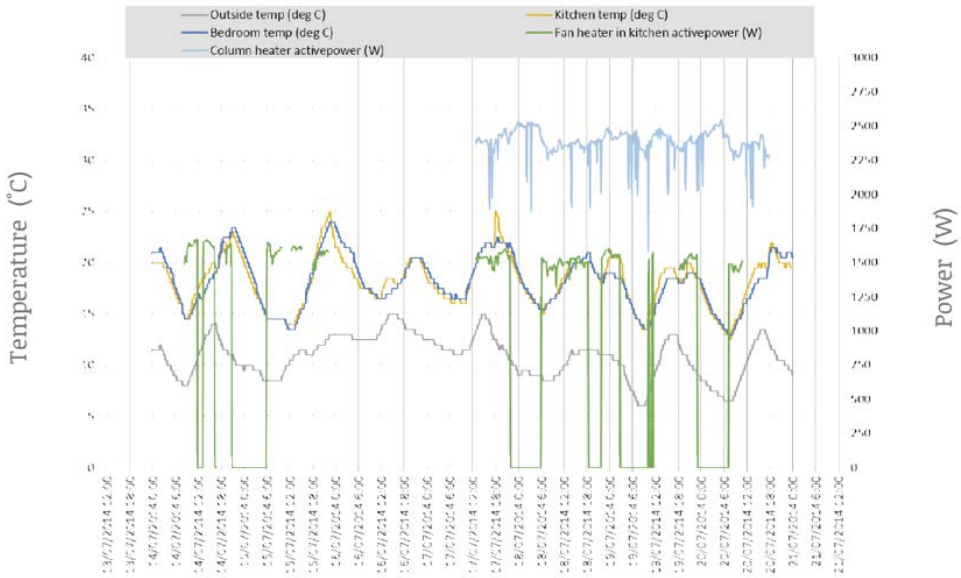


Figure 7: example of graphically presented temperature and energy data.

Left vertical axis = temperature (°C)

Right vertical axis = heating energy use in watts (W)

Horizontal axis= date and time of day

For some specific households where humidity/ moisture issues have been noted, analysis of the humidity levels has been undertaken and graphical representation is provided as per the example below (Figure 8). The thermal data loggers sensed both temperature and relative humidity, allowing dew point temperature to be calculated. When the air temperature reaches the dew point temperature, condensation occurs. The graphical analysis provides a visual representation of these parameters and shows when temperature and dew point are close and at risk of causing condensation and mould in a house.

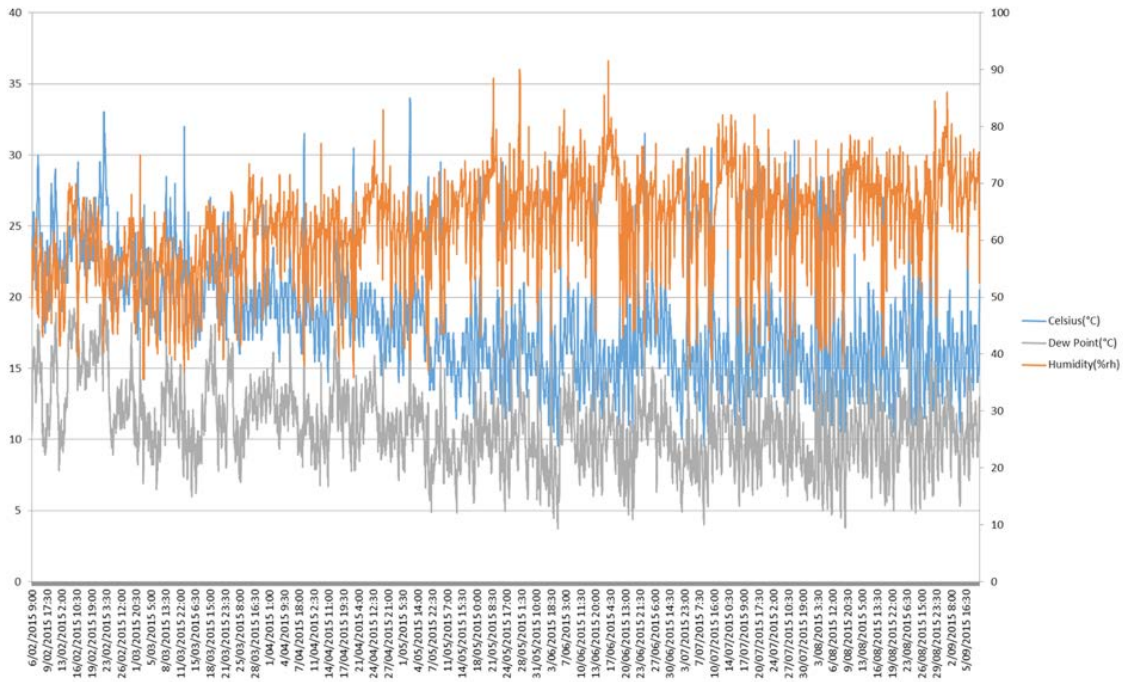


Figure 8: example of graph showing humidity and dew point.

Energy affordability

Information for this section is taken from energy billing data and energy affordability discussions in interviews. Energy bills analysis is described in the Bulk Study.

Personal and community change

This section presents a review of the information presented in the case and overlays findings from interviews in about personal backgrounds, community context and critical influences that have affected comfort and energy change outcomes. Critical findings from the case are reiterated here.

3. Case studies: house by house findings

Detailed group case studies

In this section we present the summarised findings for all households involved in the detailed study. These summaries draw on data from before and after surveys and interviews, electricity and temperature/humidity loggers, billing data from the electricity supplier, and house observations. The data collection and analysis are described fully in the methods (see 2.7.1, p24).

The detailed synthesis and discussion that follows on page 273 is based on the findings reported in these case studies.

The findings are presented in four groups:

Cases 1-11: Includes households that were provided with home energy upgrade/education visits and were exposed to community capacity building and local energy champions.

Cases 12-27: Includes households that were exposed to community capacity building and local energy champions.

Cases 28-39: Includes households that were exposed to home energy upgrade/education visits.

Cases 40-51: Includes households that provide representative data and did not receive any support activities.

Cases are presented as a mixture of both long and short reports. The short reports provide a snapshot of the key outcomes and changes within each household and key factors relating to these changes. The longer case studies provide insight into the process of data synthesis and provide more detail and context for understanding the complexities of managing thermal comfort and energy efficiency in the home.

Please note that there are also four special comparisons within the cases. Three of the special comparisons (CASE 14, 18, 19) look at the energy efficiency and thermal comfort for families who have moved house. For each family energy use and comfort are examined in both houses. Case 26, looks at the performance of the same house with two different occupying families.

Cases 1–11

HOME ENERGY UPGRADES AND COMMUNITY CAPACITY BUILDING

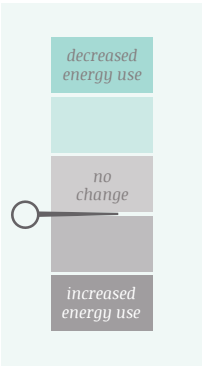
GBS support activities for these cases were:

1. Home energy upgrade/ education visits by experienced home energy helpers.
2. Exposure to community capacity building, which included local energy champions.

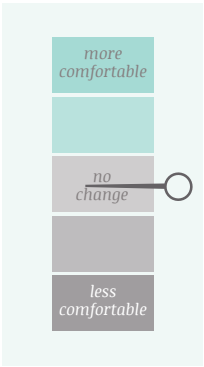
These houses were all in the suburbs of Clarendon Vale and Rokeby where community capacity building activities were also held.

CASE STUDY 1
Maureen

ENERGY USE



COMFORT



Occupants	Own or rent	Bedrooms	House type	Heating
	OWNER		FREESTANDING ONE STOREY	HEAT PUMP

What did we do?

COMMUNITY CAPACITY BUILDING

+

IN HOME EDUCATION & UPGRADES

> Well I haven't any control with visitors, but when I'm on my own, of course you do. You're conscious of the cost. You sort of begrudge paying [the electricity bill] because you don't see anything for it. It's not as though you get a chocolate or something.
> *(Before Interview 19/06/2014)*

What was the result?

Maureen attended many of the Get Bill Smart events within the community. She reported that the events were informative and helpful but also very enjoyable socially. Very little changed in terms of her energy use but she felt more confident in seeking information on thermal comfort and energy efficiency.

✗	Energy use increased by 0.89kWh (5.5%).
✓	Energy costs reduced by ~$5 per year ($1134-$1129).
~	Time spent in the comfort zone remained constant at 34%.
✓	Heating efficiency increased from 0.40 to 0.43 (7.7%).
✓	Displayed significantly improved confidence that she could find information on comfort and remained confident that she could access information on energy efficiency if needed.
✓	Draughts reduced.

Existing physical conditions of the house

The position of the living area, single glazing and the high uninsulated suspended floor over the garage creates an uncomfortable indoor winter environment.

While the physical house is in better condition than many in the area, it still performs at a poor level.

Type	Stand alone, suburban.
Age	30-40.
Construction	Brick veneer, tile roof, suspended timber (carpeted) floor with garage under.
Insulation	Ceiling only.
Windows	Single glazed, aluminium frame.
Window coverings:	Thick and think curtains, some pelmets.
Access to sun	Most rooms some sun over the course of the day, living area on south side.
Heating	Heat pump and electric blankets.

Changes to the home

Other changes to the home:

- Maureen had family visiting from Queensland who really felt the cold so used more heating and more hot water.
- Maureen now turns her heat pump off overnight to save power after advice from a Home Energy Helper.

GET BILL $MART UPGRADES

- ✔ Draught proofing of doors
- ✔ Door snakes
- ✔ Hot water system insulated
- ✔ Small fridge thermometer
- ✔ Hot water pipes insulated
- ✔ Stay Warm education booklet
- ✔ Hot water valve cosy
- ✔ Lights changed
- ✔ Shower timer

Overview

Maureen is retired and lives alone. She has family nearby and sometimes looks after her grandchildren. While Maureen is conscious of the cost of energy she manages her budget carefully and remains in control. When we first met her she managed the comfort of her home by opening and closing curtains to maximise sun, heating on the rooms she was in and using a lap rug to help keep herself warm.

Over the course of the project Maureen maintained her comfort levels to a standard that she was happy with. She maintained an average temperature in the living area of 17.8°C which is slightly lower than the average but at the median for the detailed study.

The only thing that changed Maureen's energy use was an increase in hot water use (35.8%). This was despite upgrades to her hot water system (insulation, efficient showerhead). Such an increase may be because of interstate visitors, or a small shift in her own patterns of hot water use. Maureen's other energy use remained constant across the 12 months of the project.

Maureen attended many of the Get Bill Smart events within the community. She reported that the events were informative and helpful but also very enjoyable socially.

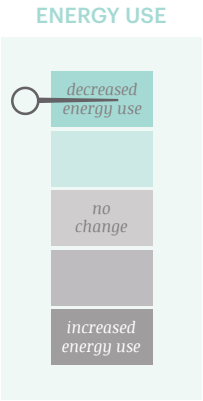
Average daily energy use and heating efficiency during winter conditions

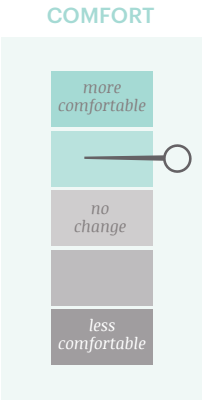
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.04	0.00	-0.04	-93.0%
T 41 Heating (hard wired heating)	12.76	12.48	-0.29	-2.2%
Total Heating	12.80	12.48	-0.32	-2.5%
Other Light and Power (T31)	-0.04	0.00	0.04	-93.0%
Hot Water	3.27	4.45	1.17	35.8%
Total Household Electricity	16.03	16.92	0.89	5.5%
House Heating Efficiency (degree-hours/kWh/day)	0.40	0.43	0.03	7.7%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	17.8	12.4	10.0	5.1	34.0%
After	17.8	11.5	9.3	5.4	34.0%
Difference between before and after	0.0	-0.9	-0.7	0.3	0.0%

CASE STUDY 2
Nonie and family



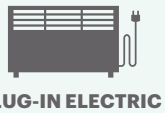


Occupants

Own or rent

Bedrooms

House type



Heating

What did we do?

COMMUNITY CAPACITY BUILDING

IN HOME EDUCATION & UPGRADES

> The only biggest thing I've got is the walls still cry... and I'm losing furniture, bedding, you name it.
>
> *(After Interview 08/09/2015)*

What was the result?

Nonie and her family felt warmer in their house and had reduced their bills. They acknowledged that the house was letting them down and that if they had more money they would have insulated the walls.

Fixing the draughts was probably what contributed most to their sense of increased comfort although the insulation was certainly important.

- ✔ Energy use reduced by 10.65kWh/day (21.8%) from 48.87kWh/day to 38.22kWh/day.
- ✔ Energy costs reduced by ~$181 per year.
- ✘ Time spent in comfort zone decreased from 17.1% to 12.7%.
- ✔ Heating efficiency increased from 0.66 to 0.89 (33.5%).
- ✔ Displayed improved confidence that she could find information on energy efficiency and comfort.
- ✔ Self reported moisture levels improved (high to medium), although mould still present in the bedrooms and temperatures still met dew point in cold weather.
- ~ Reported that draughts had improved but still present.

Existing physical conditions of the house

Nonie and her children live in a stand-alone one storey dwelling in suburbia. Although the living room is on the north end of the house, the windows only allow north west sun to enter the space. Bedrooms are along the west and south side of the house. The house is weatherboard, timber framed, with a low suspended floor (with carpet and vinyl covers) and a corrugated iron roof. The age of the house is unknown but is possibly 40-50 years old.

With little insulation, single glazed windows and poor thermal resistance in the building skin, this house does not provide much winter comfort and can overheat in summer. The very poor thermal performance also parallels with high levels of moisture in the house. Nonie installed a number of heaters to alleviate discomfort. The (initially installed) heat pump in the living room is now not used because it is ineffective. Instead, 5 plug in electric fan heaters have been hung on walls (2 in the living and 3 in bedrooms) and are used to warm the house.

Insulation	None prior; Added to ceiling at upgrades.	VERY POOR	improved to	NEAR STANDARD
Windows	Single glazed, aluminium frames.			POOR
Window coverings	Vertical blinds and medium weight curtains throughout.			POOR
Under floor space	Suspended timber at 0.2-0.4m off ground, enclosed underfloor with block. No insulation.			POOR
Mould and moisture	Reported high moisture levels and mould in bedrooms. Carpet in bedroom gets moist. Temperatures meet dew point regularly May through September 2015.			VERY POOR
Other conditions of note	House is generally well maintained. Small house for number of occupants (they make it work, but overcrowded).			

Changes to the home

Other changes to the home:

- On advice from Home Energy Helpers, Nonie and her family weighted the bottoms of their curtains to help reduce heat loss.
- Nonie changed the time of day she washes clothes to take advantage of cheaper power.
- The freezer temperature was adjusted (up) to reduce power.
- Nonie had solar panels installed in approximately July 2015 (4,000 Watt).

GET BILL SMART UPGRADES

- ✔ Ceiling insulation
- ✔ Shower timer
- ✔ Draught proofing of doors
- ✔ Door snakes
- ✔ Hot water valve cosy
- ✔ Small fridge thermometer
- ✔ Hot water pipes insulated
- ✔ Stay Warm education booklet
- ✔ Lights changed
- ✔ Water saving shower head

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (%)
T 31 Heating (plug in heating)	7.50	5.24	-30.1%
T 41 Heating (hard wired heating)	0.00	0.00	0.00
Total Heating	7.50	5.24	-30.1%
Other Light and Power (T31)	19.36	11.76	-39.3%
Hot Water	22.01	21.21	-3.6%
Total Household Electricity	48.87	38.22	-21.8%
House Heating Efficiency (degree-hours/kWh/day)	0.66	0.89	33.5%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	17.4	15.3	11.4	5.0	17.1%
After	16.4	14.2	10.7	4.6	12.7%
Difference between before and after	-1.0	-1.1	-0.7	-0.3	-4.4%

Referring to the tables and graphs presented, multiple changes were noted. Nonie's household saved electricity over the study period with a 21.8% reduction in electricity use. Reductions came from a 30.1% reduction in heating energy and a 3.6% reduction in hot water. Heating efficiency improved 33.5% from 0.66 to 0.89(oh/kwh/day). Despite these improvements, time spent in the comfort zone reduced from 22.1% of the time to 12.7% of the time (which is comparatively low). This means that some comfort was lost for the heating savings made (please note that before after period average temperatures were similar with only about one degree colder in the after period).

The reduction in time spent in comfort zone was not noted by Nonie, who actually reported that the family's comfort had improved. Improved comfort was likely in part due to a reduction of draughts from draught proofing and installation of ceiling insulation during GBS upgrade. Insulation effects are not always well represented in daily averages (as we are using here) but can assist at critical times of cold to hold in heat and improve comfort.

Despite better perceived comfort, Nonie reported children were still getting ill in the winter. The low internal temperatures may have affected illness rates. High occupancy levels are likely to have added to humidity levels and mould issues which would also affect illness rates.

Similar before and after average daily temperatures and continuing moisture issues indicates that the

thermal performance of the building skin was so poor that it undermined possible effects of GBS upgrades. Nonie was aware of this continuing poor physical performance saying how much she would appreciate it if she could organise a payment plan for installation of sisalation in the walls.

Nonie's household saw a very slight reduction in hot water use, but was still using 21kWh per day (in the after period) to heat water. This level of water heating is the highest of any house in the detail study (and would mean the hot water was heating 10 hours a day) but is not surprising considering the number of occupants.

Other light and power use is quite high in the table summary. We cannot fully account for this and suspect there may have been other heaters that were not plugged into sensors (or there were new heaters) that we did not know about. It is likely that, due to a lack of power points, existing sensors installed on plug in heaters were intermittently removed as children plugged in/pulled out chargers and electrical appliances. Removing sensors would have meant that heating was only registered on the light and power circuit.

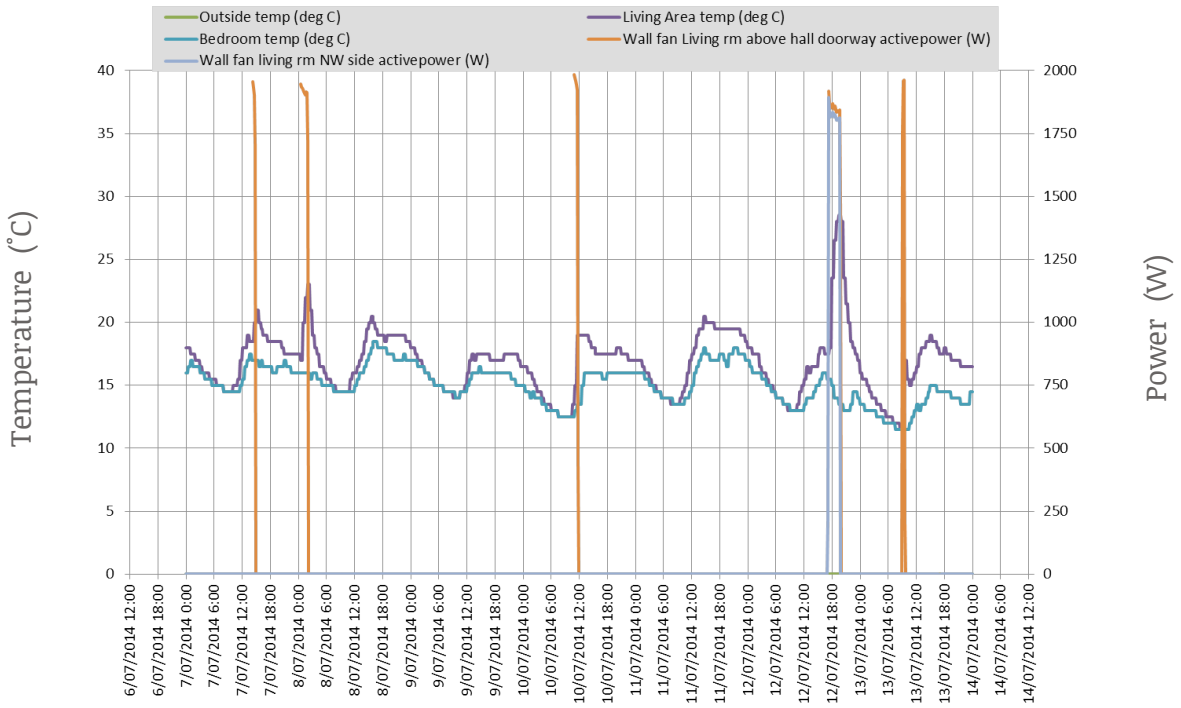
> She's had asthma most of the winter. It hasn't been as bad this year due to the--I'm positive--of the warmth. It's [the insulation in the roof] made a difference to her asthma... You don't realise what insulation can do... which sounds absolutely stupid, but you know... *(After Interview 08/09/2015)*

Nonie had solar panels installed several months before the end of the project, which likely reduced her energy bills somewhat. The effect of the on-site power generation was not measured in this detail study.

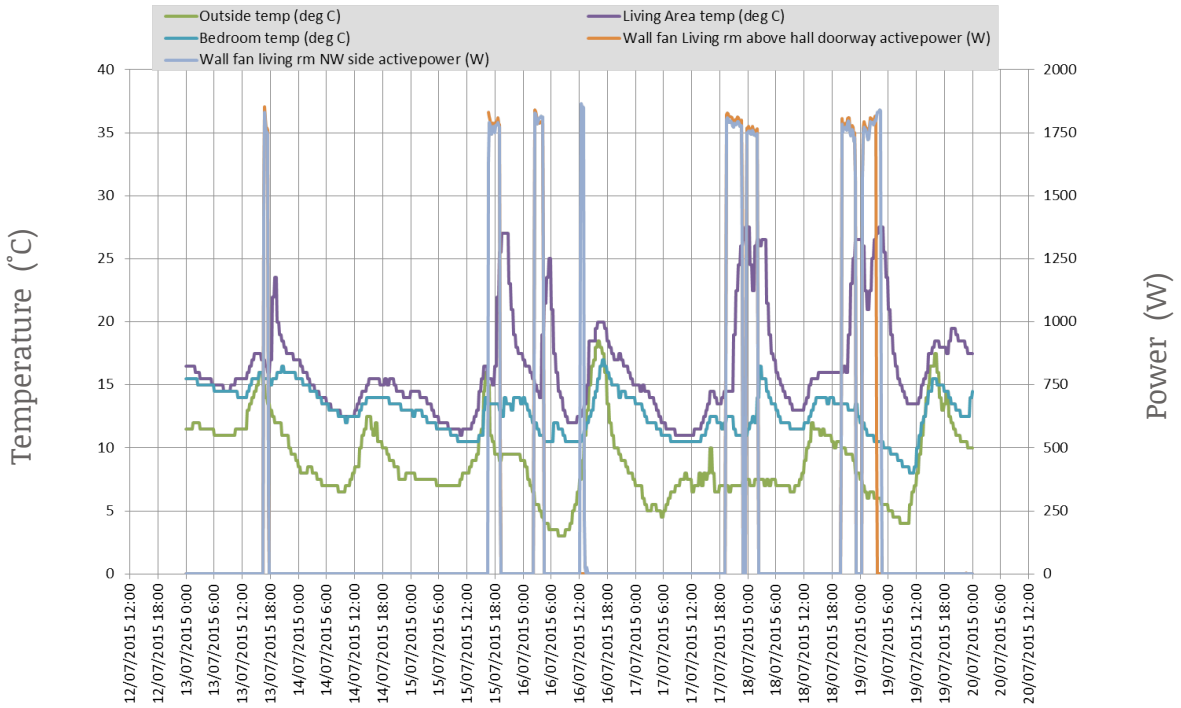
While upgrades helped with heating efficiency, temperatures were still meeting dew point regularly in the after period. The living and bedroom sensors recorded temperature meeting dew point throughout cold weather (May to September) which continued in the after period. The bedroom was the most susceptible to moisture condensing, but the living area was also vulnerable. Humidity rose a little in the after winter period – ranges before were 35% to 85% and increased to 40-90% afterwards. The extra time spent around 80 and 90% relative humidity indicates there was more opportunity for dew point to occur. Along with self-reported moisture and mould accounts, this data shows us that Nonie and her family had to deal with persistent moisture and mould issues. Moisture and mould was in part due to the number of occupants (all of whom breath and shower), but was also due to the very poor thermal performance and poor moisture extraction in the house. More draught proofing could have added to indoor moisture levels a little because it stopped some (drying) air movement. Even at times when air temperature may have improved, uninsulated walls and single glazed window surface temperatures would still be the same, so condensation would still occurred on these surfaces. Another likely cause of moisture issues in this house is the poor construction and detailing and proximity of floor to soil (with no barriers).

> It's horrible to warm up.... And the house doesn't hold heat. There's actually nowhere really in the whole house that gets warmer.
> *(Before Interview 10/6/2014)*

Before period: example week in winter showing selected energy use and temperature readings

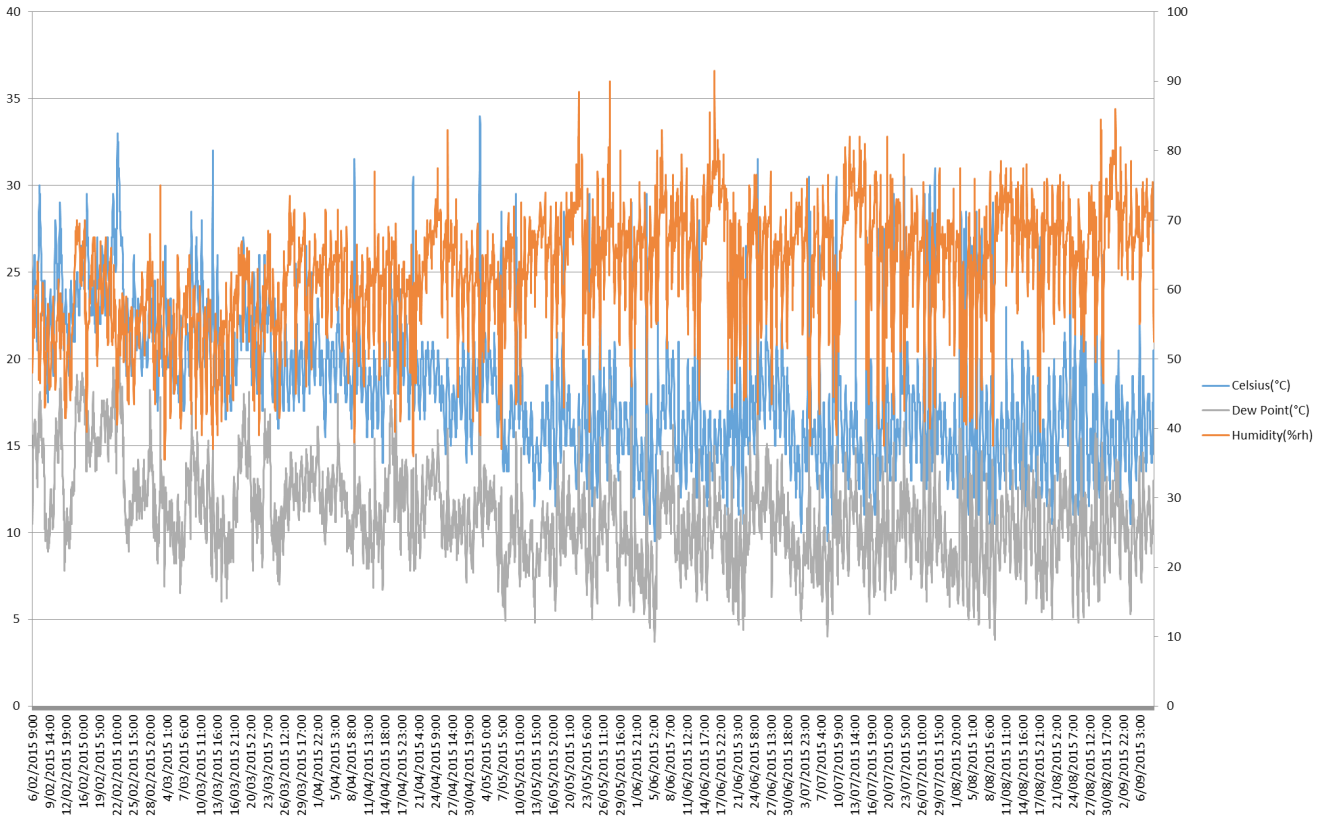


After period: example week in winter showing selected energy use and temperature readings



Energy and comfort

Temperatures, humidity and dewpoints example (living room sensor) recorded Feb 2015 to Sep 2015



Energy affordability

With ten people in the house to feed Nonie was often stressed about the price of electricity. She explained:

It concerns me on the amount of electricity we use because I know we use a lot... I'd like to do it [be more energy efficient] for affordability plus other reasons. That way I can do things with the kids because I'd have the money. *(Before Interview 10/16/2014)*

Nonie regularly had to juggle bills and admitted to cutting back on groceries in order to pay for electricity. Such restrictions made her stressed.

You do, you get stressed and you feel down because you can't provide what you've got to provide. You [I] can go without but it's horrible seeing your kids go without. *(Before Interview 10/16/2014)*

After the GBS assistance Nonie's bills decreased by ~$181 per year – a significant amount. When asked whether the changes she made to her practices (such as when she used the washing machine) had many any difference she laughed and said:

Oh yeah!

Personal and community change

Nonie and her 9 children lived in a small, cold, draughty and very damp house. Nonie and the children used to put their bedding in the living room and all sleep together to keep warm. After the upgrades Nonie said that they felt warmer. While the data above shows that the temperature of the house was no warmer on average, the reduction in draughts and the insulation seems to have made a difference to their comfort experience. Nonie said they no longer had to all snuggle together as often.

Before the upgrades moisture was a significant problem in the home, Nonie explained that:

> Every winter we've got to nearly redo the whole bedroom, furniture and that, we've got to replace it nearly every winter because the mould gets into the furniture. *(Before Interview 10/6/2014)*

After the upgrades moisture was still a problem. Walls in the house 'wept'.

Nonie and her family had noticed the effects of the GBS support. She thought it had been great and had helped. She did say that:

> The only thing I could suggest is someone out there that is willing to help with the insulation in the walls, the sisalation throughout and there's a payment plan. I think they need more of the payment plans to help keeping it warm. I'd jump at the chance.
>
> *(After Interview 08/09/2015)*

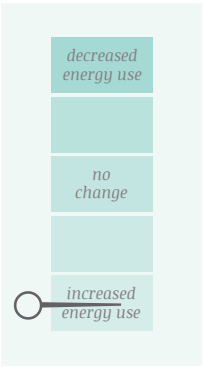
During the upgrades the Home Energy Helpers insulated the pipes on the hot water heater. Nonie had recounted (to the HEHs) how the dog had pulled insulation they had previously wrapped around the hot water heater off. The HEHs had responded by wrapping the tanks well and used a lot of extra tape. The dog chewed this off. Despite the HEHs returning and trying a different technique the dog still managed to destroy the insulation! Given the amount of hot water used, finding a solution to this problem may help Nonie and her family reduce energy use a little more.

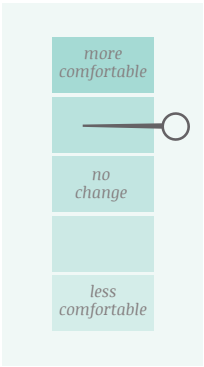
This family is in a relatively constant dynamic state. Occupancy changed with the coming and going of a boyfriend and the time people were home with illness. Nonie was heavily pregnant at the final interview and this may have changed her energy use.

Nonie showed an increased sense of community connection in the before and after surveys/interviews and an increased awareness that there were people within her community who she could ask for advice about thermal comfort and energy efficiency.

Although minor improvements were made in terms of comfort, and these were greatly appreciated by the householders, the thermal performance of this house remained very poor.

CASE STUDY 3
Emily and family





Occupants

RENTER

Own or rent

Bedrooms

FREESTANDING ONE STOREY

House type

PLUG-IN ELECTRIC

HARDWIRED RESISTIVE

Heating

What did we do?

COMMUNITY CAPACITY BUILDING

IN HOME EDUCATION & UPGRADES

> We're using heaps more power now because we had a baby and my partner has changed his work hours and goes to bed after me – I'm not awake to turn the heater off!
>
> *(After Interview 25/05/2015)*

What was the result?

Emily and her family increased their power bills and improved their thermal comfort. Power bills increased due to changes in family employment and a new baby.

Improvements were primarily due to changes in heating practices and increased awareness.

Mould was a huge issue and was the catalyst for Emily and the family to move house.

✗	Energy use increased by 24.27kWh/day (70.7%) from 34.31kWh/day to 58.59kWh/day
✗	Self reported energy costs increased significantly (no billing data available for this participant)
✓	Time spent in comfort zone moved from 20.6% to 63.9%
✗	Heating efficiency decreased from 0.77 to 0.31 (60.4%)
✓	Displayed improved confidence that she could find information on energy efficiency and comfort
✗	Self-reported moisture and mould increased (medium – high)
✗	Draughts remained problematic but were reported to have reduced at front door which helped.

Existing physical conditions of the house

Emily and her family's house (at the time of GBS before they moved) was a standalone suburban house on a smaller-sized block. The house is timber framed with corrugated iron and fibre board cladding and has suspended timber floors with carpet. Constructed in 2012 this house was constructed under en energy efficiency code (one of only a few in the GBS study) and therefore has some insulation. The long axis of the house sits north to south, which means the house is (mainly) open to sun on the long east and west sides of the house.

The living room sat on the southwest of the house generally receiving afternoon sun only. Heating was provided by a wired in radiant heater in the living room and by a plug in radiant heater. Even with some insulation and more recent construction, the orientation, single glazing and poor construction detailing undermined indoor performance. Emily found the house difficult to heat, moist and mouldy. Emily was so uncomfortable in summer and winter that she didn't think they had any insulation at all.

Insulation	In ceiling.	NEAR STANDARD
Windows	Single glazing with aluminium frames.	NEAR STANDARD
Window coverings	Blinds (thin) throughout.	POOR
Under floor space	Suspended timber floor (carpeted), underfloor enclosed with corrugated iron.	NEAR STANDARD
Mould and moisture	Noted as high in survey. Humidity measures show dew point reached regularly in winter and intermittently over rest of year.	VERY POOR
Other conditions of note	House maintained and in working order.	
	House brought to site in two pieces which were joined poorly. Water leaked through poor detailing of this join.	

Changes to the home

Other changes to the home:

- The family stopped using plug in heater.
- Emily attempted to spend less time in the shower.
- Emily regularly used moisture absorbent beads in her son's bedroom and regularly changed pillows to limit moisture and mould growth.
- Emily had a baby (soon after the first GBS visit) bringing the total occupants to 4.
- Emily's partner changed work hours and heating use practices.

GET BILL SMART UPGRADES

- ✔ Draught proofing of doors
- ✔ Lights changed
- ✔ Shower timer
- ✔ Door snakes
- ✔ Small fridge thermometer
- ✔ Stay Warm education booklet

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	5.55	0.00	-5.55	-100.0%
T 41 Heating (hard wired heating)	4.91	34.79	29.89	609.3%
Total Heating	10.46	34.79	24.33	232.6%
Other Light and Power (T31)	10.77	13.78	3.01	27.9%
Hot Water	13.08	10.01	-3.07	-23.4%
Total Household Electricity	34.31	58.59	24.27	70.7%
House Heating Efficiency (degree-hours/kWh/day)	0.77	0.31	-0.47	-60.4%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	15.9	15.4	7.6	8.1	20.6%
After	18.5	18.2	7.7	10.6	63.9%
Difference between before and after	2.6	2.8	0.1	2.5	43.3%

Energy and comfort

Referring to the tables and graphs presented, multiple changes were noted. Overall electricity use increased by 70.7%. Contributing most to this increase was an increase in heating. While the plug in heater use decreased to zero, hard wired heating used increased by 609.3%. As Emily explained, energy use habits of her household changed with the arrival of a new baby and her partner's change in working hours. Emily's partner felt the cold more than she did and often got home late from work, turned the heater on and then fell asleep. Emily was much more energy conscious but her partner's late arrival time meant she was often not awake to remind him to turn things off.

While energy use went up, time spent in the comfort zone also increased significantly from 20.6% to 63.9%. Almost no time was spent above the comfort zone of 24 degrees. This increase in the time spent in the comfort zone took the family into a much better temperature range for a greater length of time, which would have better supported health.

Average temperatures were similar in the living area and bedroom which seemed to be heated to similar levels. Average temperatures increased from approximately 15°C (before) to approximately 18°C (after). There was a reasonable difference between inside and outside temperatures in the before and after periods. These in/out door temperature differences were above both average and median for the detailed study cohort. This was in part because of the house being built with some insulation as part of energy efficiency standards.

Heating efficiency of the house went from 0.77 to 0.31, a 60.4% decrease. This change was largely because of the significant increase in heating being used. As is to be expected as heater use increased, house heating efficiency decreased. The before heating efficiency was over the average for the detailed housing group and so was comparably high (in this study that mainly has poorly performing stock). The after efficiency was more common of the rest of the detailed group houses.

Other light and power (with plug in heating removed) increased by 27.9% from 10.77kWh/day to 13.78kWh/day. This increase was likely from more than just an increased use of lighting and may have been from an increase use of appliances or changed habits.

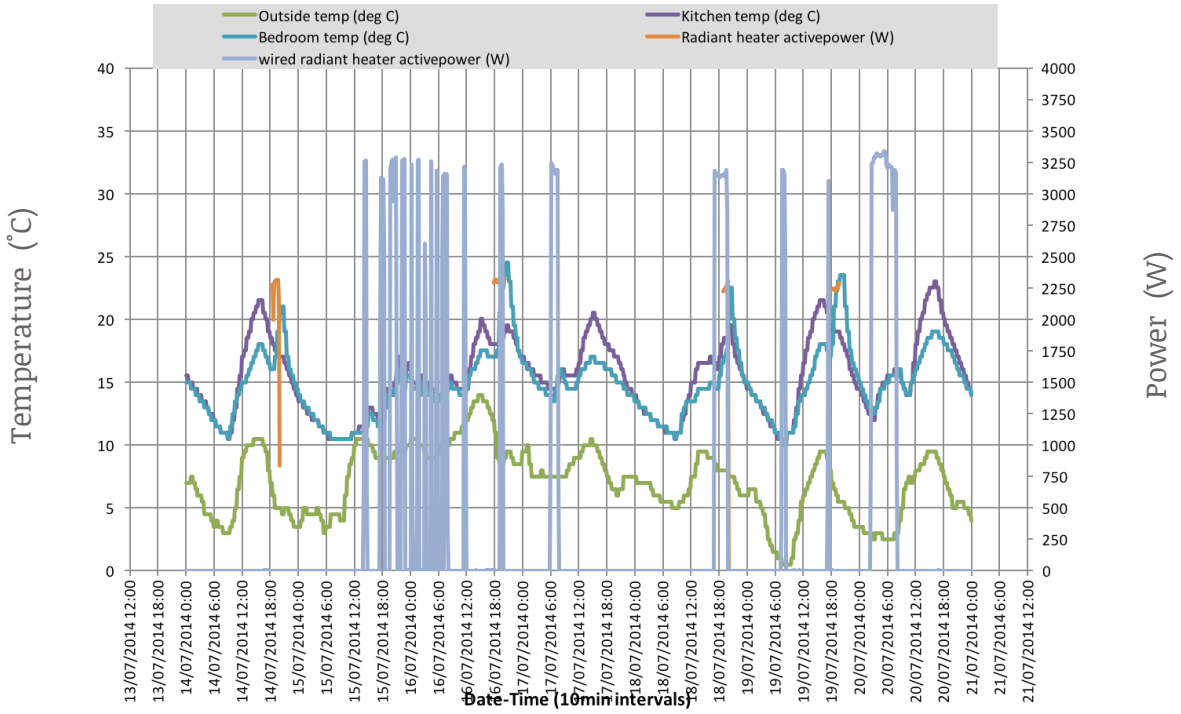
Hot water usage decreased from 13.08 kWh/day to 10.01 kWh/day (23.4%). This is likely due to Emily's increased attention to the time she (and her children) spent in the shower – something she was attempting to reduce.

Humidity was an ongoing problem for Emily and her family. Both bedroom and living area temperature/humidity loggers recorded indoor temperatures regularly reaching dewpoint throughout winter and intermittently during the rest of the year. Temperature and dew points recorded in the bedroom up to the interim visit are provided as an example. Maintaining warmer temperatures should have helped to reduce the likelihood of temperatures reaching dew point, however in this case, where the house had design and detailing issues that caused entrenched moisture and mould problems, increased heating was not much help.

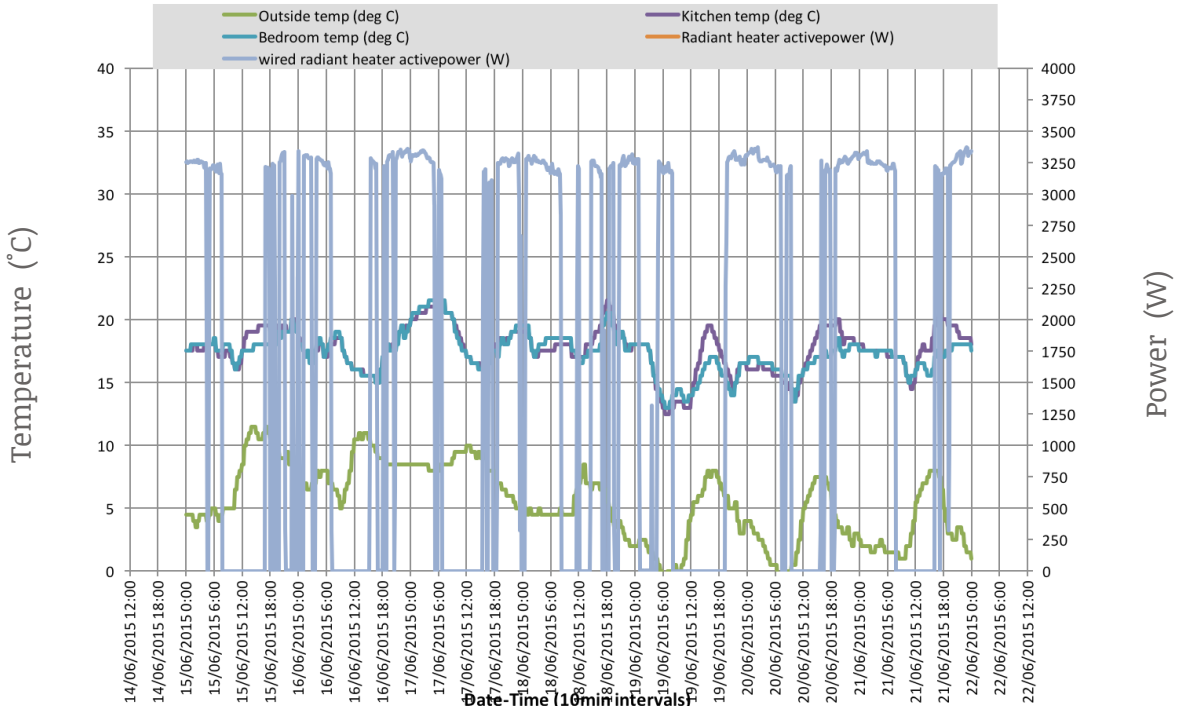
> The heater will warm the house up, but then it just doesn't stay warm, like that heater will have to keep going constantly, it doesn't click off, with the thermostat. The wind comes straight through, I sit on the couch, you can feel the draught.
> *(Before Interview 04/07/2014)*

> The windows still rattle, but yeah, there's no door draught now. *(After Interview 25/05/2015)*

Before period: example week in winter showing selected energy use and temperature readings

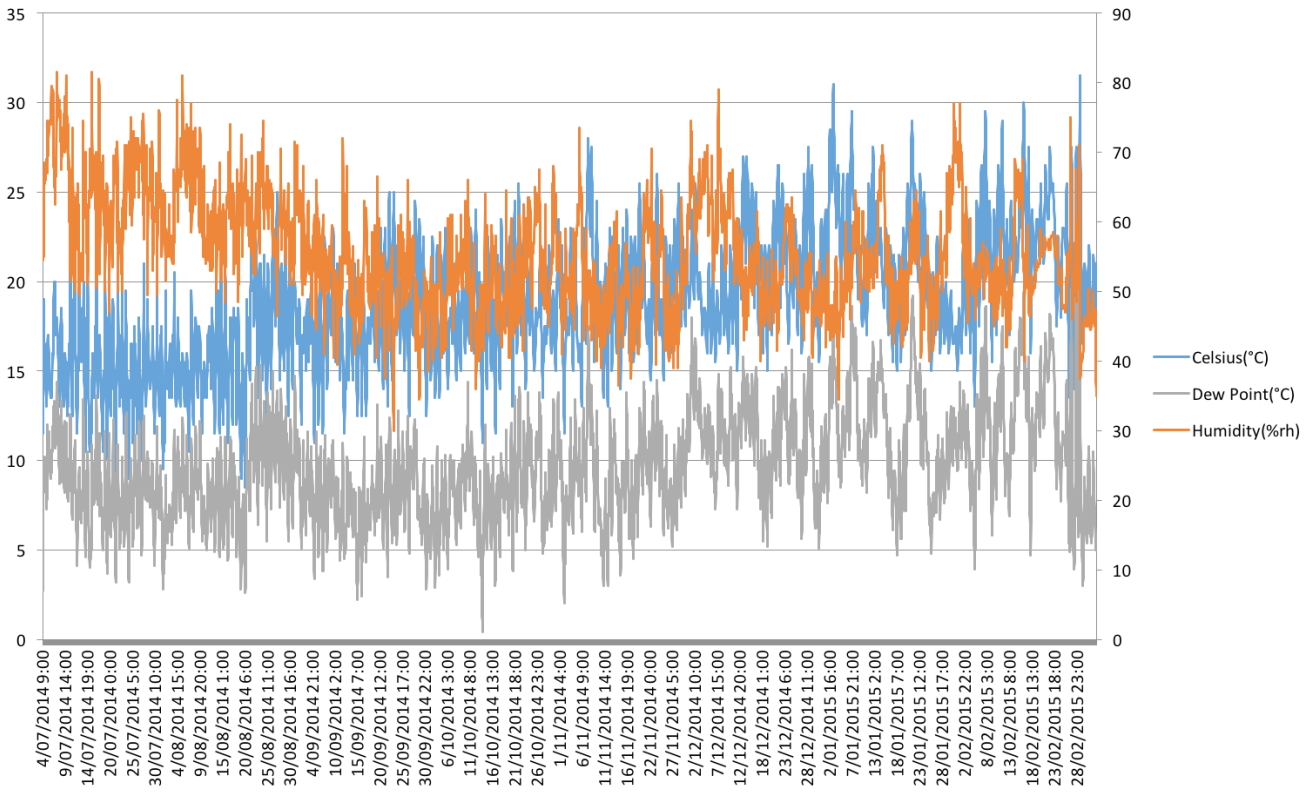


After period: example week in winter showing selected energy use and temperature readings



Energy and comfort

Temperatures, humidity and dewpoints recorded July 2014 to February 2015



Energy affordability

While we were unable to obtain billing data for Emily, she reported that her bills were substantially higher. This matches with the data above showing a dramatic increase in energy use.

Emily very carefully monitored power use and electricity costs in her home. She was very strict about this when we first met her and continued to be so throughout the project. Emily reported that she turned appliances off at the powerpoint and encouraged energy saving behaviours:

> Yeah, and that's why I've got blankets on the couch because I tell my partner, put a blanket over you because I'm not putting the heater on, as it costs too much.
> *(Before Interview 04/07/2015)*

Energy costs in her household increased significantly due to a new baby and a very different work schedule for her partner:

> Yeah it was $7.33 a day. I think my bill was $600 or $700. We pay $50 a week so we still got in credit, but still $50 a week is quite a bit for power. *(After Interview 25/05/2015)*

Personal and community change

When we met Emily she lived in her house with her partner and three year old son. At the time she was pregnant with her daughter who arrived just weeks after the first GBS visit.

Emily described the house as horribly cold in winter and horribly hot in summer. The draughts in winter contributed significantly to her discomfort. When it was too hot in summer, Emily would take her son for a drive in the air-conditioned car to get away from the heat that made them cranky. In winter, she used the living room heater (wired into the wall) and sometimes a plug in electric heater in the hallway to heat the bedrooms.

One of the biggest challenges for Emily and her family was managing the moisture in the house. Prior to the upgrades she explained that while she kept some doors of the house closed to stop heat loss, she did have to keep others open to manage the mould:

I keep the bathroom[s]... closed, and the baby's rooms closed, but I can't keep them closed all the time because that's where the mould is in too, so I need to open that up as well. *(Before Interview 04/07/2014)*

To prevent mould Emily regularly used moisture absorbent beads and wiped moisture from the windows, especially in her son's bedroom. Despite this, mould growth continued. In her son's room the moisture problem was so bad that his pillow had to be changed every few months because it would go mouldy.

After the home energy upgrades Emily reported increased moisture in the living areas. She explained that:

Last year it was on most windows, and it seems to be more in the windows this year, yeah, it's thicker. Normally I'd wipe it over with a towel and that would be enough, but now I'm going, you know, two or three towels will dry it. *(After Interview 25/05/2015)*

Extra moisture on windows may have been due to: colder outdoor temperatures, more moisture being generated indoors, or draughts being reduced somewhat by the GBS home visit.

Prior to the GBS activities Emily kept a close eye on the energy use in her home. She did this by monitoring power usage and attempting to reduce costs. She tried to keep this monitoring up after the GBS home visit as well.

I try and make my partner stop watching the TV so late at night because he falls asleep with it on, but I always go out and check my meter, with the Aurora thing and see how my bill is going and all that, too. *(after Interview 25/05/2015)*

Emily displayed increased confidence that she knew where to go to get further information on thermal comfort and energy efficiency after the GBS home visit. Emily also expressed a greater sense of control over her energy use, explaining that she knew the places where she could cut down if she was desperate.

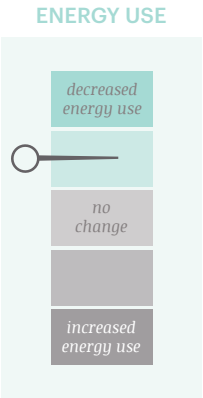
While Emily's house was relatively new, it was poorly built which undermined thermal performance and moisture management:

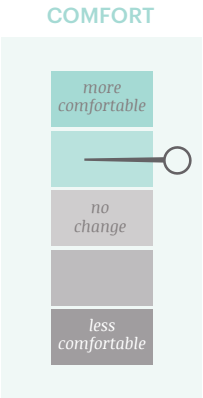
It was two houses together, it came as a kit-home or whatever like this because they didn't join it up very well and see where it's leaked, because this came on the truck and then that bit came on the truck, that's why this wall's double the width, and then they joined them together, so I don't know, because they are quite cheap, and everything is made quite cheap in them. *(Before Interview 04/07/2014)*

Overall although there were minor improvements made in terms of comfort that were appreciated by the householders, they came at high financial (and energy) costs. Emily did gain from the GBS home visit, but this support was undermined by the poor thermal, moisture and energy performance of this house.

The poor performance of the house meant Emily and her family decided to move to a more functional home.

CASE STUDY 4
Ralph and Sally





Occupants	Own or rent	Bedrooms	House type	Heating
	OWNER WITH MORTGAGE		FREESTANDING ONE STOREY	PLUG-IN ELECTRIC + HARDWIRED RESISTIVE

What did we do?

COMMUNITY CAPACITY BUILDING

+

IN HOME EDUCATION & UPGRADES

What was the result?

Ralph and Sally were warmer in their house for slightly longer periods of time after the GBS upgrades visit but they also used more power. While power use overall went up, savings were made in hot water and lighting. Ralph was unwell and had been for an extended time and needed to keep warm. Upgrades and changes to energy use behaviour helped to limit energy costs associated with keeping Ralph warm.

- ✗ Energy use increased by 1.94kWh/day (5.3%) from 36.55kWh/day to 38.49kWh/day.
- ✓ Energy costs decreased by ~$50 per year.
- ✓ Time spent in the comfort zone increased from 38.0% to 41.3%.
- ✗ Heating efficiency decreased from 0.38 to 0.31.
- ✓ Displayed improved confidence that they could find information on energy efficiency.
- ✓ Self-reported moisture levels decreased (high – low) and no longer throughout the entire house. Measures show temperatures close to dew point in living and bedroom in winter before and after, but winter humidity ranges reduced in both areas in the after period.
- ✓ Draughts still present but reduced.

[I'd like the government to know] how high our power bills are. Reduce the cost of power. We are supposedly a hydro state, we have dams and something, you'd think power would be a little bit cheaper. *(After Interview 04/09/2015)*

Existing physical conditions of the house

Ralph and Sally live in a one storey suburban standalone house on a standard sized suburban block. The house is approximately 30-39 years old and is constructed of brick with timber frame, a tile roof and suspended timber floors (with carpet and vinyl). The long axis of the house sits north east to south west. Sun comes into the kitchen in the morning and the living room during the middle of the day. For the majority of the house the sun comes in during the afternoon.

The living room is located on the north west corner of house. The living and kitchen are open plan. The main heat source is a large wired-in radiant resistance heater which is located in a disused fire place. The fire place is blocked off. There is also a radiant panel heater on the wall in the hallway.

Uninsulated walls and floor and the single glazed windows and the orientation all contribute to making the thermal performance in this house poor.

Insulation	Ceiling insulation.			POOR
Windows	Single glazed, aluminium frames, no pelmets.			POOR
Window coverings	Blinds and light weight curtains.			POOR
Under floor space	Suspended timber floor 0.2-0.8m off ground, underfloor enclosed with brick, no insulation.			POOR
Mould and moisture	Measures show temperatures close to dew point both before and after in the living and main bedroom in winter.	POOR	improved to	NEAR STANDARD
	Winter humidity ranges, however, reduced in both areas in the after period. Self-reported moisture levels decreased (from high – low) with less of the house affected than during the before period.			
Other conditions of note	House is well maintained.			
	Issues with draughts (reduced in after period).	POOR	improved to	NEAR STANDARD

Changes to the home

Other changes to the home:

On the advice of the Home Energy Helpers, Ralph and Sally have changed some of their behaviours and now:

- Unplug appliances when not in use
- Use the fan on the heater rather than just bars
- Close the door to the living room, heating only the space they are in.

Ralph has been unwell and has recently spent considerable time in hospital.

GET BILL SMART UPGRADES

- ✔ Temperature turned down on hot water system
- ✔ Water saving shower head
- ✔ Draught proofing of doors
- ✔ Shower timer
- ✔ Hot water system insulated
- ✔ Door snakes
- ✔ Hot water pipes insulated
- ✔ Small fridge thermometer
- ✔ Hot water valve cosy
- ✔ Stay Warm education booklet
- ✔ Lights changed

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	3.23	2.41	-0.82	-25.3%
T 41 Heating (hard wired heating)	17.48	24.17	6.69	38.3%
Total Heating	20.70	26.58	5.88	28.4%
Other Light and Power (T31)	8.01	6.49	-1.52	-19.0%
Hot Water	7.84	5.42	-2.42	-30.8%
Total Household Electricity	36.55	38.49	1.94	5.3%
House Heating Efficiency (degree-hours/kWh/day)	0.38	0.31	-0.07	-17.8%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	17.3	16.2	8.9	7.9	38.0%
After	17.5	16.7	8.8	8.3	41.3%
Difference between before and after	0.2	0.5	-0.1	0.4	3.3%

Referring to the tables and graphs presented, multiple changes were noted.

There was a slight increase (1.94 kWh/day) in Ralph and Sally's Total Household Electricity from 36.55kWh/day to 38.49 kWh/day (5.3%).

Ralph and Sally reduced their use of plug in heating by 25.3% (0.82kWh/day) and increased their hard wired heating use by 38.3% (6.69kWh/day). The hard wired heater is a large radiant heater in the living room. Overall energy use for heating increased by 5% which reduced the Household Heating Efficiency from 0.38 to 0.31 (17.8%). Ralph and Sally reported changing the way they used the wired in living area heater. They used it more often on medium and reduced their use of the low and high settings.

They also began using the fan function in the heater and not just the radiant aspect by itself.

Average indoor temperature figures were lower than the average and median figures for the detailed participants and international comfort standards, but were higher than many other detailed participants. Temperatures stayed within the comfort zone for over a 1/3 of the day with increases in the after period. In the before period, the house sat in the comfort zone 38.0% of the time. In the after period it sat in the comfort zone for 41.3% of the time. Temperatures went over the comfort zone in the living area in the before period for 1.3% and in the after period for 5.1% of the time. The average temperature in the bedroom did not ever go above

24°C (and so never went above the comfort zone). Therefore there were significant periods where Ralph and Sally lived below the comfort zone.

The increase in energy use can in part be explained by Ralph's poor health – this was a problem during the after period.

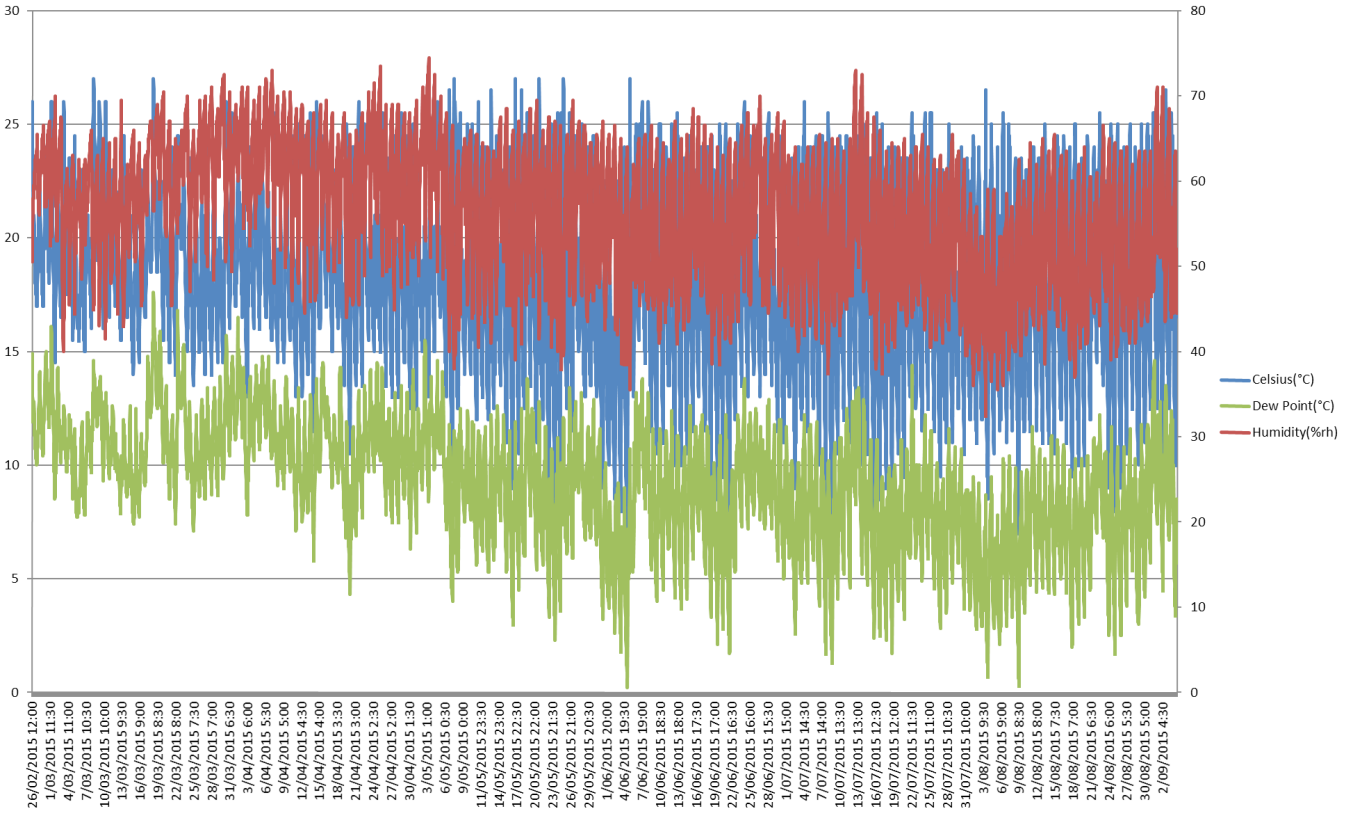
Other light and power and hot water energy use both decreased. Light and power decreased by 19%, while hot water decreased by 30.8%. Ralph and Sally received lighting and hot water upgrades during the GBS home visit, likely influencing these energy reductions.

Ralph and Sally reported moisture issues in the before survey and some improvement in the after survey. Temp/humidity measures in the living and bedroom show that temperatures tended to regularly go to a point just above dew point in both before and after periods in winter. Living room temperatures more regularly got close to dew points. Temperature close to dew point can cause condensation on some surfaces, particularly cooler external walls and windows. Humidity improved in the after period. The bedroom improved from a winter humidity range of 50-85% to 45-75% after. The living room improved from a winter humidity range of 45-80% before to 35-70% after. These humidity reductions align with Ralph and Sallys' accounts of moisture becoming more manageable.

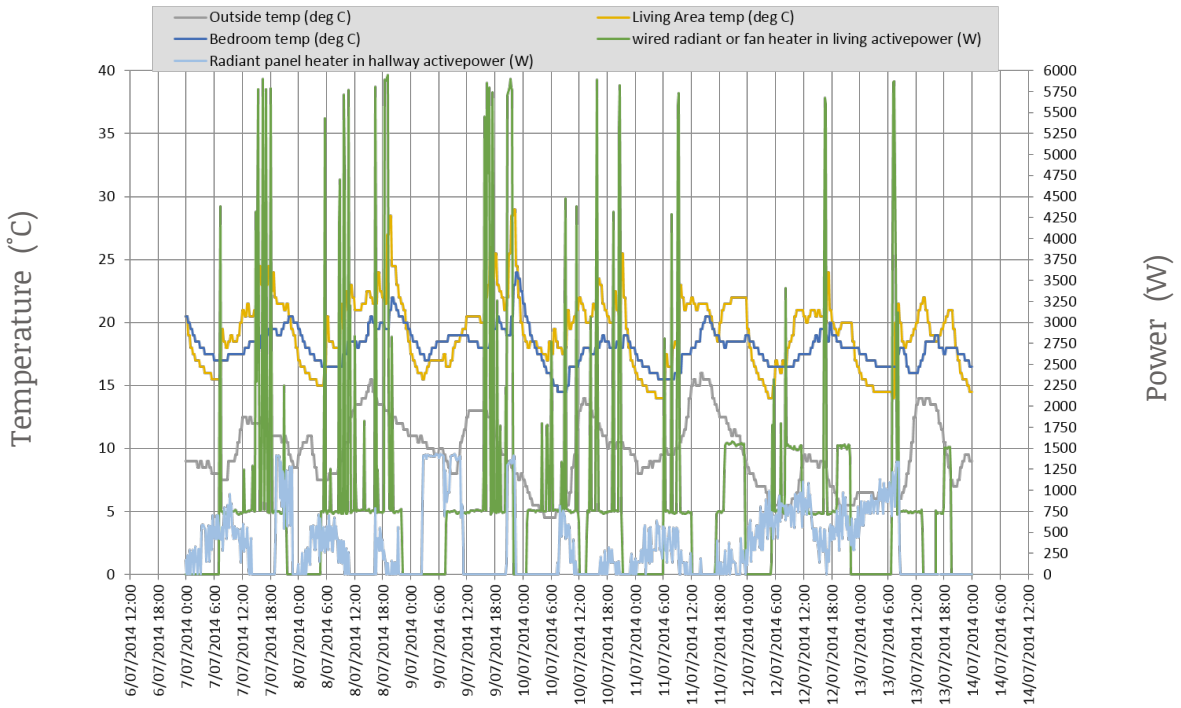
> Yeah and a terrible draft comes down the hallway. I guess with these houses you kind of expect it.
> *(Before Interview 28/05/2014)*

> Oh, we have been going to bed early too of a night. [A] nice place to be on a cold night, and we're saving on power. *(After Interview 04/09/2015)*

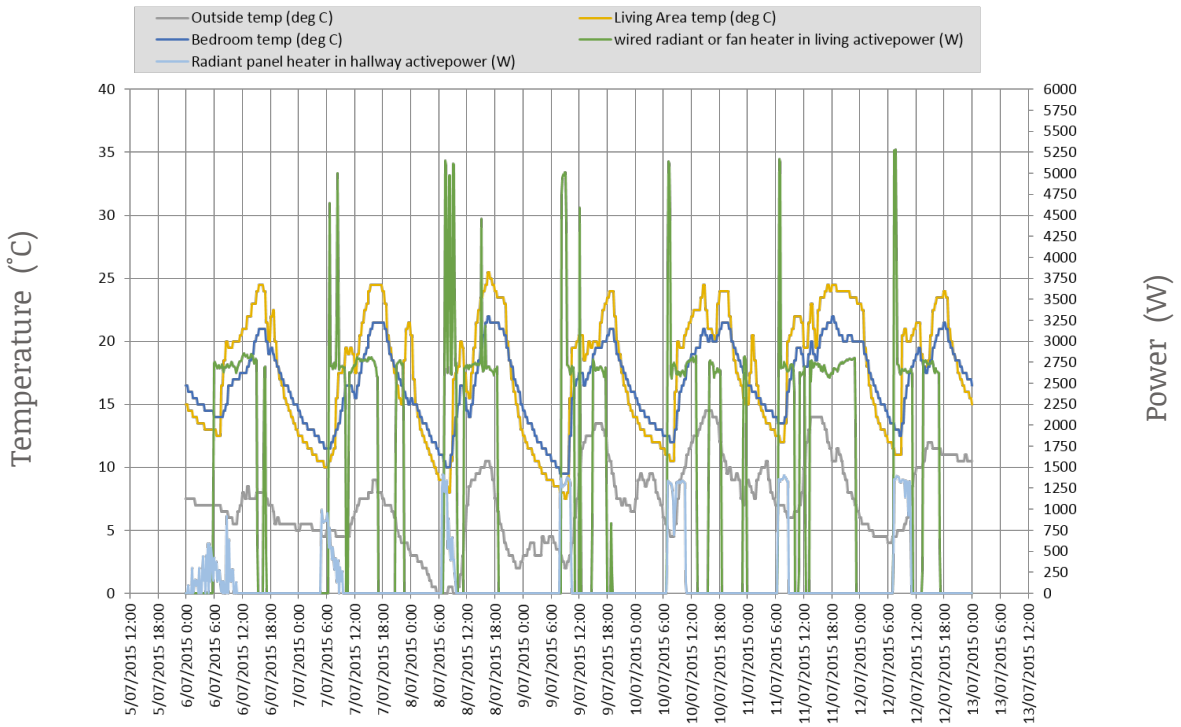
Temperatures, humidity and dewpoints example (living room sensor) recorded May 2015 to Sept 2015



Before period: example week in winter showing selected energy use and temperature readings



After period: example week in winter showing selected energy use and temperature readings



Energy affordability

Until he got sick, Ralph had been the main breadwinner for the family. With this history he tends to feel more stress and greater responsibility when the household bills arrive. Sally explained:

[The bill] bothers my husband more than it bothers me. Because he's been active and working, yeah, being a carpet layer, vinyl layer. Now my husband's illness you know, so I'm his carer so we kind of used all our Super, not that we had much. So now we're on the pension, so it worries him more than it worries me. I'm the one that sort of sits down, pays the bills. When he comes across a [power] bill he goes 'ah my god we can't do this...' I just say 'steady on, cool down, it'll be right, [and I] fix it'.
(Before Interview 28/06/2014)

While Ralph and Sally's energy use increased, their bills suggests that their costs reduced by approximately $50 per year. These savings likely came from a reduction in kWh costs, the reduced light and power and hot water energy use and the changes of heating to the wired in heater, which was cheaper to use.

Sally said that she felt that she was doing everything that she could to reduce energy costs:

I mean, I only wash, I wait until the clothes basket's full before I wash. And we do turn all the power points off, and the TV off, and stuff like that. *(After Interview 04/09/2015)*

Personal and community change

Ralph and Sally are a couple in their 60s and 70s. They have lived in their house for over thirty years tending to it and keeping it kept it neat and tidy. Previously a tradesman and the type of person who 'got the job done', Ralph would attend to maintenance jobs around the home. Just as involved, Sally ensured the house ran smoothly.

As an older couple, and with Ralph's health problems, they have been heating the house. Ralph is feeling the cold. As Ralph said:

I feel the cold, I've got blood like water.
(Before Interview 28/05/2014)

While Sally wasn't too badly affected by the cold, Ralph said that when he was cold:

You sort of don't feel like doing anything.

and that he got

...a bit dirty in the cold weather,
I'm a summer person.
(Before Interview 28/05/2014)

Sally explained that she staved off the cold by being:

Constantly on the go, I mean I'm not having a dig at my husband, well I am a couple of years younger than him. Thank god I'm in reasonably good health. *(Before Interview 28/05/2014)*

It was not only Ralph's health that affected how they heated their home. Ralph and Sally often looked after a young granddaughter with asthma. To reduce the impact of the asthma they used the hallway panel heater to keep the air warmer for her to breathe.

Personal and community change

Ralph and Sally carefully balanced comfort/health and the consequent energy use with the costs. Sally sometimes decided to choose comfort and explained that:

> [When Ralph says] to me, 'turn the TV off' or 'turn the heater [off]', because sometimes I'll sneak it on two bars, and he'll be 'what are you doing that for?' I just say I want to be warm rather than having to worry about the bill. I think I'll worry about that when it comes.
> *(Before Interview 28/05/2014)*

As they said in the second interview, this is just:

> Something to try and balance.
> *(After Interview 04/09/2015)*

The reductions in light and power and hot water energy use (after GBS upgrades) and a kWh price reduction allowed Ralph and Sally to better afford the power they needed to heat their home to a comfortable temperature while Ralph is ill.

Ralph and Sally expressed agreed strongly in the survey that there were people within their community whom they could ask for help and advice on energy efficiency and thermal comfort. This agreement remained high in the after survey. During the After Interview they also acknowledged that their children were likely to be helpful sources of information, mostly because:

> ...they're greenie-type people.
> *(After Interview 04/09/2015)*

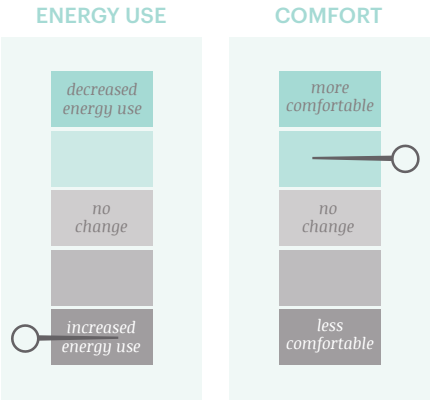
who would be interested and willing to help. While Sally explained that she and Ralph tended to keep to themselves a bit, they also clearly knew their community and 'belonged' to the community. Having lived in their home for over thirty years they were familiar with many people in the area, including other family members. Even when 'keeping to herself', Sally was always willing to give someone a lift home from the shops and have a chat to them.

Sally was unable to attend any of the Get Bill Smart community events and activities as they either clashed with family events or she was busy looking after Ralph while he was sick.

Ralph and Sally, while they live in an under-performing house, manage their house well and make clear choices about using energy. They were receptive to the GBS home visit, are well connected and are willing to learn about things that may help them out. However, Ralph's health and a limited budget were major limits to making energy use and comfort choices. After the GBS home visit/upgrade they took action to be a little warmer in their house for a longer period of time and had to use a little more energy to do this.

CASE STUDY 5

Matthew and Narelle



What did we do?

> When we want to [reduce energy use], at the moment we've got no damn control over it. We try to do the right thing but nobody else does.
>
> *(After Interview 08/09/2015)*

What was the result?

For Matthew and Narelle, significant changes to household occupancy (from 2 – 7) overrode any sense of control or ability to manage thermal comfort and energy efficiency.

As a result of changed occupancy levels energy use increased as did the time spent in the comfort zone. Unfortunately for a household already conscious of bills, energy bills also increased.

The Get Bill Smart upgrades did not seem to make a difference to the home given the significant change in occupancy.

✗	Energy use increased by 12.71kWh (36.7%) from 34.67kWh/day to 47.38kWh/day.
✗	Self-reported increase in energy bills (no data available from energy supplier).
✓	Time spent in the comfort zone increased from 37.3% to 41.8%.
✗	Heating efficiency decreased from 0.32 to 0.27 (13.9%).
✓	Displayed significantly improved confidence that they could find information on thermal comfort and energy efficiency if needed.

Existing physical conditions of the house

Despite uninsulated floors and (some) walls and the single glazing, the solar access of the living room, the inclusion of insulation during an extension ten years ago, and the addition of front and back door airlocks (during the extension) created a house that is more thermally resistive than other pre 2003 energy efficiency standards houses in the study.

Matthew and Narelle installed photovoltaic prior to Get Bill Smart visits and therefore were also able to produce power and reduce the cost of their energy bills. Overall this house performed better than many in the study and sat at an almost near standard performance.

Type	Stand alone, suburban.
Age	40-49 years.
Construction	Concrete block painted, tin roof covered with tiles, suspended timber floor (.2-2m high) (carpet, vinyl, tiles), workshop and laundry under.
Insulation	Ceiling (batts 7 yrs old and 45 yr old insulation under), in walls in extension (7 yrs old).
Windows	Single glazed, aluminium frame.
Window coverings	Vertical blinds and curtains in living and bedrooms; curtains in other beds, noted as heavy.
Access to sun	All day, northwest orientation, living room on north corner with east and west windows.
Heating	Column heater in bedroom, wired storage heater in living room, wired storage heater bedroom.

Changes to the home

Other changes to the home:

- Matthew and Narelle installed roller shutters on the outside of the windows for privacy and warmth.
- Four family members have moved back into the house (son and teenage grandchildren aged 11, 13 and 14).

GET BILL $MART UPGRADES

- ✔ Draught proofing of doors
- ✔ Door snakes
- ✔ Hot water pipes insulated
- ✔ Small fridge thermometer
- ✔ Hot water valve cosy
- ✔ Stay Warm education booklet
- ✔ Water saving shower head
- ✔ Lights changed
- ✔ Shower timer

Overview

When we first met Matthew and Narelle they lived together in their suburban home. They had installed solar panels prior to participation in the Get Bill Smart program, showing an interest in energy use. Matthew explained that he hoped the solar panels would help to reduce bills. However, the first bill that they received after the PV installation suggests that there is a fault with the solar system.

At our After Interview Matthew and Narelle said that their son and three of his children had moved in with them. This change in household make up put a financial strain on the couple and contributed to an overall increase of energy use of 36.7% (12.71kWhrs/day). Much of this increase can be seen in hot water and heating use. Matthew and Narelle felt that they lost a lot of control of house management at this point and they appeared stressed by this change.

In the before period the couple had been using what was a fairly normal amount of energy for two people, not too high or low. Interestingly the increase in energy use was not actually that high for the addition of another five occupants.

Matthew and Narelle were quite security conscious and in between our visits had installed some security window shutters for safety and to help manage indoor temperatures. They felt that this change had helped to keep the heat in.

The couple had attended to several Get Bill Smart events in their community (likely the BBQs). They reported that not many people attended and there was no discussion of energy efficiency or thermal comfort but that they were socially enjoyable.

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.73	0.00	-0.73	-100.0%
T 41 Heating (hard wired heating)	20.27	28.57	8.30	41.0%
Total Heating	21.00	28.57	7.58	36.1%
Other Light and Power (T31)	10.38	12.91	2.53	24.4%
Hot Water	3.30	5.90	2.60	78.7%
Total Household Electricity	34.67	47.38	12.71	36.7%
House Heating Efficiency (degree-hours/kWh/day)	0.32	0.27	-0.04	-13.9%

Average daily temperatures and time in comfort zone during winter conditions

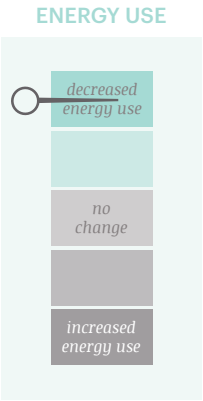
	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	19.0	13.6	9.6	6.7	37.3%
After	19.6	13.9	8.9	7.8	41.8%
Difference between before and after	0.6	0.3	-0.7	1.1	4.5%

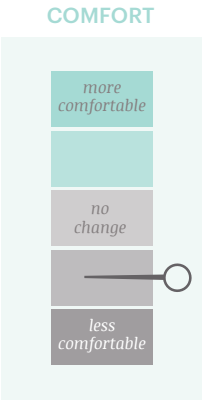
Overview

While they had a GBS home education/upgrade visit, Matthew and Narelle did not really feel that they learnt anything new. With the changes they and already made and the conversation they had with GBS researchers it was clear that they were already reasonably informed about energy efficiency. It appears though that addition of more householders strongly overrode earlier energy practices in the home.

As a result of the change in household make up energy use increased as did the time spent in the comfort zone. For a household already conscious of bills, energy bills also increased. The Get Bill Smart upgrades did not seem to make a difference to the home which would in part be because of the change in occupancy and the higher level of thermal performance in this house compared to others.

CASE STUDY 6
Caitlin and family





What did we do?

Well, I mean this has been really good and it's not all done in all high-tech fancy-pants talk, so you--and you don't feel stupid if you are asking something and I mean I think that this whole thing is, yeah, as a package, it's been brilliant, like it really has ... *(After Interview 08/09/2015)*

What was the result?

Caitlin and her family improved the average winter temperature of her home and dramatically improved home heating efficiency. They reduced their electricity bill but likely increased their wood costs.

Thanks to her friendship with an Energy Champion, Caitlin said she learnt lots of tips and tricks that made her feel confident in her ability to manage her home effectively for thermal comfort and energy efficiency.

✔	Energy use reduced by 15.26kWh/day (36.5%) from 41.82kWh/day to 26.56kWh/day.
✔	Energy costs reduced by ~$758 per year.
✘	Time spent in comfort zone moved from 63.0% to 54.7% (still reasonable and higher than most homes).
✔	Heating efficiency increased from 0.41 to 1.17 (181.2%). (wood heater affected this)
✔	Displayed improved confidence that she could find information on energy efficiency and thermal comfort.
✔	Self reported moisture levels decreased and mould was no longer evident.
✔	Benefitted from connection with local Energy Champion.

* paid off during project

Existing physical conditions of the house

Caitlin and her children live in a one storey standalone suburban house, on a standard sized suburban block. The house is approximately 40-49 yrs old. It sits on a (close to) north to south long axis. A shed sits to the north of the house which blocks some sun, but otherwise there is all day solar access to the house. The kitchen/dining receives northern and afternoon sun and the living room receives afternoon sun. The bedrooms sit to the south and the south east so receive less sun.

The house is timber framed, with concrete block veneer walls, a tile roof and a suspended timber floor (covered with carpet and vinyl). Heating is provided by a wood heater, a fan heater in kitchen and (in the before period) a column heater.

A lack of effective insulation, the age of the house, the single glazing and the western orientation of the living all undermine this house's thermal performance, which is poor.

Insulation	Old loose rock wool in ceiling only.	POOR
Windows	Single glazed, aluminium frames, no pelmets.	POOR
Window coverings	Vertical blinds and heavy weight curtains.	NEAR STANDARD
Under floor space	Suspended timber floor approx. 1.0m above ground, underfloor enclosed with block wall, no insulation.	POOR
Mould and moisture	Some mould and moisture. Mould reduced in after period. Measures show winter temp irregularly neared dew point with high humidity (reaching 80%) occasionally, which may have led to some surface condensation at times.	POOR
Other conditions of note	Uses wood heater along with a couple of other heaters. House is reasonably well maintained.	

Changes to the home

Other changes to the home:

- Caitlin no longer uses a plug in heater.
- On the advice of the Home Energy Helpers Caitlin installed bubble wrap on the front door and laundry door windows.
- Caitlin's teenage boys have learnt about power savings and now try to turning things off at the power points when not in use.
- Generally Caitlin has been more conscious of the little things she can do around the house.
- Caitlin changed the way she uses her blinds to bring heat into the house (to warm the house).

GET BILL SMART UPGRADES

- ✔ Draught proofing of doors
- ✔ Door snake
- ✔ Hot water system insulation
- ✔ Small fridge thermometer
- ✔ Hot water pipes insulated
- ✔ Ecoswitches (2)
- ✔ Water saving shower head
- ✔ Stay Warm education booklet
- ✔ Lights changed
- ✔ Shower timer

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	17.96	6.53	-11.43	-63.6%
T 41 Heating (hard wired heating)	0.00	0.00	0.00	0.0%
Total Heating	17.96	6.53	-11.43	-63.6%
Other Light and Power (T31)	12.17	12.12	-0.05	-0.4%
Hot Water	11.68	7.91	-3.78	-32.3%
Total Household Electricity	41.82	26.56	-15.26	-36.5%
House Heating Efficiency (degree-hours/kWh/day)	0.41	1.17	0.75	181.2%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	19.5	18.7	11.5	7.4	63.0%
After	19.1	17.6	10.5	7.6	54.7%
Difference between before and after	-0.4	-1.1	-1.0	0.2	-8.4%

Referring to the tables and graphs presented, multiple changes were noted. Overall electricity use decreased by 36.5%. Most of the decrease can be attributed to the removal of the plug in heater (a reduction of 11.43kWh/day) and decreased hot water use (a reduction of 7.91kWh/day).

The decreased use of hot water is likely due to the insulation on the hot water system and pipes and the energy saving shower head. Caitlin did note that the shower head was not as nice as the old one but that it meant her son spent less time in the shower.

Example graphs show by the temperature peaks that after Caitlin stopped using the plug in column heater (and only used the fan heater every few days) she continued using the wood fire. The Heating Efficiency of the home increased dramatically with her change in heating practices from 0.41 to 1.174 (181.2%). This increase in efficiency is in large part due to the use of the wood fire instead of the column heater (which was a less powerful heater) but would have also been affected by a reduction in draughts and efforts made to resist heat loss (like the bubble wrap put on the doors). Heating efficiency figures used only measure electrical energy, so the wood fire energy is not factored in. If it was the heating efficiency would not have increased this much.

Given that Caitlin paid off her house over the GBS study period and now owns it outright, she also has had more money in the after period to spend on wood and can heat the house more often. Related to this, the example graphs show that inside temperatures became less responsive to the outside temperatures in the after period. This change correlates with the change in heating practices,

more use of the wood fire and the actions taken to stop heat loss from the house. Other Light and Power use remained fairly constant.

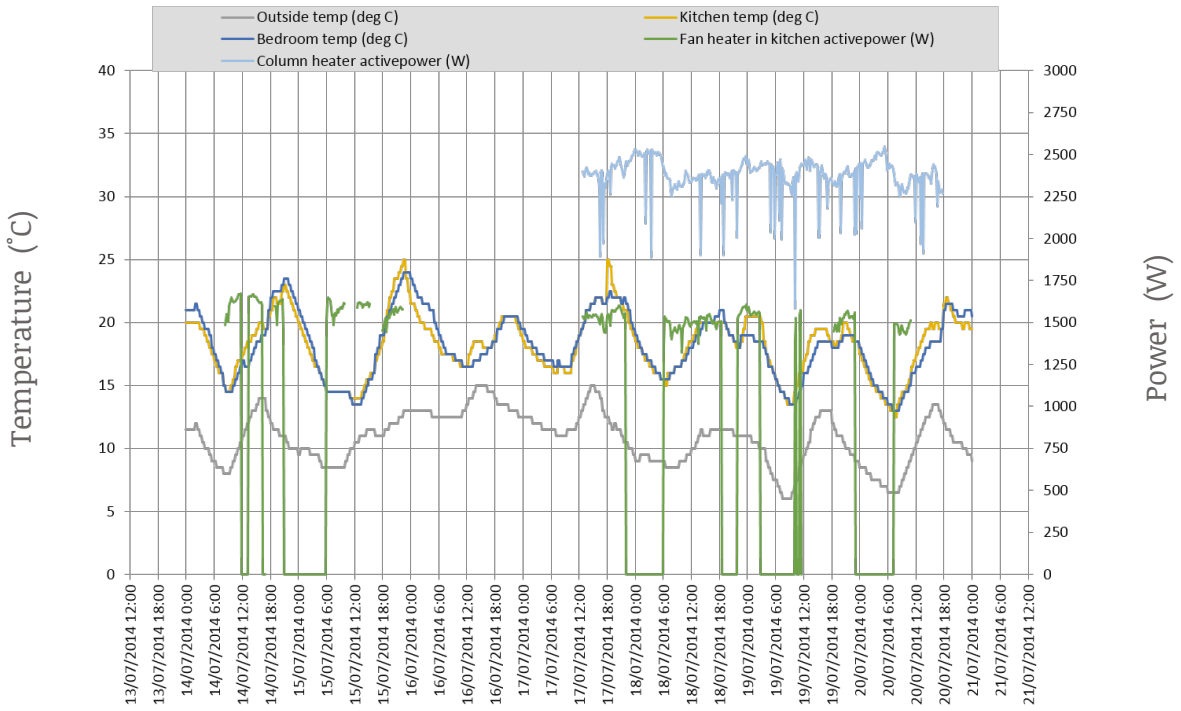
With such notable changes elsewhere, time spent in the comfort zone also changed reducing somewhat from 63.0% of the time to 54.7%. Although this change reduced time in the comfort zone, the after percentage is a high comfort zone percentage when compared to other houses in the detail group and is regarded as quite reasonable when compared with reports from other studies from Tasmania. While 5.8% of the time in the living room was spent above the comfort zone before GBS activities (and 3.0% above the comfort zone in the main bedroom), notably time above the comfort zone reduced in the living room to 2.7% and 0.1% in the bedroom in the after period. This time spent over the comfort zone likely occurred when the wood fire was used as that heat is hard to control. Despite the changes in comfort zone, average living room and bedroom temperatures only decreased a little (-0.4°C for living and -1.1°C for bedroom).

Some mould and moisture was reported (with reduced mould in the after period). Measures showed that there were occasional times when condensation could occur on surfaces (where temps almost met dew point and humidity was high enough), but there is little evidence of it being a serious issue in this house. There was a slight improvement, or a lessening of temp nearing dewpoint, in the living area in the after period. Humidity ranges did get up to 80% at times in winter, which would have contributed to surface condensation. The HEHs noted a small amount of mould in the kitchen which also had the highest humidity recorded. Caitlin reported she felt it had reduced.

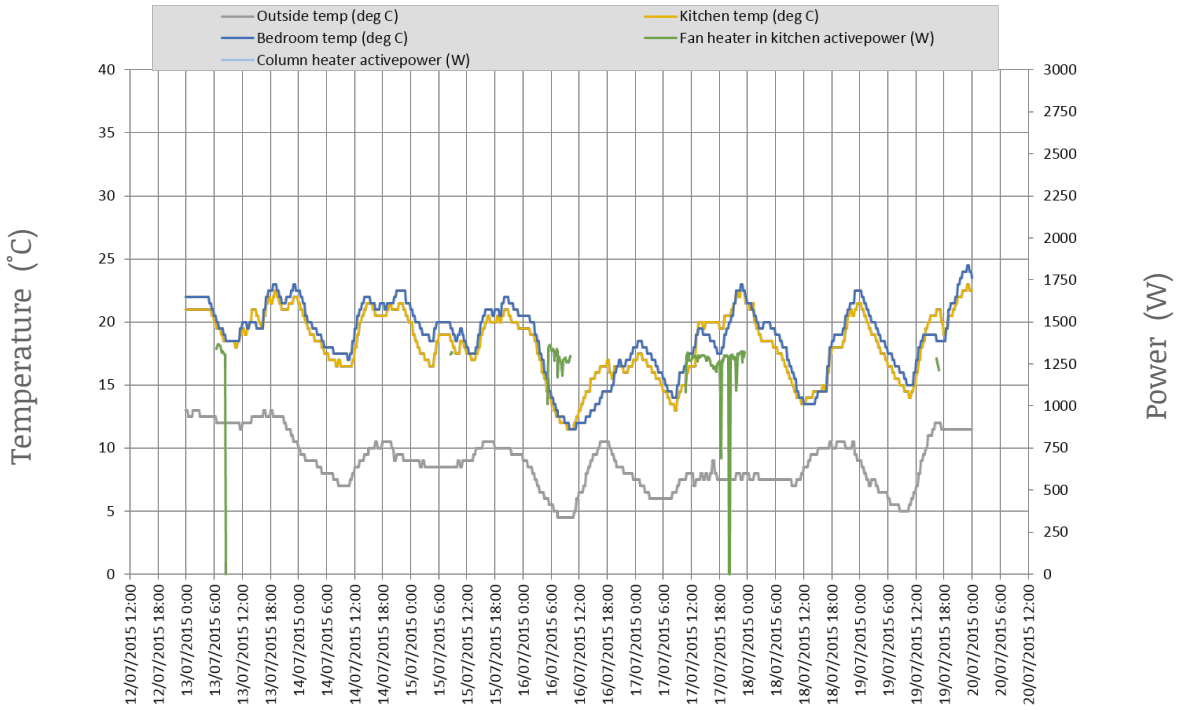
I would link his cold, yeah, his asthma flaring up to if the house happened to be particularly cold and [Reuben] and I also notice that if I couldn't keep the house fairly warm for him that, yeah, he was just forever getting ear infections... *(Before Interview 02/05/2004)*

I really think the only thing that I could do to probably make it a little bit better is maybe ... save up the money and get insulation because I've only got that poxy stuff that I think was in the house like when I originally bought it. *(After Interview 08/09/2015)*

Before period: example week in winter showing selected energy use and temperature readings



After period: example week in winter showing selected energy use and temperature readings



Energy affordability

Caitlin used a wood heater as the primary means of heating her home. She said it cost approximately $180 for a tonne of wood. Given the price she could not often buy either the amount or the quality of wood that she wanted. Caitlin was frustrated by this saying,

> Yeah. It craps me because I can't get the house warm for the kids. *(Before Interview 02/05/2014)*

Caitlin's electricity use decreased by approximately $570 per year – primarily because she stopped using her plug in heater and had upgrades to her hot water.

When we first spoke to Caitlin she said she could not afford as much wood as she would like. When we spoke to her a second time she had paid off her mortgage and it is likely she was able to spend more on heating her home. These costs are not captured in the electricity data.

Personal and community change

Caitlin had lived in her house for over twenty years. She lived with her two teenage sons and her three year old. Caitlin had always made an effort to manage her home effectively for comfort and affordability.

> When I actually moved in [pause] there was a front you know where you walked in the front door there used to be a door there so I blocked that up because that was just ridiculous in winter time. You'd go and open the front door and all the hot air was just thrown straight out of the lounge room.
> *(Before Interview 02/05/2014)*

Caitlin was practical and careful about her energy use and explained how she would bring her youngest son into bed with her on really cold nights. She said,

> When it has been a real cold night and if I only have like the electric heater going, yeah, I've put [Ron] in bed with me and just shut his bedroom door. What's the use in heating it, you know, and it's less space that the heater has to find.
> *(Before Interview 02/05/2014)*

Personal and community change

Get Bill Smart Energy Champions and the home upgrades visit project helped her to make some significant practical changes. During the GBS home visit Home Energy Helpers suggested (as an extra thing to do) that Caitlin bubble wrap the windows on some of the doors to keep the heat in. Caitlin did this and was pleased with the result.

In the after period, Caitlin also slightly changed the way she opened her vertical blinds to enable the sun to 'beam in' for more warmth. She was pleased to have learnt this and other small tips:

> You know, I mean I've been here, what? Twenty years ... I mean the sun's out, pulling those verticals back just like, you know, just how much difference it made, like the kitchen wasn't like <shudder> at four o'clock in the afternoon. I was like, 'Gees, you know, this is all right'. <laughs>
> *(After Interview 08/09/2015)*

She reflected that the program had been good because of the "things that have just been brought to my attention that I could be doing differently, so yeah, more control" (After Interview 08/09/2015).

Caitlin was involved in the local community. She had lived in the area a long time and was socially well networked. Caitlin became involved in the Get Bill Smart project because one of the Energy Champions is a close friend and the aunt of her son.

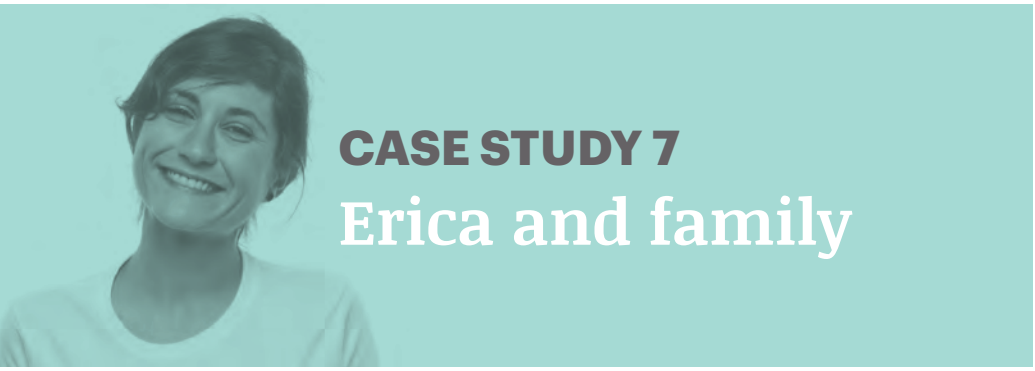
Caitlin explained that:

> When [the Energy Champion] first mentioned about it... I said to her: 'come and tell me all about it. If it helps you out, money in your pocket. It's only going to help me out'. *(After Interview 08/09/2015)*

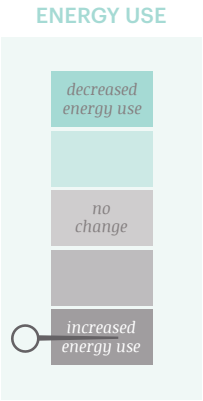
Caitlin did not attend any of the Get Bill Smart events within the community because they were inconveniently timed. She did explain however that she could always talk to her friend who was the Energy Champion,

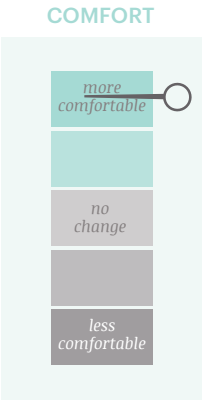
> I'll just ring her and just say--I mean and she's always, ta-ta-ta-ta-ta-ta-ta-ta-ta about it because I know her personally too.
> *(After Interview 08/09/2015)*

Compared to many people in this study Caitlin and her family were able to keep their house reasonably warm. Home Heating Efficiency (of the electrical heating) improved greatly. After GBS activities Caitlin felt more empowered when managing thermal comfort and energy efficiency in her home. She benefitted from both the home energy visit and her connection with a local Energy Champion.



CASE STUDY 7
Erica and family





What did we do?

I've been really monitoring the power points, turning lights off when not needed, haven't been using the heat pump running all the time because we're not here half the time. And instead of leaving heaters on just using it to warm up the room rather than leaving it on.
(After Interview 25/09/2015)

What was the result?

Erica was really pleased to be involved in the project and felt that she had learnt a lot. She changed the way she used her heat pump and paid extra attention to her energy use practices. Erica was surprised to see her power use had increased so dramatically in the after period. This may have been due to another adult living in the house and changed household practices, including changes in heater use.

- ✗ Energy use increased by 20.22kWh/day (54.1%) from 37.35kWh/day to 57.57kWh/day.
- ✗ Energy costs increased by ~$694 per year ($2,060-$2,754).
- ✓ Time spent in the comfort zone increased from 13.9% to 30.3%.
- ✗ Heating efficiency decreased from 0.26 to 0.20 (22.8%).
- ✓ Displayed improved confidence that she could find information on thermal comfort and energy efficiency if needed.
- ✓ Self reported moisture levels decreased (high – medium), mould levels also decreased. Measures show instances where temp may reach dew point decreases in after period, but with problematic humidity peaks of 85%.

Existing physical conditions of the house

Erica's house has little thermal resistance with single glazing, vertical blind window coverings and a poor orientation. GBS installed ceiling insulation, but the walls and floor are uninsulated. The house is open plan and also has an internal stairwell between a downstairs room and the living area. These open spaces mean it is hard to zone. Mould was noted by Erica and Home Energy Helpers in the bedrooms. Although points where temperature could reach dew point reduced in the after period, humidity still peaked at 85% in winter. Overall the house performs at a poor standard, but did improve from a very poor standard in the before period.

Type	Stand alone, suburban.
Age	40-49 years.
Construction	Upper floor (main living area) timber frame, weatherboard cladding, suspended timber floor (polished finish, tiles, carpet); lower floor (bedroom, garage) brick walled, concrete floor, open (unzoned) stairwell.
Insulation	None IMPROVED TO ceiling only.
Windows	Single glazed, aluminium frame, skylight in kitchen.
Window coverings	All vertical blinds.
Access to sun	Long axis northwest to south east, house morning and afternoon sun, living room southwest – receives some afternoon sun.
Heating	Heat pump (living), radiant fan (bedroom), radiant column (bedroom), panel heater, electric blankets (3).

Changes to the home

Other changes to the home:

- Erica's partner moved into the home at the end of summer.
- Erica has been turning power points off and has stopped using the clothes dryer.
- The heat pump is now turned off when Erica leaves the house.
- Erica has introduced a new plug in heater to her house.

GET BILL $MART UPGRADES

- ✔ Ceiling insulation
- ✔ Hot water system insulated
- ✔ Hot water pipes insulated
- ✔ Hot water valve cosy
- ✔ Water saving shower head
- ✔ Lights changed
- ✔ Shower timer
- ✔ Door snakes
- ✔ Small fridge thermometers
- ✔ Stay Warm education booklet

Overview

When we first met Erica she lived with her two children in a two story suburban home. Halfway through her involvement in the Get Bill Smart project her partner moved into the house, changing some of the patterns of the household.

Erica was really pleased to be involved in the project and felt that she had learnt a lot. She changed the way she used the heat pump and paid extra attention to her energy use practices. When Erica received her 2015 winter energy bill she was shocked to note that her energy use was almost double that of the previous year. Erica said that in her mind the bill should have been less.

Erica's use of her heat pump more than doubled in the after period, from 15.40kWh/day to 31.37kWh/day. At the same time, the time spent in the comfort zone also more than doubled, from 13.9% to 30.3%. Likely because of this extra heat pump use, Erica noted that the mould levels in her house had decreased. Erica also felt that the house held heat longer, which was likely due to the ceiling insulation.

Hot water heating increased 2.62kwh/day (40.2%). Erica worried the hot water system might be faulty, but this increase could conceivably come from showering and use by a new occupant.

As an employee of a local community provider, Erica was well known and well networked in the community. She used the information she gained through participation with Get Bill Smart to provide advice to others. Erica did not attend any Get Bill Smart community activities as she was too busy working, parenting and studying.

Erica felt that the thermal performance of the house had improved and it is likely that the insulation helped this. However, existing thermal performance issues and significant energy increases that came with a new occupant meant that improvements were swamped and energy use significantly increased.

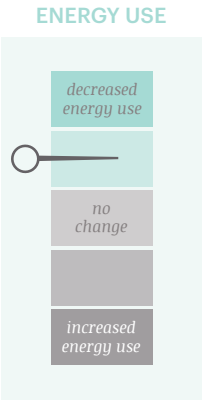
Average daily energy use and heating efficiency during winter conditions

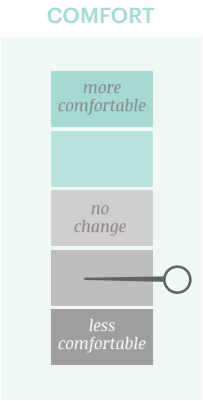
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	1.38	1.08	-0.30	-22.0%
T 41 Heating (hard wired heating)	15.40	31.37	15.97	103.7%
Total Heating	16.78	32.44	15.67	93.4%
Other Light and Power (T31)	14.07	16.00	1.94	13.8%
Hot Water	6.50	9.12	2.62	40.2%
Total Household Electricity	37.35	57.57	20.22	54.1%
House Heating Efficiency (degree-hours/kWh/day)	0.26	0.20	-0.06	-22.8%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	16.6	14.0	9.9	4.4	13.9%
After	17.8	12.7	9.1	6.5	30.3%
Difference between before and after	1.2	-1.3	-0.8	2.2	16.4%

CASE STUDY 8
Jess and her daughters





What did we do?

I don't know what more I could do without becoming a power Nazi. My youngest daughter has asthma and I have adult onset asthma, I'm a little bit croaky at the moment. So when that cold sets in, which is why I tend to light the fire when my youngest daughter is here she's only here half a week at a time. *(Before Interview 12/06/2014)*

What was the result?

Jess and her daughters lived in a cold house with low average temperatures and little time spent above 18°C. Minor reductions in energy use helped with bills. Jess appreciated the Get Bill Smart upgrades and was interested in attending community activities however she lacked the time and capacity to do so.

✔	Energy use decreased by 2.41kWh (2.4%).
✔	Energy costs reduced by ~$117 per year ($1,062 – $945).
✘	Time spent in the comfort zone decreased from 6.8% to 5%.
✔	Displayed significantly improved confidence that she could find information on thermal comfort if needed.
✘	Displayed a decrease in confidence that she could access information on thermal comfort and remained confident that she could access information on energy efficiency if needed.
~	Self-reported moisture remained low, some mould noted, Temperature occasionally near dew point in living. Humidity readings up to 80-85% in bed and living which can cause condensation.

Existing physical conditions of the house

Despite a wood fire and two thirds of the day with solar access, this house is uncomfortably cold. The uninsulated wall and floors, single glazing, the shading of the living area from the north east and the light window coverings lead to poor thermal performance in this house.

Type	Stand alone, suburban with open field behind.
Age	30-39 years.
Construction	Concrete brick, tile roof suspended timber floor boards (0.2-1.25m high), carpet, floorboards, tiles.
Insulation	Ceiling only (batts).
Windows	Single glazed, aluminium frame.
Window coverings	Mostly timber venetians, living also light drape, kitchen/ laundry none.
Access to sun	Mainly midday through afternoon. Living room on NE corner but large shrub and tree overshadows on NE.
Heating	Wood fire in living, plug in electric heater in bedroom, heat exchange from living room to bedroom.

Changes to the home

Other changes to the home:

- Jess and her family switched bedrooms which changed how they used and heated their house.
- Pulled up carpet in the living room.

GET BILL $MART UPGRADES

- ✔ Draught proofing of doors
- ✔ Door snakes
- ✔ Lights changed
- ✔ Small fridge thermometer
- ✔ Hot water valve cosy
- ✔ Stay Warm education booklet
- ✔ Hot water pipes insulated
- ✔ Water saving shower head
- ✔ Shower timer

Overview

Jess and her daughters (5 to 18 years old) have lived in their home for over a decade. The two younger daughters live with Jess half-time (and half with their father). Jess has suffered with depression which impacts management at home. She has also had difficulties sorting out home content clutter after separating from her husband. Despite this she has managed (around her job) to install a warm and dry air exchange and to gradually work towards energy and comfort change.

During the before period the family heated with the wood fire and occasionally a plug in column heater (in the bedrooms). The plug in heating stopped in the after period and what heating they did continued with the wood fire. The average temperature, comparatively low, decreased in the after period to 12.2°C (living) and 12.5°C (bedroom). The average time in comfort zone (18-24°C) also reduced from 6.8% to 5%. Some time was still spent above 24°C when the wood heater was in use but this was minimal (and also indicated the wood heater was not often used). The heat transfer system assisted to keep temps a little more even between living and bedrooms.

The sense that there were people nearby who could help with thermal comfort improved over the GBS study period. Despite interest, Jess did not attend Get Bill Smart activities. Activities were often on when she was at work and text reminders were sent too late for her to plan ahead. Previously Jess had been an active community member (and had a local business) but found she didn't have the time or energy to engage anymore.

Jess valued her participation in the Get Bill Smart project and was appreciative of the upgrades. In particular she felt 'encouraged and supported' and 'not judged' in any way.

Overall the family lived in a cold house with low average temperatures and little time spent above 18°C. Minor reductions in energy use helped with bills. Jess appreciated the GBS upgrades and while interested in connecting with the community and GBS activities, found she didn't have the capacity for it.

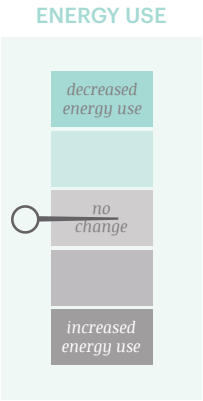
Average daily energy use and heating efficiency during winter conditions

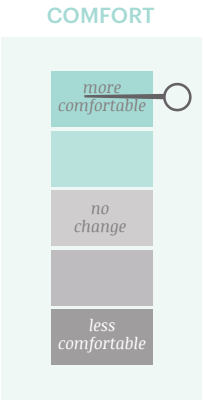
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.18	0.00	-0.18	-100.0%
T 41 Heating (hard wired heating)	0.00	0.00	0.00	0.0%
Total Heating	0.18	0.00	-0.18	-100.0%
Other Light and Power (T31)	8.21	6.93	-1.28	-15.6%
Hot Water	5.58	6.70	1.12	20.1%
Total Household Electricity	13.97	13.63	-0.34	-2.4%
House Heating Efficiency (degree-hours/kWh/day)	22.67	0.00	0.00	0.0%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	13.2	13.5	9.2	4.2	6.8%
After	12.2	12.5	8.0	4.4	5.0%
Difference between before and after	-1.0	-1.0	-1.2	0.2	-1.9%

CASE STUDY 9
Dale and Joanne





Occupants	Own or rent	Bedrooms	House type	Heating
	OWNER		FREESTANDING ONE STOREY	HARDWIRED RESISTIVE + HEAT PUMP

What did we do?

Yes we work on a budget each pension day we've got a set amount for groceries, a set amount for our bills and a little bit of spending money for ourselves. The bill money and the groceries come first and after that... *(After Interview 04/09/2015)*

What was the result?

Dale and Joanne had generally improved their energy efficiency knowledge, had some more little tips and tricks and reduced moisture levels.

With an already comparatively efficient house (mostly due to a renovation 9 years ago), small adjustments to heating and practices seemed to make a big difference to time in comfort zone and heating efficiency. Overall this was an efficient house with good outcomes. They used less energy and were warmer because they used more efficient heating.

- ✔ Energy use reduced by 0.22kWh/day (1.3%) from 17.37kWh/day to 17.15kWh/day.
- ✘ Energy bills increased by ~$80 per year.
- ✔ Time spent in the comfort zone increased from 34.3% to 54.4%.
- ✔ Heating efficiency increased from 3.5 to 5.23 (49.3%).
- ✔ Displayed improved confidence that they could find information on energy efficiency and thermal comfort if needed.
- ✔ Self reported moisture reduced from low to none. No mould reported.
- ✔ Self reported reduction in draughts (from some to none).

Existing physical conditions of the house

This house whilst fairly old was renovated and extended in 2007 with insulation added at the time. The house had heat pumps for heating and a warm and dry transfer and also had enclosed zones under the house. Along with the insulation all these features assisted with thermal performance. Dale and Joanne use gas for cooking and often cooked outside on their eastern deck. Self-reported moisture reduced from low to none. No mould reported. Measures show temperature does not reach dew point in bedroom and in the living room it did only occasionally in before period (not in after). Humidity peak was 70%. The dry bedroom was likely from heat pump use and warm air transfer system.

This house is quite efficient. Despite the vertical blinds and single glazing, insulation put in during the renovation and heating being provided with heat pumps and a warm and dry transfer has helped this house performs at a near standard level, which is above the standard of most houses in the study.

Type	Stand alone, large suburban block
Age	40-49 years.
Construction	Rendered block veneer, corrugated metal roof with mill roof vents, suspended timber floor (carpet and vinyl), workshop under and enclosed with wall. Extension with new rooms 7 years ago.
Insulation	Ceiling (batts, 9 years ago), walls in living room.
Windows	Single glazed, aluminium frame, awnings.
Window coverings	Vertical blinds.
Access to sun	All day sun with square plan, living room on northern corner receiving northern sun, eastern sun blocked by deck.
Heating	3 heat pumps (living, rear living, bedroom), radiant heater (kitchen), warm and dry circuit.

Changes to the home

Other changes to the home:

- Dale felt more aware of energy efficiency and thermal comfort and made an effort to keep some doors closed.
- Dale and Joanne had blocked off some air vents in the ceiling
- Dale had experienced some illness this year and felt the cold more.
- Due to the colder winter, Dale and Joanne set their heat pump at 21 degrees rather than their usual 18.

GET BILL SMART UPGRADES

- ✔ Draught proofing of doors
- ✔ Small fridge thermometer
- ✔ Hot water pipes insulated
- ✔ Stay Warm education booklet
- ✔ Hot water valve cosy
- ✔ Water saving shower head
- ✔ Shower timer
- ✔ Door snakes

Overview

Dale and Joanne had lived in their house for over a decade. They had strong family connections and are the 'go to people' for their friends and family in the community.

Dale was a bit of a handy man and did things like helping his daughter to clean the filter on her heat pump.

Their renovation included insulation and new heat pumps which have assisted this house to be impressively (comparatively) efficient. The heating efficiency ratio was very good, even when they did use heating. A small reduction in heat pump use of 0.19kWh/day provided significant improvement in their heating efficiency (3.5 to 5.23). Hot water and heating reduced in the after period which might be attributable to the hot water upgrades they received. There was a slight rise in Other Light and Power. Hot water and heating energy were both low for two occupants.

Despite the reduction of heating they spent more time in the comfort zone in the after period. This suggests one of two things, either: an un-sensored heater was used; or the insulation, heat pumps and warm and dry worked quite well. The warm and dry transfer would be able to make use of solar gain throughout the house and transfer it elsewhere, which could also improve comfort zones without heating input.

These are really good results.

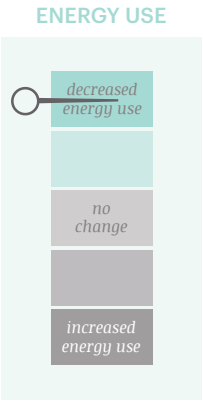
Average daily energy use and heating efficiency during winter conditions

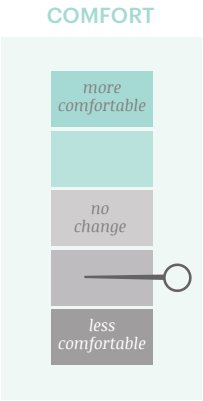
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.00	0.00	0.00	0.0%
T 41 Heating (hard wired heating)	1.76	1.56	-0.19	-11.0%
Total Heating	1.76	1.56	-0.19	-11.0%
Other Light and Power (T31)	10.87	11.33	0.46	4.2%
Hot Water	4.75	4.26	-0.48	-10.2%
Total Household Electricity	17.37	17.15	-0.22	-1.3%
House Heating Efficiency (degree-hours/kWh/day)	3.50	5.23	1.73	49.3%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	18.1	15.8	10.4	6.2	34.3%
After	20.1	16.3	9.8	8.2	54.4%
Difference between before and after	2.0	0.5	-0.6	2.0	20.1%

CASE STUDY 10
Susie and family





Occupants	Own or rent	Bedrooms	House type	Heating
	RENTER		FREESTANDING ONE STOREY	HARDWIRED RESISTIVE + HEAT PUMP

What did we do?

COMMUNITY CAPACITY BUILDING

+

IN HOME EDUCATION & UPGRADES

What was the result?

Susie reduced her energy use and subsequently decreased the time she spent in the comfort zone, however this still remained relatively good.

Although frustrated by the draughts in the home, Susie did apply some of the lessons from the Home Energy Helpers and felt warmer as a result.

Most significantly for Susie, she had recently moved from a very poorly performing house and felt relief at the contrast.

- ✔ Energy use reduced by 9.88kWh/day (28.2%) from 35.03kWh/day to 25.15kWh/day.
- ~ No data available from electricity supplier. Likely that electricity bills decreased with reduced energy use.
- ✘ Time spent in comfort zone decreased from 49.3% to 32.5%.
- ✔ Heating efficiency increased from 0.47 to 0.66 (40.6%).
- ✔ Displayed improved confidence that she could find information on energy efficiency and thermal comfort.
- ✔ Self-reported decrease in mould.

> Yeah it was easier, I mean down at my other house I used to go home and I used to crawl into bed because it was a cold house and watch TV where here I don't. The big difference was the first night I moved in here I had my sister down and she would normally have seven blankets on her bed down at the old house. The first night she was here she slept with one doona. *(After Interview 21/09/2015)*

Existing physical conditions of the house

This house has little thermal resistance in the walls but has ceiling insulation, some solar access and a heat pump that provides effective heat. This house feels much more comfortable to Susie than the one she lived in previously. Overall this house is poor to near standard.

Type	Stand alone, suburban.
Age	40-49 years.
Construction	Brick veneer, timber framed, tile roof, suspended floor enclosed with brick (carpet and tiles).
Insulation	Ceiling only.
Windows	Single glazed, aluminium frame.
Window coverings	Curtains in living and dining after home visit.
Access to sun	Long axis north east, dining with a deck to the north, living to the west with clear solar access to the north.
Heating	Heat pump (living).

Changes to the home

Other changes to the home:

- Susie started to set the heat pump at 16°C rather than a higher temperature.
- Susie hung curtains in her living area to keep the heat in.
- Prior to moving into this house, Susie had been involved in some Get Bill Smart activities (see case study #18).

GET BILL $MART UPGRADES

- ✔ Draught proofing of doors
- ✔ Small fridge thermometer
- ✔ Hot water system insulated
- ✔ Stay Warm education booklet
- ✔ Hot water pipes insulated
- ✔ Lights changed
- ✔ Shower timer
- ✔ Door snakes

Overview

Susie and her family moved to their house in January 2015. This move was partly in response to the poor performance of her original house (see case study #18).

When Susie first moved into this home she was frustrated that there was no door between the laundry and the rest of the house. Without a door draughts and cold air flowed through into the living space. Susie approached the landlord to get this changed but he was not interested. It was clear that Susie would have made further changes to the home if she had the money and/or owned the place herself.

The Home Energy Helpers could not fit a door but they did draught proof the external doors of the house and this did improve comfort somewhat.

Susie did reduce her energy use after the Home Energy Upgrades. Most of this reduction came from changes to how she used the heat pump – using it less and maintaining it at lower temperatures. However Susie's family spent less time in the comfort zone (from 49.3% to 32.5%). At the same time they also reduced the time they spent above the comfort zone by ~18% (time spent above 24°C).

Keeping kids warm so that they didn't get sick was a priority for Susie. It was also important for her own health,

> If I'm not comfy then I'm grumpy.
> I get shivery and then I throw up.
> *(After Interview 21/09/2015)*

Susie felt more in control of her energy use thanks to a shift to the Pay As You Go system. She said that this helped her to manage her use. When use did get too high however it meant that she didn't go out and her socialising was limited.

Susie was well networked in the community with friends she could talk with about thermal comfort and energy efficiency. She had previously attended some Get Bill Smart activities (before moving into this house) and felt confident that the Energy Champions would be able to answer any questions she might have. Susie was also good friends with several other participants in the program and they were all able to share their experience.

Susie really appreciated what she was provided through the Home Energy Upgrades and valued the educative component.

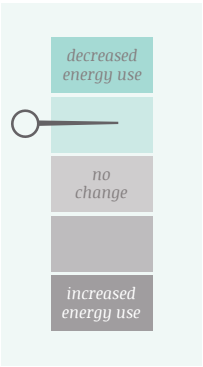
Average daily energy use and heating efficiency during winter conditions

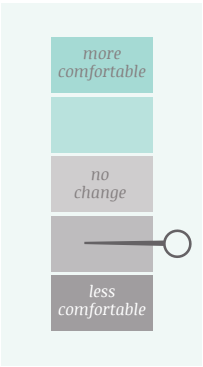
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.00	0.00	0.00	0.0%
T 41 Heating (hard wired heating)	22.53	11.71	-10.82	-48.0%
Total Heating	22.53	11.71	-10.82	-48.0%
Other Light and Power (T31)	5.35	5.23	-0.12	-2.3%
Hot Water	7.16	8.21	1.05	14.7%
Total Household Electricity	35.03	25.15	-9.88	-28.2%
House Heating Efficiency (degree-hours/kWh/day)	0.47	0.66	0.19	40.6%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	20.6	17.0	8.2	10.6	49.3%
After	17.4	15.1	8.5	7.8	32.5%
Difference between before and after	-3.2	-1.9	0.3	-2.9	-16.8%

CASE STUDY 11
Selena and family





Occupants

Own or rent

Bedrooms

House type

Heating

What did we do?

COMMUNITY CAPACITY BUILDING

IN HOME EDUCATION & UPGRADES

> Yes we did we just sort of had it set at 22 and so I have dropped the temperature down but in saying that, somebody else in the house puts it back up again. <laughs>
>
> *(After Interview 25/09/2015)*

What was the result?

Selena and her family reduced their energy use but also reduced the time they spent in the comfort zone. A reduction in draughts helped the family to feel more comfortable than they otherwise would have.

Selena found the upgrades and education helpful but struggled to find a solution to the moisture and mould problems present in the bedroom.

✔	Energy use reduced by 5.17kWh/day (12.4%) from 41.77kWh/day to 36.60kWh/day.
✘	Time spent in the comfort zone decreased from 27.2% to 18.5%.
✔	Heating efficiency increased from 0.79 to 1.17 (48.8%).
✔	Displayed improved confidence that she could find information on thermal comfort and energy efficiency if needed.
✔	Self-reported draughts reduced.
✘	Mould remains problematic on bedroom walls.

Existing physical conditions of the house

From the evidence from the householder and observation of the poor thermal performance of the building materials this house performs at a very poor level. The suspended timber floor is just above ground and as a result significant moisture is likely coming up from below. This moisture has led to problematic levels of mould in the bedrooms.

Type	Stand alone, suburban.
Age	30-39 years.
Construction	Weatherboard, corrugated metal roof, suspended timber floor (polished floorboards, tiles, carpet), old brick chimney, small block skirt around underfloor.
Insulation	Possible ceiling.
Windows	Single glazed, wood frame.
Window coverings	Curtains (heavy), venetians (kitchen).
Access to sun	Main living access to northern sun, all day sun, long axis is east west.
Heating	Heat pump.

Changes to the home

Other changes to the home:

- Open windows to let moisture out.
- Set the heat pump to 20°C rather than 22°C.

GET BILL $MART UPGRADES

- ✔ Draught proofing of doors
- ✔ Door snakes
- ✔ Draught proofing of windows
- ✔ Small fridge thermometers
- ✔ Hot water pipes insulated
- ✔ Stay Warm education booklets
- ✔ Water saving shower head
- ✔ Lights changed
- ✔ Shower timer

Overview

Prior to moving into their home, Selena and her family had lived in another house in the same area. As a result they had previously been exposed to the Get Bill Smart program.

Energy use decreased by 12.4% (from 41.77kWh/day to 36.6kWh/day). This decrease is mostly seen in the reduction of heating (from 9.71kWh/day to 5.87kWh/day) and from the reduction in hot water use (17.89kWh/day to 16.85kWh/day). Selena noted that she had made an effort to reduce heat pump temperatures. Hot water use is very high in the house (well above both average and mean use for the CVR area) and reductions are possibly due to the upgrades conducted.

Heating efficiency of the home improved but this is most likely due to a reduction in heating rather than any significant improvement to the thermal efficiency of the building.

The time Selena's family spent in the comfort zone also decreased with the decrease in energy use (from 27.2% to 18.5%). In the AFTER interview Selena explained that due to lifestyle changes, they spent significantly longer out of the house than previously. Despite an active lifestyle, this is still a poor amount of time in the comfort zone.

Selena was grateful for the education and upgrade and felt that it had made a difference to her home. In particular draughts improved and she felt more empowered to actively manage moisture in her home (unfortunately with little success thus far).

Selena noted that it had taken several years for her to feel a part of the community and the community centre but now has some employment in the area and this has helped. While she didn't really know who she could ask for help, she had previously lived next door to one of the Energy Champions and when prompted agreed she could talk to her. She did not attend any community activities.

Selena was motivated to be energy efficient not only to save money but to save resources and reduce her environmental impact.

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.00	0.00	0.00	0.0%
T 41 Heating (hard wired heating)	9.71	5.87	-3.84	-39.5%
Total Heating	9.71	5.87	-3.84	-39.5%
Other Light and Power (T31)	14.16	13.88	-0.28	-2.0%
Hot Water	17.89	16.85	-1.04	-5.8%
Total Household Electricity	41.77	36.60	-5.17	-12.4%
House Heating Efficiency (degree-hours/kWh/day)	0.79	1.17	0.39	48.8%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	17.0	15.1	8.4	7.7	27.2%
After	15.9	14.8	8.4	6.9	18.5%
Difference between before and after	-1.1	-0.3	0.0	-0.8	-8.7%

Cases 12–27

COMMUNITY CAPACITY BUILDING

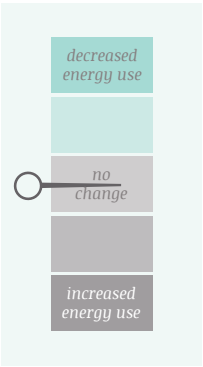
GBS support activities for these cases were:

1. Exposure to community capacity building, which included local energy champions.

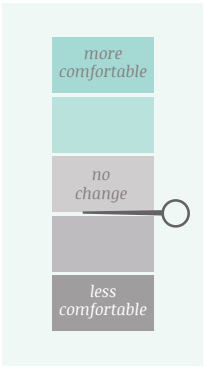
Houses in this case group were all in the suburbs of Clarendon Vale and Rokeby where community capacity building activities were held.

CASE STUDY 12
Troy

ENERGY USE



COMFORT



Occupants	Own or rent	Bedrooms	House type	Heating
	RENTER		FREESTANDING ONE STOREY	PLUG-IN ELECTRIC + HARDWIRED RESISTIVE

What did we do?

COMMUNITY CAPACITY BUILDING

What was the result?

Troy lives in a cold house that is hard to warm. Troy was a relatively low energy user. He has not reported any attempts to improve the comfort or energy efficiency of his home and did not attend any of the community events.

- ✔ Energy use reduced by 1.74kWh/day (6%).
- ✘ Time spent in comfort zone reduced from 1.4% to 0.7% – very poor.
- ✔ Heating efficiency increased from 0.16 to 0.28 (74.5%) – efficiency is still very low.
- ✔ Displayed improved confidence that he could find information on energy efficiency and comfort.
- ✘ Self-reported moisture levels increased (none – medium). Dew point was reached May-Sept (before and after).
- ✘ Draughts remained a problem.

> It's been a colder winter and I've had the heater on more.
>
> *(After Survey 22/09/2015)*

Existing physical conditions of the house

Troy's house is a 30-40 years old three bedroom detached house on a standard sized suburban block. The house is an L-shape with the long axis running north to south. Despite some walls facing north windows are mainly on the long east and west sides, so sun is poorly controlled. The living room sits on the southwest side of the house and has three external walls enclosing it which makes this room more thermally reactive to outside temperatures. The house is constructed with timber frames, brick veneer walls, a tile roof and suspended timber floors. The floors are covered with carpet and vinyl. Troy reported the house had some insulation, but the GBS team suspect there is little to no effective insulation in the house. For heating Troy uses an electric resistive heater wired into the wall and a plug in heater in the hallway (near the bedrooms). With the age of the house, general poor thermal resistance in construction materials, east west exposures and three external walls on the living area, this house overall has very poor thermal performance.

Overall this house performs at a poor to very poor level.

Insulation	In ceiling (self-reported).	NEAR STANDARD
Windows	Timber framed, with gaps, single glazed.	POOR
Window coverings	Aluminium blinds throughout.	VERY POOR
Under floor space	Suspended timber floor (carpet and vinyl) 0.3 -0.9m above ground, underfloor enclosed with brick walls, no insulation.	POOR
Mould and moisture	Self-reported moisture levels increased. Humidity measures show dew point reached regularly May-Sept in bedroom and Apr-Aug in living and intermittently over rest of year in both.	VERY POOR
Other conditions of note	Kitchen electrical circuitry unusable at second visit.	VERY POOR
	Infiltration through windows and doors.	POOR

Changes to the home

Other changes to the home:

- Troy used the heater more due to colder winter in 2015.
- Troy changed his working hours and began studying so changed the times he was in the house.
- Due to a change in work patterns Troy used less electronic music equipment.
- The electrical circuit in Troy's kitchen blew and this changed his appliance use.
- Troy's girlfriend started staying over some nights.

GET BILL SMART UPGRADES

Not relevant for this participant.

Energy and comfort

Referring to the tables and graphs presented, changes were observed in energy use and comfort. Overall electricity use reduced by 6%. This was due to shifts, both up and down in heaters, light and power and hot water use.

Total heating reduced by 30.2% – 12.67 kwh/day to 8.8 kw/h. This shift came from significant reduction in use of the plug in heater. There was a slight increase in Troy's use of the wired in resistive heater.

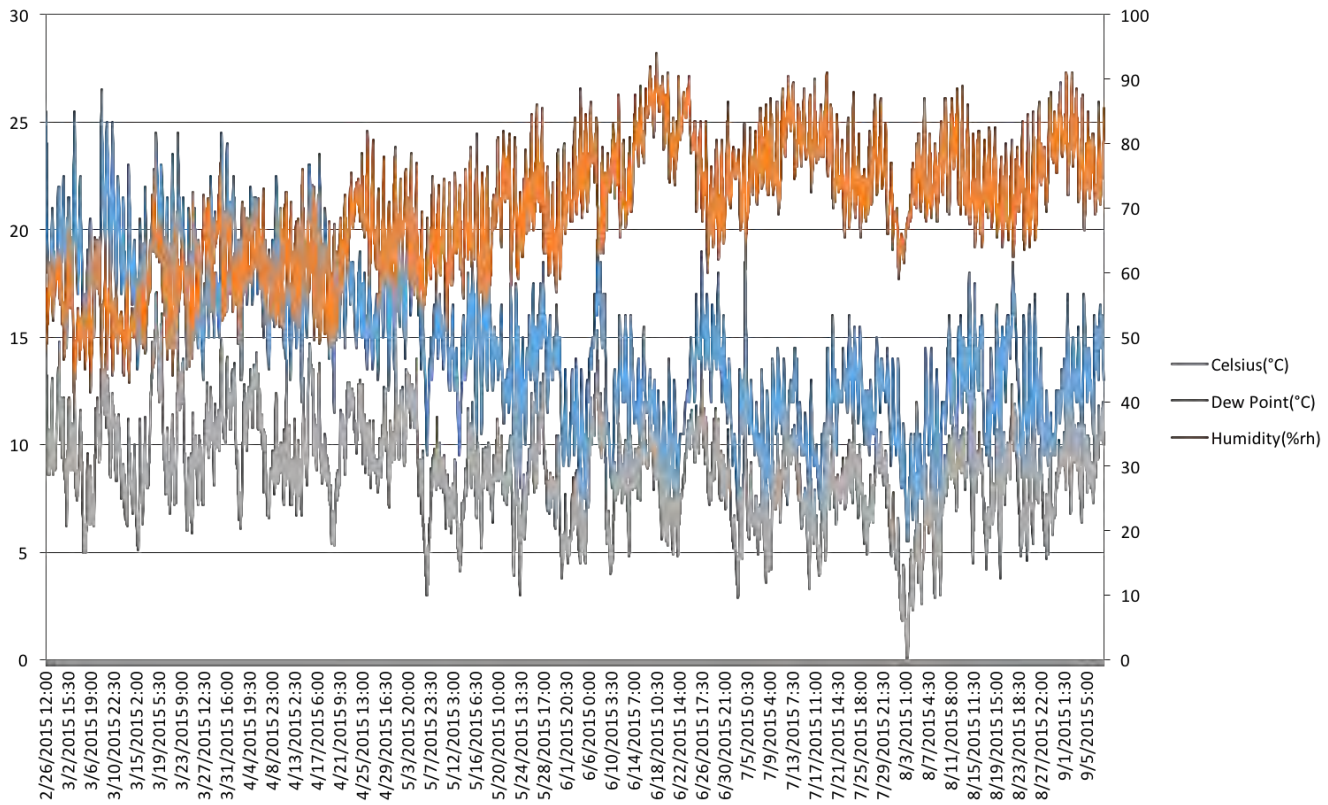
Troy's heating efficiency increased somewhat from 0.17 – 0.28 (74.5%). This increase in efficiency is likely due to the fact that Troy reduced his overall heating. The heating efficiency of Troy's house remained low, even in comparison to many other houses in this project.

Troy still spent very little time in the comfort zone: 1.4% of time before and 0.7% after. No time was spent above the comfort zone. The average living room temperature was at 12.1°C before which decreased to 11.5 degrees. The average outdoor/indoor temperature difference was 2 °C before and 2.5°C afterwards, so the house was tracking close to the outdoor temperatures on many occasions. The heating efficiency and temperatures indicate that the building skin was doing little to resist heat flow. Even when Troy heated the house he was living in a cold house. The graphs provided show more response to the cycle of the day than to the heating.

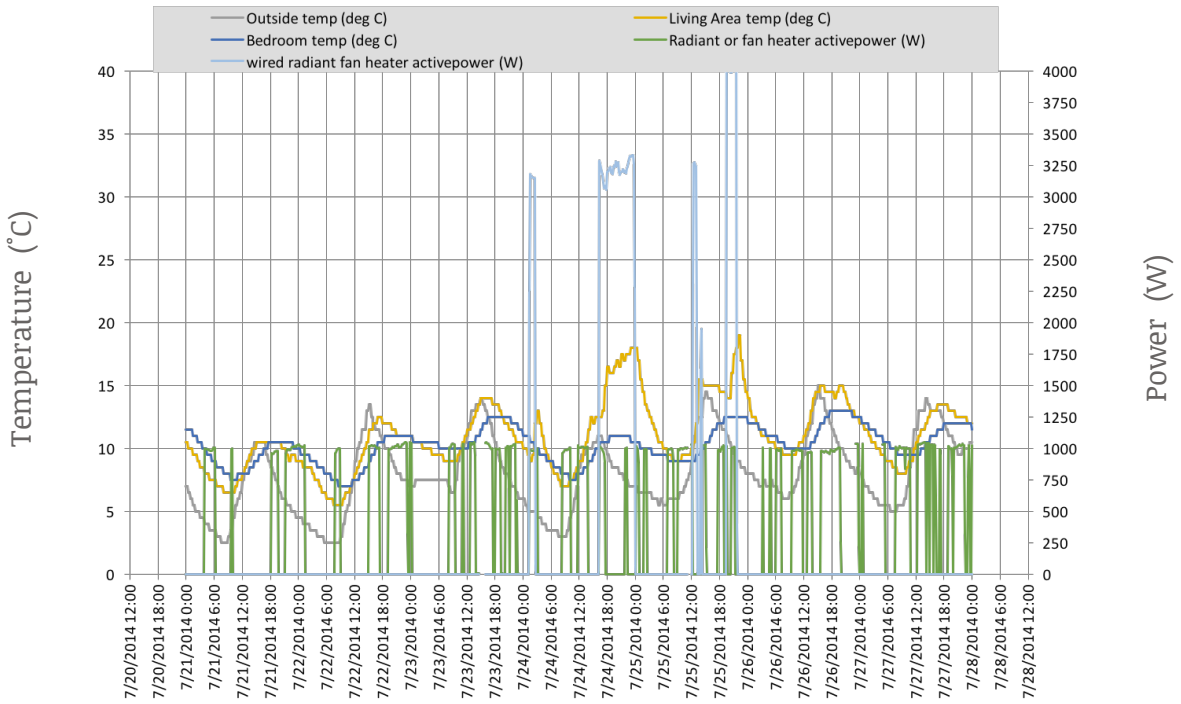
Hot water use did increase somewhat over the period of logging. This and other shifts may be due to: the presence of a girlfriend who began to stay over in the after period; Troy beginning a course which took him out of the house regularly on weekdays and changed his night time heating patterns; and, the electrical circuit in the kitchen being out of action (changing how Troy used the kitchen and prepared food).

Overall this house has a very poor thermal environment. Troy's time spent in the comfort zone was one of the lowest of all the detailed households.

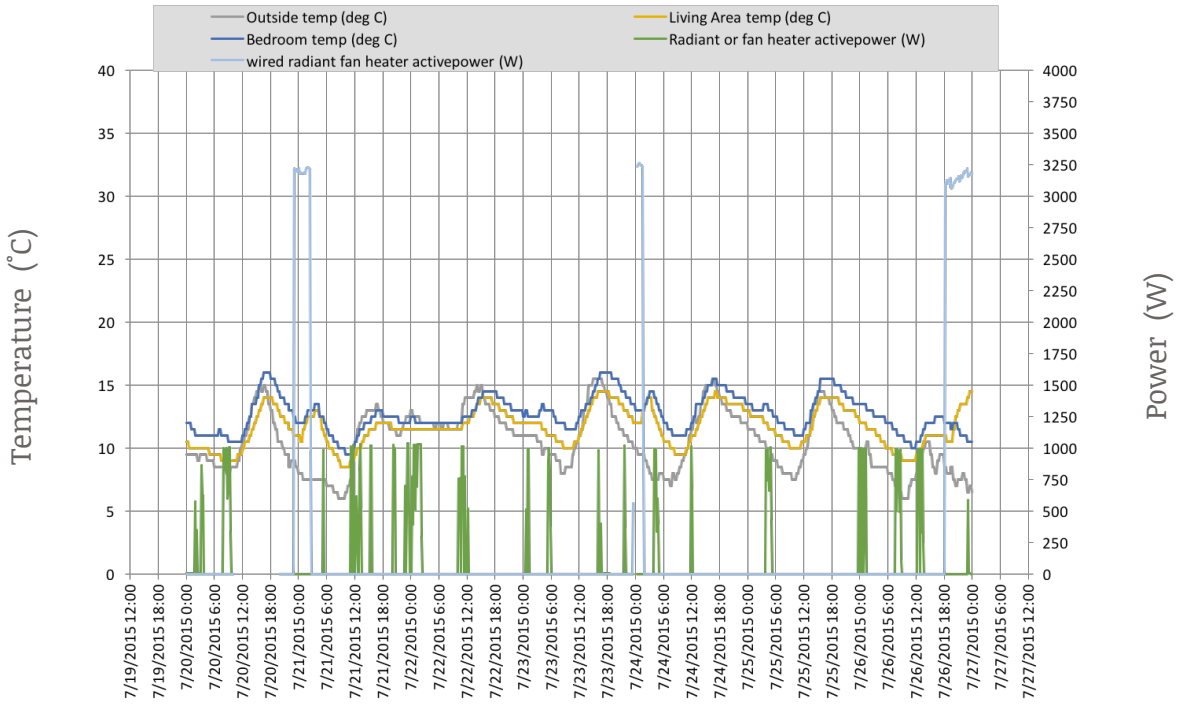
Temperatures, humidity and dewpoints example (bedroom sensor) recorded February to September 2015



Before period: example week in winter showing selected energy use and temperature readings



After period: example week in winter showing selected energy use and temperature readings



Energy and comfort

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	6.97	0.76	-6.20	-89.0%
T 41 Heating (hard wired heating)	5.71	8.08	2.37	41.6%
Total Heating	12.67	8.84	-3.83	-30.2%
Other Light and Power (T31)	4.30	4.88	0.58	13.5%
Hot Water	12.26	13.77	1.51	12.3%
Total Household Electricity	29.23	27.49	-1.74	-6.0%
House Heating Efficiency (degree-hours/kWh/day)	0.16	0.28	0.12	74.5%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	12.1	11.7	9.9	2.0	1.4%
After	11.5	12.3	9.4	2.5	0.7%
Difference between before and after	-0.7	0.7	-0.4	0.4	-0.7%

Energy affordability

While we have no billing data for Troy, it is likely that his bills have reduced in line with the reduction in energy use.

Troy was a reasonably low user of energy and explained that:

It's the lack of money. I don't have many hours at work. I try to keep the power bill down. *(Before Interview 25/06/2014)*

Yeah, it makes me feel uncomfortable if I get too hot. I don't like it too hot, I prefer to be in a cool house.

(Before Interview 25/06/2014)

Personal and community change

Troy mostly lives in his house alone, occasionally has his two children for short visits and his girlfriend over to stay.

Troy described the house as very cold, saying that:

> It takes a while, it takes about 30 minutes [to warm the house with the heater].
> *(After Interview 25/06/2015)*

Even then, the temperature data suggests the house is never really warm. Troy seemed accepting of the indoor comfort challenges and tended to put on more clothing when he was cold.

In the before period Troy usually heated the bedrooms in his house with a plug in heater located in the laundry by heating the hallway. He explained that:

> [the plug in heater] tends to heat up those rooms up and down the corridor, but I close the doors. Like my son's room is closed and the daughter's and the bathroom, so it just heats up that side of the house and the bedroom. *(Before Interview 25/05/2015)*

In the after period Troy changed his heating practice and began more frequently using the wired in resistive heater in the living room.

Troy had mentioned that he would have liked to make some small changes, like hanging a curtain over the open doorway to hold in heat, but then said:

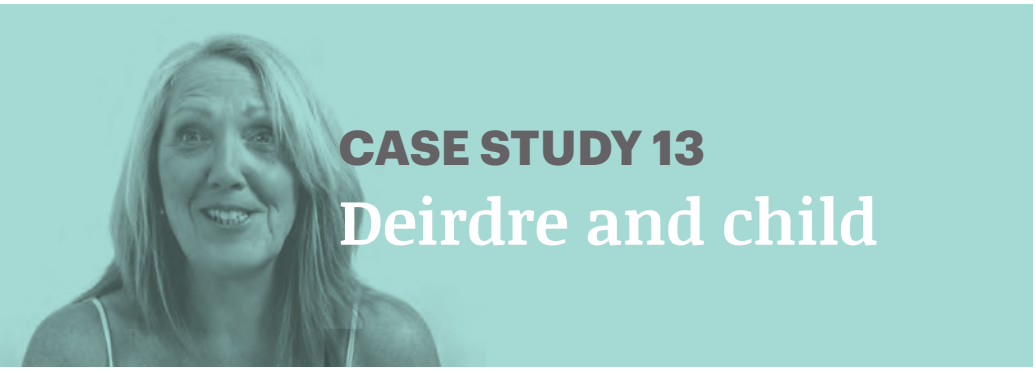
> It's not my house to do it.

and

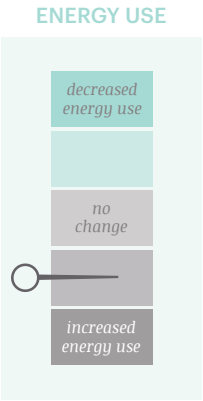
> I guess I don't want to ruin their house.
> *(Before Interview 25/6/14)*

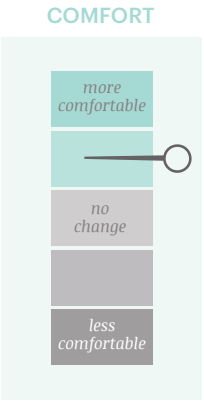
Troy did not really engage with the community around him and made no use of the Get Bill Smart activities. He mentioned that he had not talked to anyone in the community for 4 years. He was not deliberately isolated from the community, rather his activities took him elsewhere and he was limited in his capacity and motivation to seek community assistance.

Overall Troy's house was cold and hard to heat up. As a lower energy user there was not a lot he could do to reduce his energy use and he felt he shouldn't make changes in the house because the landlords would not like it.



CASE STUDY 13
Deirdre and child





Occupants	Own or rent	Bedrooms	House type	Heating
	RENTER		FREESTANDING ONE STOREY	HEAT PUMP

What did we do?

COMMUNITY CAPACITY BUILDING

> Oh, you can pretty much just go and talk to pretty much all of [the Energy Champions]. Like [my friend], I can duck up to her place and, you know, ask her things or she'll come down ... Oh she's brilliant... She'll just go and yack, yack, yack, yack, and yeah she's good.
>
> *(After Interview, 9 Sep 2015)*

What was the result?

Thanks to helpful advice from both her landlord and an Energy Champion, Deirdre felt more in control of how she managed her home for thermal comfort and energy efficiency.

Her house sat more consistently in the comfort zone rather than swinging between temperatures. Deirdre was keen to continue to improve the comfort of her home and intended to draw on skills in the community to help make better curtains.

✗	Energy use increased by 5.07kWh (6.5%), from 78.45kWh/day to 83.51kWh/day.
✗	Energy costs increased by ~$537 (18%) (self-reported decrease in winter bills).
✓	Time spent in the comfort zone increased from 74.4% to 83.5%.
~	Heating efficiency remained consistent changing from 0.19 to 0.20 (0.7%).
✗	Displayed decreased confidence that she could find information on thermal comfort if needed.
✓	Displayed increased confidence that she could find information on energy efficiency if needed.
✓	Self-reported moisture decreased (from medium to none) and mould was no longer a problem.

Existing physical conditions of the house

Deirdre reported mould on her window frames, likely due to some surface condensation because of the single glazing and poor thermal resistance. Humidity in the before period peaked at 75% and at 55% in the after period, so the heat pump was keeping things dry. Inside temperatures did not reach dew point. There were noticeable draughts. The internal brick walls contributed to the thermal mass of the building, but overall, despite having some thermal mass holding heat inside, the thermal resistance of the windows and the walls was poor, leading to an overall poor performance rating.

Type	Stand alone, suburban with rural neighbour.
Age	20-29 years.
Construction	Brick veneer, tile roof, suspended timber floor (0.3 – 1.0m off ground) (vinyl, tiles, carpet).
Insulation	Ceiling only (batts – five years old).
Windows	Single glazed, aluminium frame.
Window coverings	Vertical blinds (living and bedrooms) and medium curtains (dining).
Access to sun	Large gumtree to northeast of house, living room sits on the north corner of the house and gets midday to afternoon sun.
Heating	Heat pump, electric radiant panel heater, plug-in radiant bar heater (bathroom).

Changes to the home

Other changes to the home:

- Changed heating practices (from spiking to more consistent heating) on advice from landlord and GBS team.
- Closed doors and use of curtains and door snakes to retain heat.
- Some broken venetian blinds replaced with vertical blinds.
- Reduced tea/coffee intake (kettle boiled less often).

GET BILL $MART UPGRADES

Not relevant for this participant.

Overview

It was very important to Deirdre to keep her house warm because her daughter had health problems — she suffered from recurring runny noses and chest infections and was constantly using an asthma pump. Before the GBS project, Deirdre had heated her home with a 'spiking' pattern, turning the heat pump up to 30 and then turning it off again. Following advice from her landlord, who is an electrician, she started setting it on 18° and leaving it on. As a result, she and her daughter spent more time in the comfort zone and less time above 24°. Deirdre thinks that this change also helped her daughter's health. The temperature in the living room and bedroom is never below 18° (comparatively making it a well heated house in this study).

Deirdre's landlord was difficult to get on to, but helpful when he was around. He has agreed to remove the carpet in the home; this will make the house feel colder but will help Deirdre's daughter's dust mite allergy. He also intends to remove the internal brick wall at the same time, however, which will probably negatively affect the thermal performance of the home, and demonstrates the importance of landlord literacy regarding thermal comfort and energy efficiency.

Deirdre reported that her electricity bills had decreased dramatically, but this was not evident in the billing data. Her perception may have been muddled by the fact that she was paying off the electricity bill of the previous tenant (combined with her own high use, this was very stressful) and because she had recently changed her payment plan arrangements.

Deirdre had good connections with her local community. She often had family and friends dropping in, which may have contributed to some of the changes in her energy use (e.g. hot water). She was also good friends with one of the Energy Champions, who came over to her house and swapped her light bulbs over (although Deirdre later changed them back). Deirdre had attended some of the GBS activities and found them useful and enjoyable. She was planning to use her community networks to get someone to help her make new curtains to replace her existing, poor quality ones.

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.01	0.01	–0.01	–54.4%
T 41 Heating (hard wired heating)	53.46	54.05	0.59	1.1%
Total Heating	53.47	54.05	0.58	1.1%
Other Light and Power (T31)	14.07	16.25	2.18	15.5%
Hot Water	10.91	13.21	2.31	21.1%
Total Household Electricity	78.45	83.51	5.07	6.5%
House Heating Efficiency (degree-hours/kWh/day)	0.19	0.20	0.00	0.7%

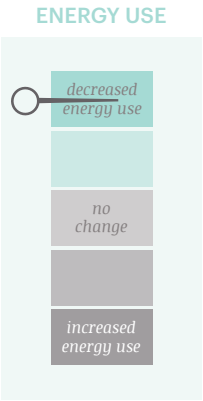
Average daily temperatures and time in comfort zone during winter conditions

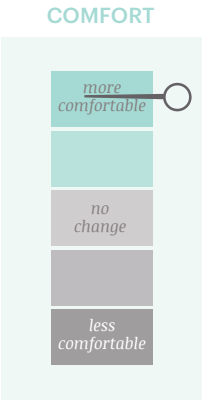
	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	22.3	23.8	12.7	10.4	74.4%
After	21.9	23.3	12.0	10.5	83.5%
Difference between before and after	–0.5	–0.5	–0.7	0.2	9.2%

CASE STUDY 14

Pam and family

(a 2 house comparison before and after moved)





Occupants	Own or rent	Bedrooms	House type	Heating
	RENTER		FREESTANDING ONE STOREY (both houses)	PLUG-IN ELECTRIC (044) + HEAT PUMP (724)

What did we do?

COMMUNITY CAPACITY BUILDING

> With the heat pump we have decent heating, which we didn't have down at the old house. We had no heating.
>
> *(724 After Interview 21/09/15)*

What was the result?

Pam and her family felt much more comfortable once they had moved house (from 044 to 724). Pam chose 724 because of the heat pump and the existing curtains and capacity to zone. The second house (724) also sat in a higher and sunny spot. Pam's choice to move enabled her to reduce her energy use and dramatically improve her comfort and wellbeing.

- ✔ Energy use decreased by 18.06kWh (22.2%).
- ✔ Time spent in the comfort zone greatly increased from 22.7% of time to 80.0%.
- ✘ Displayed reduced confidence that she could find information on thermal comfort.
- ✔ House 044 was draughty while 724 reportedly had not draughts.
- ✔ Moisture and mould reduced 044 had medium moisture throughout house and mould in bath, 724 had no moisture and no mould.

Existing physical conditions of the house

House 1: 044

Internal temperatures occasionally approached dew point, especially in July 2014. There may have been problems in the bedrooms during winter with a maximum of 80% humidity.

Medium moisture levels were reported in the house and mould was reported in the bathroom.

The landlord did not maintain the house to Pam's satisfaction.

The house was brick veneer, timber framed construction with a suspended timber floor and a tile roof; the house required insulation but had little to none. Sun hit the long axis of the house. Pam found the house was always uncomfortable. With poor thermal resistance in the building skin and single glazed windows this house provided POOR opportunity for thermal comfort indoors.

Type	Stand alone, suburban.
Age	30-40 years.
Construction	Brick veneer walls, tile roof, timber suspended floor (0.3m off ground) (carpet, tiles), unused old chimney.
Insulation	Unknown, suspected none.
Windows	Single glazed, aluminium frame.
Window coverings	Curtains and blinds (some light weight, some medium weight).
Access to sun	All day sun to house, living room north east but window sheltered by roof of deck.
Heating	Heat pump, radiant fan in hall, hardwired heaters in bedrooms (not used because not needed).

House 2: 724

Moisture was not a major problem in this house. Curtains and draught proofing was already present in the house when Pam and family moved in.

Single glazing, lack of insulation and living orientation make this house perform poorly

Curtains for zoning areas off and draught proofing already in when moved in. Single glazing, lack of insulation and living orientation make this house perform poorly, however the heat pump, reasonable solar access to kitchen and curtains hung for zoning appeared to assist it to perform better than 044.

Type	Stand alone, suburban.
Age	30-40 years.
Construction	Brick veneer walls, corrugate metal roof, floor (height), unused chimney.
Insulation	Unknown, suspected none.
Windows	Single glazed, aluminium frame.
Window coverings	Vertical blinds, blinds and curtains.
Access to sun	Northwest to south east long axis, living to west with afternoon sun access, shed north west blocks a little sun (to kitchen).
Heating	Heat pump in living, radiant fan in hall, electric blankets.

Changes to the home

GET BILL SMART UPGRADES

Not relevant for this participant.

Overview

When we first met Pam and her family Pam was pregnant with her third child who arrived only weeks later. Pam and her family were cold in the original house (044).

One of Pam's children had health problems exacerbated by the cold and in a cold house this added considerable stress to Pam's life.

The landlord of house 044 was unwilling to make necessarily maintenance changes to the home which Pam and her family found incredibly frustrating.

Seeking to improve her comfort Pam moved to house 724.

The new was substantially better and Pam declined GBS upgrades because she felt they were unnecessary. With the move to the new house, Pam's partner also moved in.

One reason that Pam chose to move to 724 was because of heat pump which would enable her to control comfort levels in both summer and winter.

When Pam made the move from 044 to 724 she was able to reduce her energy use by 22.2% (from 81.27kWh/day to 63.21kWh/day). These savings can be attributed primarily to a reduction in plug in heating (from 51.78kWh/day to 6.12kWh/day, a saving of 88.2%). Wired in heating did increase in house 724 from 0 to 22.10kWh/day, but this was much less than was used by the plug in heater in 044.

Notably time in the comfort zone was dramatically different between the two houses. In 044 Pam and her family spent 22.7% of their time in the comfort zone, while in 724 this increased dramatically to 80% of the time. As expected, House Heating Efficiency also increased significantly (by 311.2%) from 0.08 to 0.32.

Hot water also decreased in 724 despite the addition of an extra adult. It is likely that showers were used less to stay warm and/or that the hot water system was more efficient.

When Pam moved into her new house she was pleased to note that the house already had some good systems for thermal comfort such as good curtains and zoning. We also noted that Pam seemed to have used her improved understanding of energy efficiency when choosing her new home.

Pam had friends in the neighbourhood who also participated in the Get Bill Smart project and she was able to share experiences.

In house 044 Pam had been exposed to the in home education and upgrades and it is likely that she took some of this knowledge with her to 724, indeed this knowledge helped her to choose a more comfortable home.

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	51.78	6.12	-45.66	-88.2%
T 41 Heating (hard wired heating)	0.00	22.10	22.10	#DIV/0!
Total Heating	51.78	28.22	-23.56	-45.5%
Other Light and Power (T31)	12.22	21.15	8.93	73.1%
Hot Water	17.27	13.84	-3.43	-19.8%
Total Household Electricity	81.27	63.21	-18.06	-22.2%
House Heating Efficiency (degree-hours/kWh/day)	0.08	0.32	0.24	311.3%

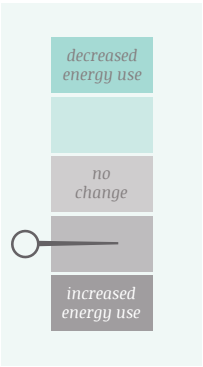
Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	13.9	16.9	11.4	4.1	22.7%
After	20.4	18.4	10.3	9.1	80.0%
Difference between before and after	6.5	1.5	-1.1	5.1	57.3%

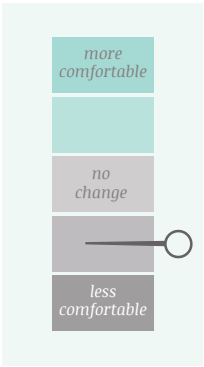
CASE STUDY 15

Gayle, Dennis and family

ENERGY USE



COMFORT



Occupants	Own or rent	Bedrooms	House type	Heating
	OWNER		FREESTANDING ONE STOREY	HEAT PUMP

What did we do?

COMMUNITY CAPACITY BUILDING

> If I had my time over again to do the house the way I wanted, I would have had double glazed windows, floor insulation and I would have insulated inside the walls.
>
> *(After Interview 08/09/2015)*

What was the result?

Gayle, Dennis and family increased their power bills and increased the temperature they heated their home to. Thermally their home performs badly but by using two heat pumps they manage to be comfortable most of the time.

While they had family access to an Energy Champion, they did not really apply any of the tips.

✗	Energy use increased by 4.21kWh/day (5.1%) from 82.31 – 86.52 kWh/per day.
✗	Energy costs increased by ~$300 per year.
✗	Time spent in the comfort zone decreased from 86.2% to 78.3% (still reasonable and higher than most homes).
✓	Heating efficiency increased from 0.20 to 0.24 (17.8%) (efficiency is still very low).
✓	Displayed improved confidence that they could find information on energy efficiency and comfort.
✗	Draughts remained a problem.

Existing physical conditions of the house

Gayle, Dennis, their daughter and their granddaughter live in a standalone suburban house that is approximately 40 years old. Their block is slightly larger than average and on a corner, allowing the house to receive all day sun. The long axis of the house sits (close to) north to south. The living room projects out on the west of the house and receives midday and afternoon sun. The kitchen/dining area receives sun in the middle of the day. Gayle and Dennis built a deck on the north east which is roofed and partly enclosed, which provides a place to dry clothes on wet days and a buffer to winds and draughts. It does however limit morning sun entering areas of the house.

The house has block veneer walls, timber frames, a tile roof, and suspended timber floors (covered in carpet, vinyl, masonite and polished timber). The house uses a gas cooktop but uses electricity to heat. Gayle and Dennis have installed 2 heat pumps, use a fan heater in the southern bedroom and a radiant bar heater in the south eastern bedroom. They also have a heater in their waterbed.

With no insulation in the walls and floors and single glazing this house's thermal performance is poor.

Insulation	Batts in ceiling (installed 2009), insulation on hot water piping (prior to GBS).	POOR
Windows	Single glazed, aluminium frames, no pelmets.	POOR
Window coverings	Curtains (heavy weight and/or lace), one venetian.	POOR
Under floor space	Suspended timber floor 0.5-1.2m off ground, underfloor enclosed with block wall, no insulation.	POOR
Mould and moisture	Low levels of self-reported moisture in living and bedroom, but no mould. Measurements show that temperature only very occasionally went near dew point in winter which would mean some surface condensation but not much more.	POOR
Other conditions of note	Well maintained house but draughty. The household is on a guaranteed continuous supply of power because of Gayle's health issues.	

Changes to the home

Other changes to the home:

- Carpet removed from living room (Gayle disliked it).
- Eco-switches placed in granddaughters' bedroom and the main living area.
- Gayle and Dennis looked after their new-born grandchild for a significant amount of time in 2015.

GET BILL SMART UPGRADES

Not relevant to this participant.

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	23.41	16.39	-7.03	-30.0%
T 41 Heating (hard wired heating)	18.85	24.06	5.22	27.7%
Total Heating	42.26	40.45	-1.81	-4.3%
Other Light and Power (T31)	17.22	25.55	8.33	48.4%
Hot Water	22.83	20.52	-2.31	-10.1%
Total Household Electricity	82.31	86.52	4.21	5.1%
House Heating Efficiency (degree-hours/kWh/day)	0.20	0.24	0.04	17.8%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	21.3	18.2	11.2	8.6	82.6%
After	22.2	18.5	10.6	9.7	78.3%
Difference between before and after	0.8	0.2	-0.6	1.1	-4.3%

Referring to the tables and graphs presented, multiple changes were noted. Overall electricity use decreased by 5.1%. Heating efficiency increased by 17.8%, going from 0.20 to 0.24 through a reduction in plug-in heating and an increase in heat pump usage. The after heating efficiency ratio is still low, showing that reaching comfort levels takes a lot of energy.

The house was in the comfort zone for 78.3% of the time – a decrease from 82.6%, but still a high percentage of time. This means that the house was at least 18°C for over 18.5 hrs a day. Added to this increase was an increase in time spent above the comfort zone in the living area– before 2.1% of time was above 24°C but after 13.5% of the time was above 24°C. Average temperatures in the living room and bedroom increased (for example the average living room temperature went from 21.3 degrees to 22.2 degrees), highlighting the increased time spent above the comfort zone in the living area.

The high level of heating that would be needed to stay in or above the comfort zone was likely influenced by Gayle's illness, along with the various needs and practices of the other householders.

Total heating reduced by 4.3% (from 42.46kWh/per day to 40.45kWh/per day). The after winter use shows there was a significant reduction in the use of plug in heating (down by 30%) and a significant increase in the use of the hardwired heaters (up 27.7%). Energy used on the light and power circuit (other than for heaters) increased (48.4%). The substantial increase of energy through the light and power circuit is possibly from the installation of a plug in heater that has not been recorded by this project.

Energy and comfort

Hot water use decreased by 10.1% which may be explained by the variable occupancy levels of the household. The energy used by the hot water system is considered high for a house with four occupants. As a comparison Case Study #02 – Nonie and family uses a similar amount of hot water and has nine occupants. Gayle and Dennis have a number of high needs occupants, and people who would often be in the house, including a very small child, an adult with down syndrome and another adult with the need for specialised electrical medical equipment.

Temperature was only very occasionally measured as going near to dew point in winter, which correlates with householder accounts.

While the house has poor heating efficiency, Gayle and Dennis manage to keep the inside rooms nearly 10 degrees above outside temperatures. To do this they use two heat pumps in the kitchen/living areas on a regular basis in winter, which helps to explain the high energy use.

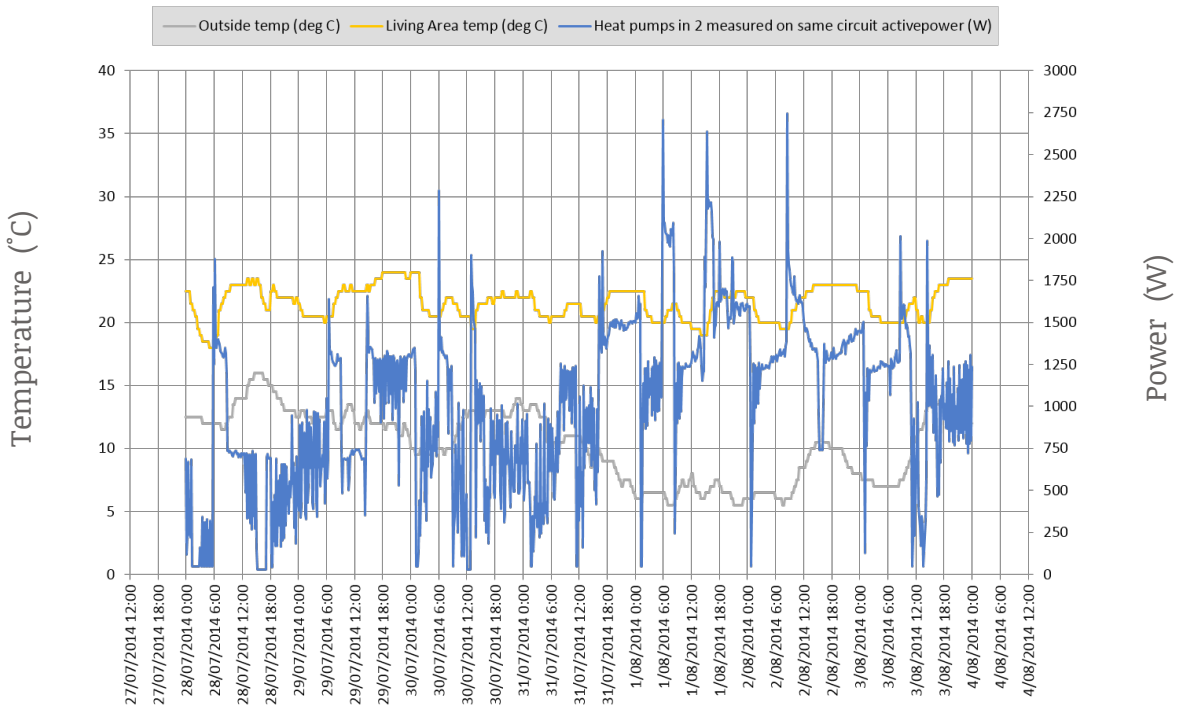
I've got a Downs daughter who doesn't like to wear clothes so she's got to stay... she's terrible, she just sits in a summer nightie and she won't put a dressing gown on, nothing, so we've got to keep her room warm.

(Before Interview 24/05/2014)

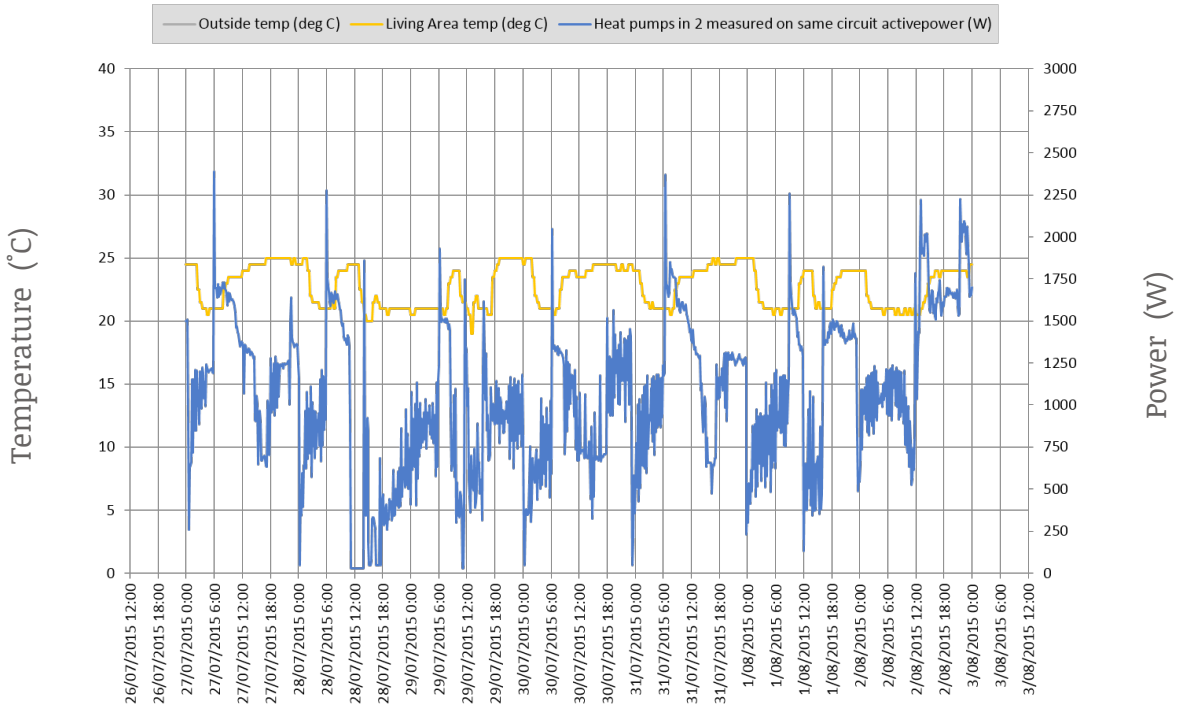
Yeah. It's draughty. Sometimes I see the curtains move, moving through the wind.

(After Interview 08/09/2015)

Before period: example week in winter showing selected energy use and temperature readings



After period: example week in winter showing selected energy use and temperature readings



Energy affordability

Gayle and Dennis were concerned about energy use in their home because of,

> The money. As I said I think it's ridiculous just to keep warm, for god's sake.
> *(Before Interview 24/05/2014)*

The household increased their energy use between 2014 and 2015. Interestingly they believed that their bills had decreased. This may have been because they managed to get ahead in their payments.

As Gayle explained,

> The last bill we got the Hydro owed us over $1200 so... Couple of years ago I was behind and I was paying $189. I still pay $180 something and then all of a sudden instead of me owing them they owe me. And the last bill they owed me over $1200... *(After Interview 08/09/2015)*

Personal and community change

Gayle and Dennis live with their adult daughter who has Down syndrome and their teenage granddaughter. In 2015 they began looking after their new born grandchild during the day.

Technologically aware and skilled, Dennis had spent considerable time and effort establishing energy use routines, organising the technology he thought was best and planning for the future. He intended to install solar panels when they could afford them. Gayle was at home a lot and had significant health issues. At times each week she needed to use medical equipment for treatment, which not only used electricity but also limited her movements in and out of the house.

Managing the needs of everyone in the house and allowing people to get comfortable in their own way clearly influenced energy use in the home. Gayle talked about the difficulty of managing a house with high needs occupants. As she explained,

> You've got the Downs daughter. She'll sit in the lounge room, but she'll sit on the floor. Of all places to sit. It's a cold draft that comes through. I'm cold. I'm cold, you know. So you boot the heater up. If she sat in a chair and that, you know. They're very, you know, the both of them. *(After Interview 08/09/2015)*

Personal and community change

Gayle used the heater according to her needs on any given day but was aware that her daughter and granddaughter didn't heat all that efficiently.

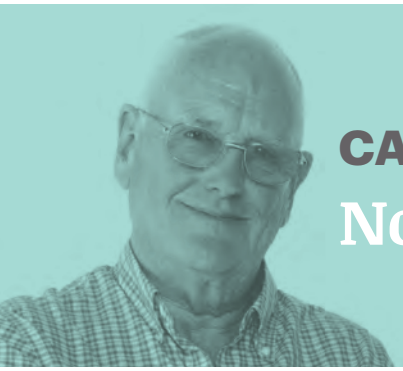
> Look, I'm cold, I want to be hot, so I just change it. I don't like wasting heat though and, as you know, Janice's got a heater in her room, but if she'd leave her door open she wouldn't need a heater in her room. She won't do that. Jacqui's got that invalid heater in her room. But then she sits in there with the door open, but it's still cold, so yeah.
>
> *(After Interview 08/09/2015)*

Gayle and Dennis felt strongly connected to their community. They felt that there were people that they could ask for help. Another of their daughters was a local Energy Champion and they knew they could always go to their neighbourhood centre if needed.

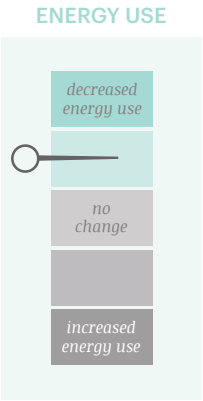
> [Our daughter is] involved, was involved a lot with the, you know, community centre and the family child centre and--but I know where they are and I know if I needed anything I'd only have to go there so, you know. *(After Interview 08/09/2015)*

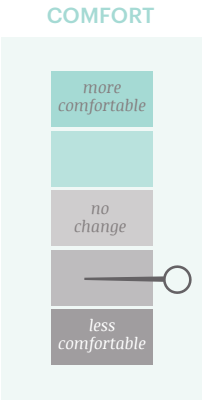
Despite these connections, Gayle and Dennis' clear awareness and some evidence they shared discussions about the Energy Champion role with their daughter. While the Energy Champions did change the lightbulbs for Gayle and Dennis (which blew after a very short time), there is little evidence to suggest that discussions with the daughter led to any change. This lack of apparent uptake of ideas a may have been because: they lived with other householders who did not (or could not) change their energy use practices; Dennis was already practical and didn't really learn anything new from his Energy Champion daughter; or because their house was very busy and dynamic which made it hard to make changes or to make time.

Overall Gayle, Dennis and their family increased their power bills and increased the temperature in their home. Thermally their home performs poorly so they use two heat pumps to keep warm. They are knowledgeable about energy efficiency, well connected to the community and related to an Energy Champion, but could not manage to reduce their energy use.



CASE STUDY 16
Norm and partner





What did we do?

COMMUNITY CAPACITY BUILDING

[If I could] I'd sell [this house] and go somewhere else and get one that was more updated. One with a better set up, probably more glass in it so you get more light and more use of the energy. And I'd probably – I've often thought of it but it's a waste of time in a place like this but with solar panels.

(Before Interview 09/07/2014)

What was the result?

Norm and his wife saw very little change to both their comfort levels and their energy use. They continued to heat the house to a very high degree with the wood heater and occasionally used the heat pump in the shoulder season.

The only way Norm could have improved the performance of his house was to knock it down and start again – prohibitively expensive.

✔	Energy use reduced by 0.8kWh (4.2%) from 20.55kWh/day to 19.69kWh/day.
✘	Energy costs increased by ~$100 per year.
✘	Time spent in comfort zone decreased from 40% to 29.9% (90.8% of their time above the comfort zone of 24°C in the living).
✔	Displayed improved confidence that he could find information on energy efficiency and thermal comfort.
~	*Electrical heat efficiency not relevant in winter as wood fire the main source of heat and no other data available.*
~	Average temperature in the living area was 33°C.

* rent-to-buy scheme

Existing physical conditions of the house

Living room on west received a little bit of northern sun. Most northern sun blocked by entry deck. Very small windows on the north. Eastern and northern sun blocked by sheds and deck roof.

Very poor solar orientation, blocked northern sun and a lack of insulation, among other things, means this house performs thermally very poorly.

Type	Stand alone, suburban.
Age	40-49 years.
Construction	Block veneer, concrete block, tile roof, suspended timber floor (carpet and vinyl).
Insulation	None.
Windows	Single glazed, old wooden frame
Window coverings:	Vertical blinds and light curtains.
Access to sun	Very small window on north side.
Heating	Wood heater (winter), heat pump (spring and autumn).

Changes to the home

Other changes to the home:

- Norm installed a new draught stopper on his back door as the old one was broken.
- Norm and his wife stopped using the heat pump so much in winter, but may have used it more during the shoulder seasons.
- Norm's wife was very sick during some of this period and felt the cold more, especially after her chemotherapy treatment.

GET BILL SMART UPGRADES

Not relevant for this participant.

Overview

Norm and his wife live in a house that they almost own outright. They bought the place when the opportunity arose using the rent-to-buy scheme. Since they bought the place Norm has made as many changes as possible to improve the thermal comfort and energy efficiency. These changes have included: replacing the solid wood front door with glass panels to allow more direct sunlight into the house; draught proofing the doors and doorways; and building an outside living area on the northern side of the house. Norm explained that given the poor design of the house (badly orientated, small windows etc.) there was nothing more he could do. If they could afford to he would just sell the place and move to somewhere more comfortable. Norm was clearly incredibly frustrated by the poor design of the house.

While the house is poorly designed, the wood heater enables Norm and his wife to heat the house to unusually high temperatures (in winter 90% of the time the living room is above 24°C).

They often use the heat pump during the shoulder seasons (spring and autumn) and we picked up some use in the winter season. Norm's wife was quite sick during the after period and this may have changed the way that electricity was used in the house.

Norm himself had energy use requirements and managed a back injury through hot showers but there was some reduction in the after period. Norm and wife also looked after their grandson on occasion which would have affected energy use.

The Energy Champions visited Norm and his wife on several occasions, Norm explained how good this was for social reasons and for general information exchange. They did not attend any Get Bill Smart events.

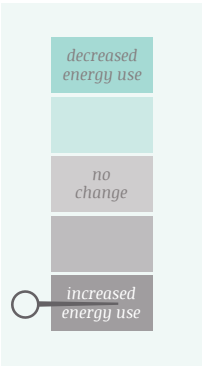
Average daily energy use and heating efficiency during winter conditions

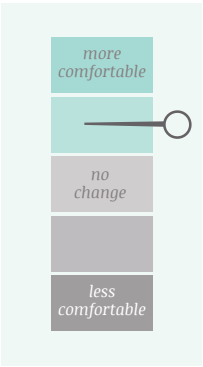
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.00	0.00	0.00	0
T 41 Heating (hard wired heating)	2.52	3.86	1.34	53.0%
Total Heating	2.52	3.86	1.34	53.0%
Other Light and Power (T31)	9.67	8.27	-1.40	-14.5%
Hot Water	8.35	7.56	-0.80	-9.5%
Total Household Electricity	20.55	19.69	-0.86	-4.2%
House Heating Efficiency (degree-hours/kWh/day)	7.16	5.06	-2.11	-29.4%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	31.3	23.1	9.1	18.1	40.0%
After	33.3	24.0	9.1	19.5	29.9%
Difference between before and after	2.0	0.9	0.0	1.4	-9.7%

CASE STUDY 17
Sarah and family





Occupants	Own or rent	Bedrooms	House type	Heating
	RENTER		FREESTANDING ONE STOREY	PLUG-IN ELECTRIC + HARDWIRED RESISTIVE

What did we do?

COMMUNITY CAPACITY BUILDING

What was the result?

Sarah was annoyed at having to live in this house because it was hard to heat, draughty and moist. The heater was ineffective. Despite her husband's construction skills and knowledge of energy efficiency, renting meant they were unable to make any effective changes to their home.

- ✗ Energy use increased by 11.57kWh/day (23.7%) from 48.81 – 60.38kWh/day.
- ✗ Energy costs increased by ~$300 per year.
- ✓ Time spent in comfort zone increased from 6.4% to 10.4%.
- ✗ Heating efficiency decreased from 0.15 to 0.14 (6.7%) – efficiency is very low.
- ✓ Sarah displayed improved confidence that she could find information on thermal comfort.
- ✗ Self-reported moisture and mould remained. Measures support this report with temp reaching dew point in winter in living room with 85% humidity peak.
- ✗ Despite attempts to draught proof, draughts remained problematic.

> Don't move into this house.
>
> *(After Interview 24/09/2015)*

Existing physical conditions of the house

The house is a 40-50 year old standalone suburban house on a slightly larger block. It sits with its long axis north/south and therefore mainly receives east/west sun. It has all day solar access, but few windows are to the north. It is single storey but has a split level, so heat can flow from the living room on the lower level up to the bedroom area on the upper level. The house is constructed of weatherboard cladding with timber frame walls, a corrugated iron roof and concrete block plinth/skirt. The long axis of the house is north to south. The living room is on the south east corner and sits in open plan with the dining on the southwest. The living only receives morning sun. Overall the house has solar access for most of the day. Bedrooms are to the east and north. Heating is provided by a hard wired resistive heater in the living area and a plug in column heater for the bedroom area.

Despite having good curtain coverage, the age, poor orientation, draughtiness, moisture issues and a lack of effective insulation leads to a POOR thermal performance.

Insulation	In ceiling (loose fill rock) only.	POOR
Windows	Single glazed, timber frames, no pelmets.	POOR
Window coverings	Throughout house, medium to heavy weight curtains.	TO STANDARD
Under floor space	Suspended floor, underfloor enclosed with concrete block skirt, no insulation.	POOR
Mould and moisture	Very moist house (wipe down to dry off), mould in the bathroom, use absorbent beads near windows. Temp reached dew point in winter in living room with 85% humidity peak.	VERY POOR
Other conditions of note	Persistent draughts despite DIY draught-proofing.	POOR

Changes to the home

Other changes to the home:

- Sarah's husband (a builder) draught-proofed bathroom and toilet doors and covered vents around house.
- Added a second fridge (for beer for others helping them build their own house).
- Brother came in a caravan to visit and plugged into electricity.

GET BILL SMART UPGRADES

Not relevant for this participant.

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	17.70	18.42	0.72	4.1%
T 41 Heating (hard wired heating)	10.88	16.42	5.54	50.9%
Total Heating	28.58	34.83	6.26	21.9%
Other Light and Power (T31)	7.21	10.31	3.09	42.9%
Hot Water	13.02	15.24	2.22	17.1%
Total Household Electricity	48.81	60.38	11.57	23.7%
House Heating Efficiency (degree-hours/kWh/day)	0.15	0.14	-0.01	-6.7%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	13.1	16.1	10.3	4.3	6.4%
After	13.2	16.1	9.7	4.9	10.4%
Difference between before and after	0.0	0.0	-0.6	0.6	4.0%

Referring to the tables and graphs presented, changes were observed in energy use and comfort. Overall electricity use increased by 23.7%. Total heating increased by 21.9% (from 28.58kWh/day to 34.83kWh/day). Over this time there was a significant increase in the use of the wired in electric resistive heater (up by 50.9%) and a slight increase in the use of the plug in heater (up by 4.1%). This extra heating likely caused the increase in the comfort zone, but was not enough to increase average temperatures. Heating efficiency decreased by 6.7%, going from 0.15 – 0.14; both ratios are low and show ineffective heating.

[John] has put, under the bathroom and toilet door where there was this big, huge gap, so he's nailed a piece of wood along the floor so once the door closes the air can't get through but we can feel, still feel draughts coming through. *(Before Interview 22/6/2014).*

Average temperatures of the living rooms and bedrooms remained constant with the living room temp at 13.1°C (up .01 of a degree) and the bedroom temperature remaining at 16.1°C. The house was only in the comfort zone for 10.4% of the after period which was an increase of 4% (up from 6.4%).

This level of time in the comfort zone is low and indicates a poor thermal environment.

The comfort zone increase coupled with constant and decreased average temperatures indicates that average temperature fluctuated more in the after period (with higher and lower temp extremes). Within this fluctuation there was probably a little more time in slightly warmer temps and slightly more time in

the comfort zone. The before and after graphs show variation in heating practices, but similar temperature ranges being achieved.

Interestingly in this house the bedroom temperature stays warmer than the living room. This is unusual, but aligns well with qualitative understanding: Sarah's baby had sleeps during the day with the door closed (and heater on), the bedroom likely had better solar gain, and Sarah was trying to maintain warm places for her children. Supporting the higher bedroom temperatures the after period column heater use shows relatively constant use. In addition graphs show changes in column heater energy patterns in the after period. This may have been due to a new heater replacing the old or use of a thermostat. The distinction in temperatures also highlights the underperformance of the living area, even when a heater is on. This position of the living room at the south of the house and the stack effect created by having the bedrooms at a higher split level would also diminish living room performance (as heat will escape to bedrooms area).

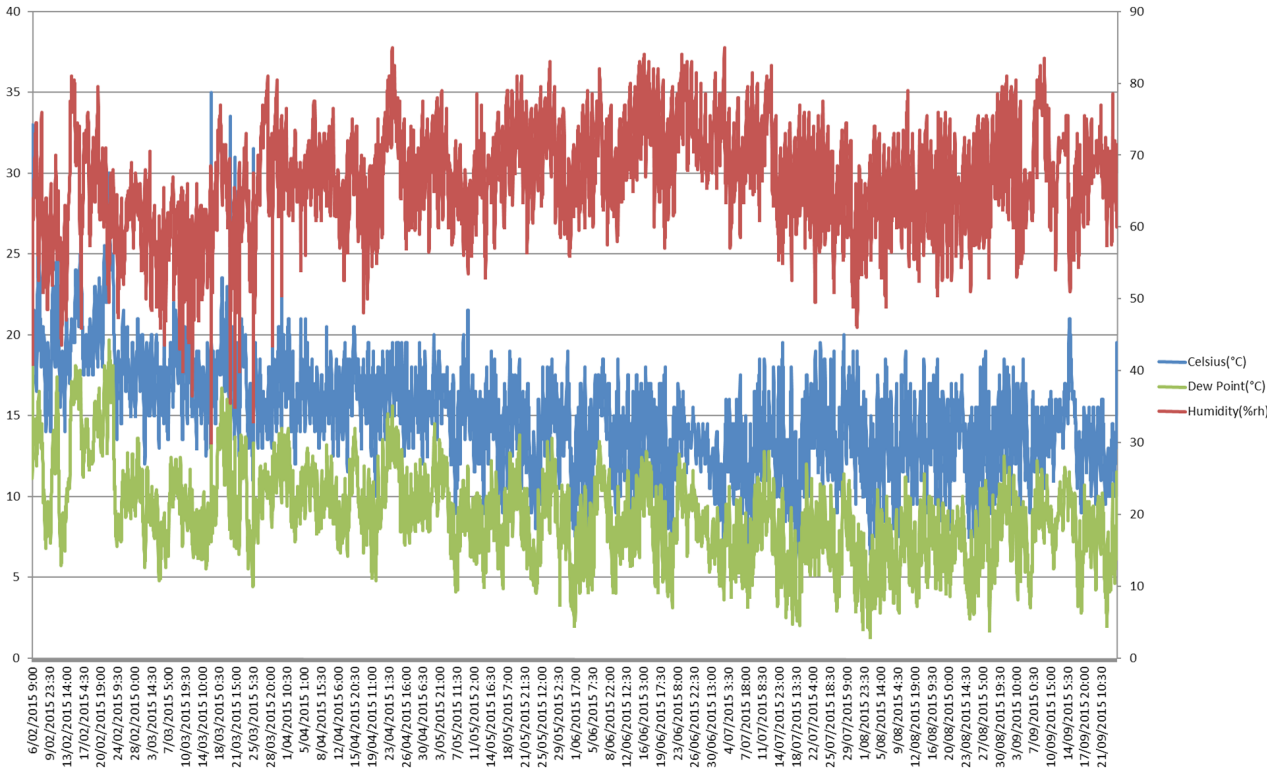
Energy used on the light and power circuit (with heating use removed) increased by 42.9%. It is likely that this increase is due to the installation of a second fridge (put in to help keep 'thank you' beer for people helping them build their own home). During GBS monitoring Sarah's brother visited with his caravan. He plugged into the general light and power circuit and would have also contributed to this increased use.

Hot water use increased by 17.1%. This is likely due to the long visit by Sarah's brother and the subsequent increase in showering.

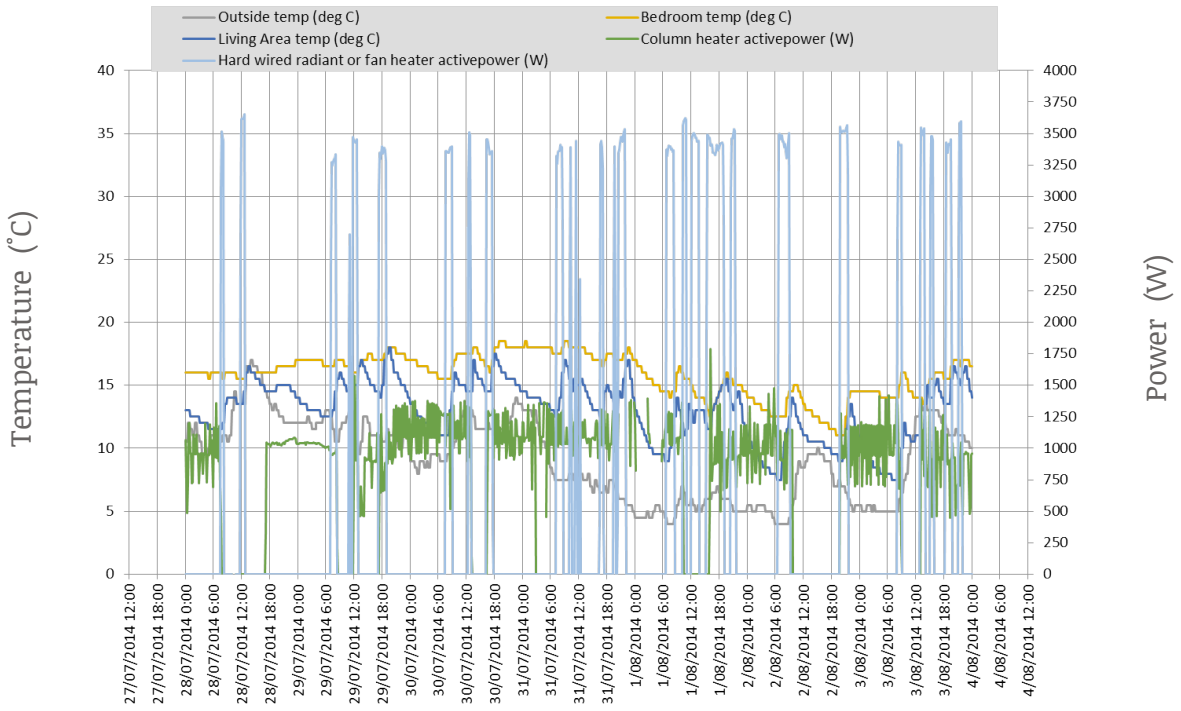
Despite Sarah's use of absorbent beads near windows, she described the house as very moist and said she wiped down to dry off windows. There was mould in the bathroom. Temperatures reached dew point in winter in living room with an 85% humidity peak which supports Sarah's accounts.

> I've asked about this, for [the landlord] to fix this [living room] heater or replace it, because it only half-works and it's chewing the power. The real estate keeps saying that he just reckons he can't afford it, so we basically have to just freeze.
>
> *(After Interview 24/09/2015)*

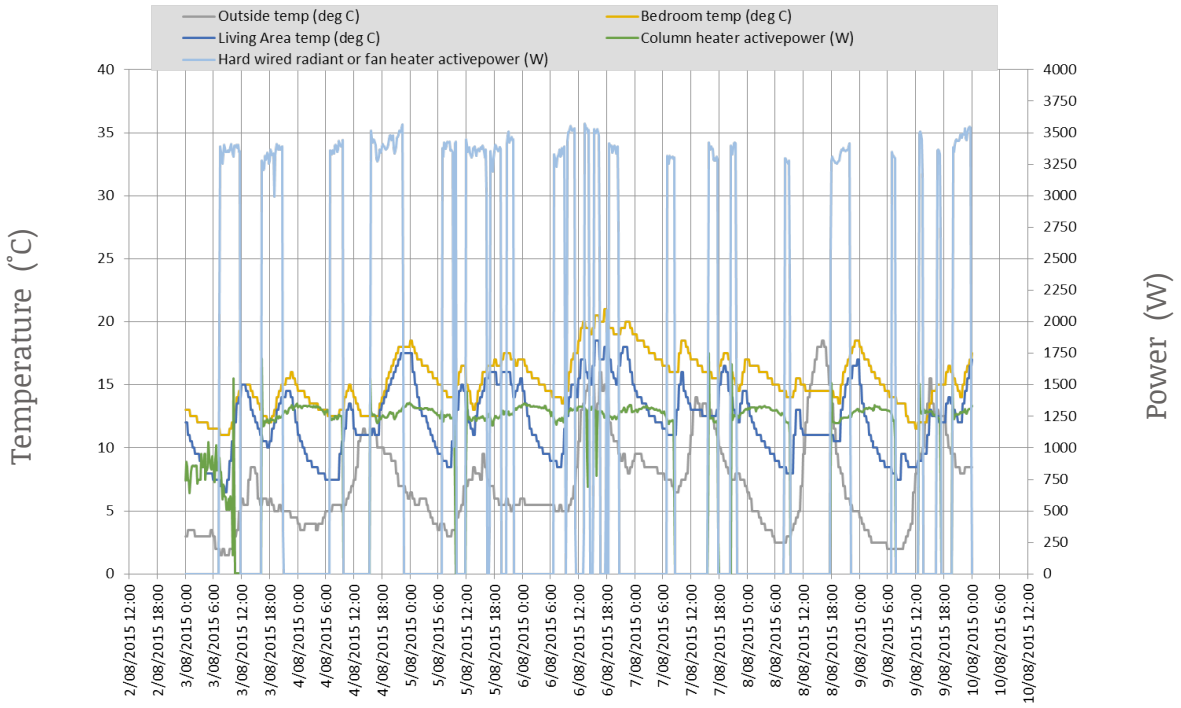
Temperatures, humidity and dewpoints example (living room sensor) recorded Feb to Sept 2015



Before period: example week in winter showing selected energy use and temperature readings



After period: example week in winter showing selected energy use and temperature readings



Energy affordability

Sarah and her family were worried about the amount of money they spent on power. Sarah explained that,

> We put on $70 a week but then by the weekend, we have to go and put another 50 on to take us through to... the Tuesday. *(Before Interview 26/05/2014)*

Over the course of this project Sarah's energy bills increased by approximately $300 per year, from $2,268 to $2,577. Given her increased power usage this is not surprising.

Such an increase in energy use was stressful, as Sarah said,

> It's quite stressful, trying to find the money for that and there are bills and...
>
> *(After Interview 24/09/2015)*

Personal and community change

Sarah and her family have rented their house for about four years. During this time they have attempted to improve the energy efficiency and thermal comfort of their home. Sarah's husband is a builder and did install some wooden draught stoppers on the bottom of the doors and over gaps. This may have helped a little but Sarah explained that the draughts still come through. They also used blankets to trap heat into certain parts of the house.

The living room was warm enough in certain places but Sarah explained the limitations of the heater saying it was,

> Just enough if you're going to sit in here, but it won't heat up the kitchen or even out near the front door, just where you're sitting right here. *(After Interview 24/09/2015)*

Sarah and her husband John have noted many things that they themselves could do to the house. Given John's professional skills they could make many quality changes around the home. Sarah explained that they did not have a good relationship with their landlord which had limited their ability to maintain a comfortable home. She said,

> We're not even allowed to hang pictures on the wall, which is really weird, and we've sent in a list of stuff, can we do this ourselves? Because my husband's a builder, it will make the house look better for the owner, but he just refuses to get back to us.
>
> *(After Interview 24/09/2015)*

Sarah explained that she and John had considered trying to buy the house they were renting but decided against this. Instead, they were building their own home. As a part of the process of building their own place, Sarah and John installed a beer fridge to provide drinks to people who were helping them with the building on their property.

Personal and community change

This new house will have solar panels and rainwater tanks, indicating a level of awareness and care about resource use and efficiency. Sarah explained that her husband was really very interested in energy efficiency.

Given that Sarah is at home a lot during the day with her young children she spends very little time in the comfort zone (10.4%). Sarah found that the kids were sick a lot during the winter and felt that the constant moisture in the rooms,

> That would add to their sickness [because] mould's not good for you to breathe in.
> *(After Interview 24/09/2015)*

By closing the doors to the bedrooms of the house during the day Sarah managed to maintain some level of comfort in the living areas. Yet as she explained,

> When the kids come home, and I want to warm their rooms up, so I open their bedrooms around three, and the cold air that just tumbles out of their rooms is unbelievable.
> *(After Interview 24/09/2015)*

Sarah did not attend any of the Get Bill Smart community events. She explained that she was too busy looking after children and studying. Sarah was friends with one of the Energy Champions and so acknowledged she had access to information through her.

Throughout the project Sarah's sense of community and the resources available to her remained the same – a somewhat neutral sense of community. Sarah and John were integral to their church community in the neighbouring suburb. Sarah felt that she and her husband were the 'go to' people in the community rather than the people who had to seek help or advice. She said,

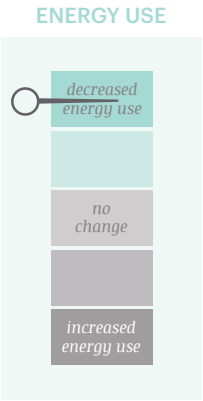
> Our track record is we offer advice, people come and ask us, and we offer advice, we suggest, but they still just potter along in their own little bubble, as you say, so we don't see the point [asking other people for advice]. *(After Interview 24/09/2015)*

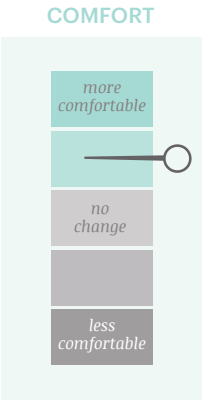
Overall Sarah and her family were uncomfortable in this house and were annoyed that it was hard to heat, draughty and moist. Poor orientation of the living room and the split level design of the house made it hard to manage. Despite her husband having construction skills and knowledge of energy efficiency, renting meant they felt unable to make any effective changes to their home.

CASE STUDY 18

Susie and family

(comparing houses before and after move)





Occupants	Own or rent	Bedrooms	House type	Heating
	RENTER	(089) → (725)	FREESTANDING ONE STOREY	PLUG-IN ELECTRIC + HEAT PUMP

What did we do?

COMMUNITY CAPACITY BUILDING

Down at my other house I used to go home and I used to crawl into bed because it was a cold house and watch TV where here I don't. The big difference was the first night I moved in here I had my sister down and she would normally have seven blankets on her bed down at the old house. The first night she was here she slept with one doona.

(House 725 After Interview 21/9/15)

What was the result?

Moving house greatly improved Susie and her family's comfort and reduced their bills. House 725 (the second house) required half the electricity and had a heating efficiency 304.6% better then house 089. Using less than half the heating and on a cheaper tariff in a house that looked nicer and had access to more sun helped Susie and her family to feel so much better about life.

- ✔ Energy use halved with the move going from 70.6 to 35.03Kwh (a 35.63kWh, 50.4% change).
- ✔ Self reported energy costs reduced by ~$1000 per year.
- ✔ Time spent in the comfort zone slightly increased from 43.9% to 49.3%.
- ✔ Heating efficiency increased from 0.12 to 0.47 (a changed of 0.36, 304.6%)
- ✔ Displayed improved confidence she could access information on energy efficiency if needed.
- ✔ Draughts were greatly reduced in the new house reduced.

Existing physical conditions of the house

House 1: 089 – This house somewhat maintained but needed work. Despite Susie hanging curtains, this house had a lot of its solar access into the living areas cut off, and little thermal resistance. The house also had no effective living room heater. Overall this house performed at a very poor to poor level.

House 2: 725 – This house has little thermal resistance in the walls but has ceiling insulation, some solar access and a heat pump that provides effective heat. This house feels much more comfortable to Susie than the one she lived in previously. Overall this house is poor to near standard.

House 1: 089	
Type	Stand alone, suburban.
Age	40-49 years.
Construction	Weatherboard cladding, timber frame, corrugate metal roof, suspended timber floor (1 m high) (vinyl and carpet cover), brick underfloor skirt.
Insulation	Unknown (likely none).
Windows	Single glazed, timber frame.
Window coverings	Lace + curtains and vertical blinds.
Access to sun	Car port on north and tree on west so morning and midday solar access, living room on west with a little northern sun; dining and kitchen to north but afternoon sun cut off.
Heating	Plug in radiant bar (dining), radiant (living), plug in column (hallway), column (bedroom), electric blankets. Had an old oil heater but was $700 to fill it and the oil only last about 2.5 weeks so cost prohibited its use.

House 2: 725	
Type	Stand alone, suburban.
Age	40-49 years.
Construction	Brick veneer, timber framed, tile roof, suspended floor enclosed with brick (carpet and tiles).
Insulation	Ceiling only.
Windows	Single glazed, aluminium frame.
Window coverings	Curtains in living and dining after home visit.
Access to sun	Dining with a deck to the north, living to the west with clear solar access to the north.
Heating	Heat pump (living), plug in radiant (hall).

Changes to the home

Other changes to the home:

- Moved house (from 089 to 725) seeking a more comfortable and nicer house.

GET BILL $MART UPGRADES

Not relevant for this participant.

Overview

Susie lived with her two young children. When we first met them they lived in house 089 which was hard to heat and uncomfortable. Susie felt embarrassed by how run down the house looked. Her new house looked and felt better. Susie had been quite depressed in her original house and the move to 725 had significantly improved her mental health; it was easier to live in, warmer and more affordable.

The data provided in this case is a comparison of Susie's before information for 089 and her before information for 725. Susie did have exposure to the GBS community events and did attend at least one.

All heating in 089 house was plug in electric. Susie felt that the house let her down in terms of comfort. In the new house all heating was wired in and included a heat pump. Susie used much less energy to heat the 725 house so total heating reduced by 30.83kWh/day (a reduction of 57.8%).

Despite the significant benefits from moving, when Susie first moved into house 725 she was frustrated that there was no door between the laundry and the rest of the house. Without a door draughts and cold air flowed through into the living space and this was exacerbated by the heat pump. Susie's frustration reveals her understanding of thermal comfort management in the home. Susie approached the landlord to change the door but he was not interested. It was clear that Susie would have made further changes to the home if she had the money and/or owned the place herself.

Keeping kids warm so that their asthma did not flare was a priority for Susie. It was also important for her own health, "if I'm not comfy then I'm grumpy. I get shivery and then I throw up" (725 interview 21/09/2015).

Pay as you Go electricity in house 725 also helped Susie feel more in control than in 089.

Susie was well networked in the community with friends she could talk with about thermal comfort and energy efficiency. She had previously attended some Get Bill Smart activities (before moving into house 725) and felt confident that the Energy Champions would be able to answer any questions she might have. Susie was also good friends with several other participants in the program and they were all able to share their experiences.

Note that after this comparison Susie's energy reduced a little more with the home energy helper visits from SLT (see Case 10).

In 089 Susie spent a lot of time in bed with electric blanket on and she was on a payment plan to cope with her high bills.

In 725 there are new ways to keep warm in the living room – the kids would comfortably snuggle on the couch near the heat pump.

Susie's experience is a fantastic example of how significantly the quality of housing can affect physical and mental health.

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	53.37	0.00	-53.37	-100.0%
T 41 Heating (hard wired heating)	0.00	22.53	22.53	#DIV/0!
Total Heating	53.37	22.53	-30.83	-57.8%
Other Light and Power (T31)	7.57	5.35	-2.23	-29.4%
Hot Water	9.72	7.16	-2.57	-26.4%
Total Household Electricity	70.66	35.03	-35.63	-50.4%
House Heating Efficiency (degree-hours/kWh/day)	0.12	0.47	0.36	304.6%

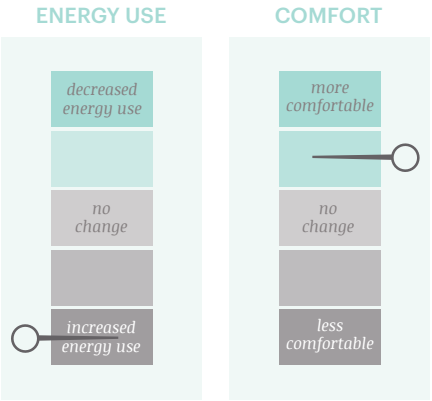
Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	16.0	18.0	10.8	6.2	43.9%
After	20.6	17.0	8.2	10.6	49.3%
Difference between before and after	4.6	-1.0	-2.6	4.4	5.5%

CASE STUDY 19

Selena and family

(comparing houses before and after move)



Occupants	Own or rent	Bedrooms	House type	Heating
	RENTER → OWNER WITH MORTGAGE		FREESTANDING ONE STOREY	HEAT PUMP

What did we do?

COMMUNITY CAPACITY BUILDING

> Not at this point because we've switched over to PAYG, it seems so much cheaper. I don't know whether it's because we've become more conscientious of it but I mean we're just paying under $50 a week whereas we used to get big bills at the other house.
>
> *(After Interview 091 25/09/2015)*

What was the result?

Selena and her family moved from renting house 091 to purchasing house 726. While the move gave them housing security and more control over what they did to the home, they also found themselves dealing with significant moisture and mould issues in the new home.

- ✗ Energy use increased by 13.85kWh/day (49.6%) from 27.92kWh/day to 41.77kWh/day.
- ✓ Time spent in the comfort zone increased from 20.2% to 27.2%.
- ✗ Heating efficiency decreased from 0.80 to 0.79 (1%).
- ✗ Displayed decreased confidence that she could find information on thermal comfort and remained unsure she could access information on energy efficiency if needed.
- ✗ Problematic levels of moisture and mould.

Existing physical conditions of the house

House 1: 091 – Due to orientation of the house and blocking of the north/east sun with a deck, the lack of insulation, single glazing and poor window coverings, this house has poor thermal performance.

House 2: 726 – From the evidence from the householder and observation of the poor thermal performance of the building materials this house performs at a very poor level. The suspended timber floor is just above ground and as a result significant moisture is likely coming up from below. This moisture has led to problematic levels of mould in the bedrooms.

House 1: 091	
Type	Stand alone, suburban.
Age	40-49 years.
Construction	Brick veneer, tile roof, suspended timber floor (polished timber floor, carpet) (1m), old chimney.
Insulation	None.
Windows	Single glazed, aluminium frame.
Window coverings	Curtains (medium in living, bedroom, lace elsewhere).
Access to sun	Living room positioned to the west (north west window/south west window) open plan with kitchen/dining to the north, north east deck with roof (cutting out sun).
Heating	Heat pump.

House 2: 726	
Type	Stand alone, suburban.
Age	30-39 years.
Construction	Weatherboard, corrugated metal roof, suspended timber floor (polished floorboards, tiles, carpet), old brick chimney, small block skirt around underfloor.
Insulation	Possible ceiling.
Windows	Single glazed, wood frame.
Window coverings	Curtains (heavy), venetians (kitchen).
Access to sun	Main living access to northern sun, all day sun, long axis is east west.
Heating	Heat pump.

Changes to the home

Other changes to the home:

- Moved house (from 089 to 725) seeking a more comfortable and nicer house.

GET BILL $MART UPGRADES

Not relevant for this participant.

Overview

Selena and her partner were in their late twenties with two young children (under 4).

With the move to a new home, Selena and her family significantly increased their energy use (by almost 50%). Most of this increase is through hot water (which increased by 58.1% from 11.31kWh/day to 17.89kWh.day) and the Other Light and Power Circuit (65% increase from 8.59kWh/day to 14.16kWh/day). The increase in hot water use is most likely due to the second house (726) having a much older and less efficient hot water system. As seen in case #30 a faulty hot water system can contribute significantly to energy use. With no changes to work or household occupants, faulty hot water is a possibility.

It is unclear why Other Light and Power increased so much. This may be due to increased energy use associated with a house move and the beginnings of small home improvements, changes to appliances, family visitors or other reasons.

In moving to the new house (726) Selena and family also shifted to the Pay As You Go Billing system. Selena found this helpful for maintaining control over their energy use. Interestingly she explained that her bills had decreased, however it seems unlikely that this is the case, rather the change in billing style helped her management practices.

Selena and her family were incredibly physically active and some of the most fit and healthy people in this study. This would have helped her significantly to feel warm in houses that perform thermally very poorly.

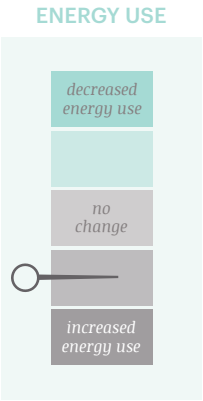
Average daily energy use and heating efficiency during winter conditions

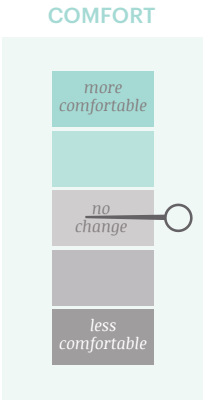
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.00	0.00	0.00	0.0%
T 41 Heating (hard wired heating)	8.01	9.71	1.70	21.2%
Total Heating	8.01	9.71	1.70	21.2%
Other Light and Power (T31)	8.59	14.16	5.58	65.0%
Hot Water	11.31	17.89	6.57	58.1%
Total Household Electricity	27.92	41.77	13.85	49.6%
House Heating Efficiency (degree-hours/kWh/day)	0.80	0.79	-0.01	-1.0%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	17.5	13.8	9.2	6.4	20.2%
After	17.0	15.1	8.4	7.7	27.2%
Difference between before and after	-0.4	1.3	-0.8	1.3	6.9%

CASE STUDY 20
Queenie and family





Occupants	Own or rent	Bedrooms	House type	Heating
	RENTER		FREESTANDING ONE STOREY	HEAT PUMP

What did we do?

COMMUNITY CAPACITY BUILDING

> Yeah, not really interested [in attending events], I just don't really have the time, with four kids, one on the way, it's pretty crazy.
>
> *(After Interview 09/09/2015)*

What was the result?

Thanks to the installation of carpet, Queenie and her family felt warmer in their home at lower temperatures. Despite this the family used more energy and heating costs increased. This is likely due to a shift in how the family used the heat pump – they went from turning it off when not in use to only turning it down.

- ✗ Energy use increased by 3.28kWh from 44.4kWh/day to 47.68kWh/day (7.4%).
- ✗ Energy costs increased by ~$320 per year (from $2,352 – $2,672).
- ✗ Time spent in comfort zone decreased from 75.1% to 74.7% (this remained excellent).
- ✗ Heating efficiency decreased from 0.84 to 0.62 (25.7%) – this is comparatively higher than others in study.
- ✓ Displayed improved confidence that she could find information on energy efficiency and thermal comfort.
- ✓ Self reported decrease in draughts.

Existing physical conditions of the house

Queenie and her family lived in a tiled, brick veneer, timber framed house with suspended floors (covered with tiles and later carpet). The house is approximately 30 years old. A stand alone suburban house sitting on a standard sized block, the house receives sun all day. The living/kitchen area sits to the north receiving sun most of the day. Bedrooms sit to the south of the house and so receive either eastern or western sun.

The family don't know if there is any insulation in ceiling. Heating in this house is provided by a heat pump in the living area.

Overall the living area position provides good solar access, but a lack of insulation means the house still only provides a poor level thermal performance.

Insulation	Unknown in ceiling, none elsewhere.	VERY POOR
Windows	Single glazed, aluminium frames, no pelmets.	POOR
Window coverings	Blinds (medium weight).	NEAR STANDARD
Under floor space	Suspended floor 0.2-0.8m, underfloor enclosed with brick wall, no insulation.	POOR
Mould and moisture	Self-reported increase in moisture (survey), however self-reported decrease in moisture (interview). Measures taken show temperature does not reach dew point when heating so moisture likely only on cold surfaces (eg windows) at specific times. Indoor winter humidity is not very high, so not likely to encourage further surface condensation.	
Other conditions of note	Overall well maintained. Draughts in the house.	

Changes to the home

Other changes to the home:

- The landlord carpeted the tiled living/dining area at Queenie's request.
- Queenie stopped paid work as she was expecting her fifth child.
- The family began to leave the heat pump on all the time as Queenie was told by someone that this was more efficient.

GET BILL SMART UPGRADES

Not relevant for this participant.

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.00	0.00	0.00	0.0%
T 41 Heating (hard wired heating)	11.11	14.78	3.68	33.1%
Total Heating	11.11	14.78	3.68	33.1%
Other Light and Power (T31)	19.75	13.12	-6.63	-33.6%
Hot Water	13.54	19.77	6.23	46.0%
Total Household Electricity	44.40	47.68	3.28	7.4%
House Heating Efficiency (degree-hours/kWh/day)	0.84	0.62	-0.22	-25.7%

Average daily temperatures and time in comfort zone during winter conditions

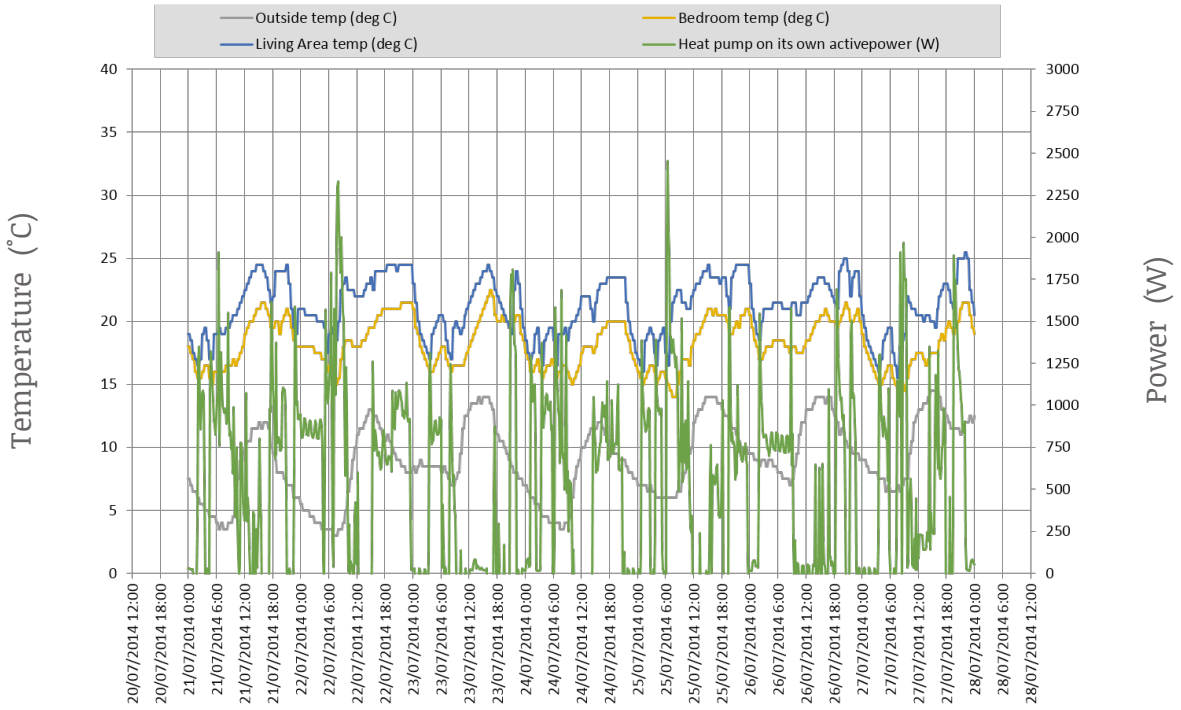
	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	21.3	18.7	10.7	9.3	75.1%
After	20.5	17.9	10.0	9.2	74.7%
Difference between before and after	-0.8	-0.7	-0.7	-0.1	-0.4%

Referring to the tables and graphs presented, changes were observed in energy use and comfort. Total Household Electricity increased by 7.4% (from 44.40kWh/day to 47.68kWh/day). This increase was primarily due to more use of the heat pump (up 33.1%). Queenie explained that she left the heat pump on at all times as she had been told this was more cost effective and energy efficiency (please note using a heap pump in this way is not necessarily more efficient). Housing heating efficiency was reasonable when compared to others in this study because of the use of a heat pump, but declined from 0.84 to 0.62 (25.7%) in the after period as more heating was used.

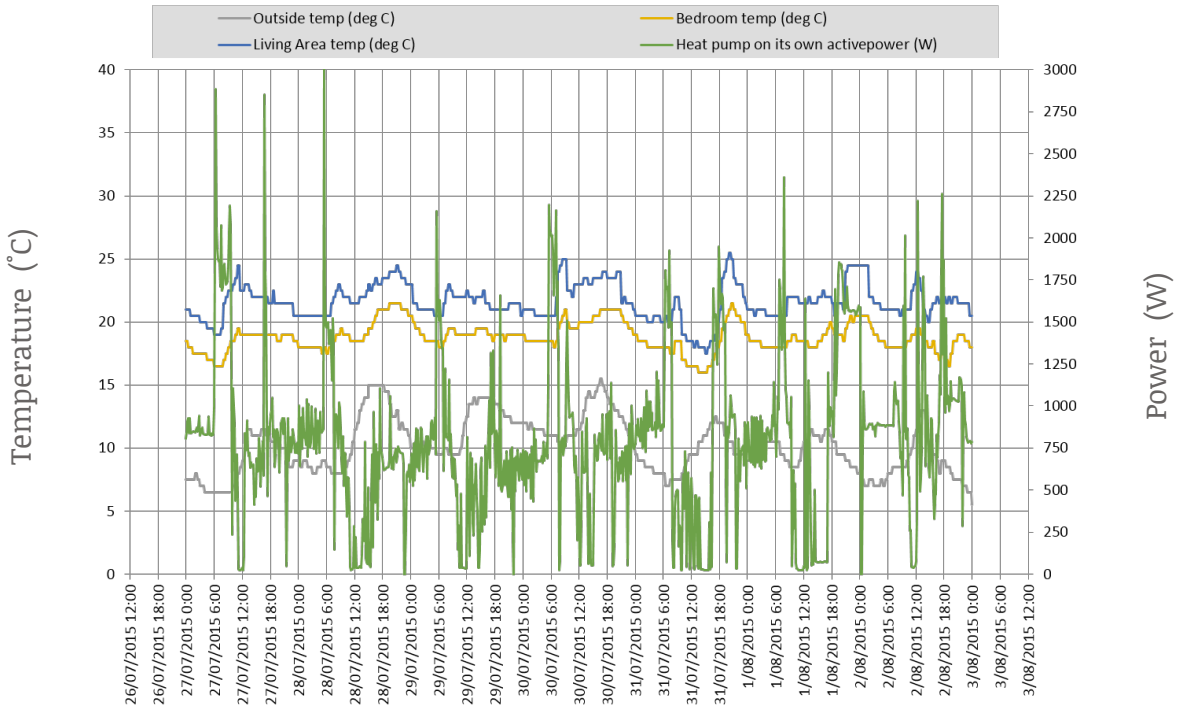
Time spent in the comfort zone minimally decreased from 75.1% to 74.7%. Time spent above the comfort zone (above 24°C) in the living area also declined from 10.7% to 6.5% of the time. The after time in the comfort zone is still very good as it would mean the house on average stayed above 18°C for about 18 hours a day. Average differences between the indoor temperatures and outside were consistently 10°C (warmer) in the living and ~7°C (warmer) in the bedroom. This temperature difference is reasonably high when compared to other detailed study houses.

Queenie reported that the family felt warmer at a lower heat now that the tiles had been covered by carpet. Average temperatures in the after period were a little lower (living average reduced by 0.8°C and the bedroom by 0.7°C) but overall heating energy increased. Despite slight changes in average temperatures, the before temperature graphs show a change in temperature dynamics. In the before period, in the living room, there tended to be large temperature swings and the temperature would rise and drop sharply when heating was turned on

Before period: example week in winter showing selected energy use and temperature readings



After period: example week in winter showing selected energy use and temperature readings



Energy and comfort

and off. There were frequent periods above 24°C and frequent periods below 17°C. This changes in the after period. There is less regular occurrence of sudden temperature drops and more comfortable temperatures were sustained for longer periods. The after graph also shows the bedroom is borrowing more of the heat from the living area.

Humidity and temperature measures taken show temperature does not reach dew point in the rooms measured. Indoor winter humidity is not very high (heat pumps tend to dry the air somewhat), so would not worsen surface condensation. So it is likely that moisture reported by Queenie is only on cold surfaces e.g. windows) at specific times. Certainly the difference between indoor and outdoor temperatures is enough to have encouraged surface condensation on windows.

Energy used on the Other Light and Power circuit decreased by 33.6% (from 19.75kWh/day to 13.12kWh/day, -6.63 kWh/day). At the same time, hot water use substantially increased from 13.54kWh/day to 19.77kWh/day (46%, 6.23kWh/day). It is difficult to tell why hot water use increased. It may have been due to changed patterns such as Queenie being home more and children staying in the shower for longer (her daughter loved a long shower).

> Yeah. I mean, in the cold the kids will just whinge because they're cold. But the hot makes them grumpy if they can't cool down.
>
> *(Before Interview 10/05/2015)*

> Oh, yes, this winter was a lot warmer because we had the carpet.
>
> *(After Interview 09/09/2015)*

Energy affordability

Queenie carefully monitored her energy use. She noted that on occasion the cost of electricity was a problem, saying:

> "I know, like, the last couple of weeks I've had to like go up to my mums to borrow money to put power on and that's only because we've had... two birthdays a day apart – we struggled. Other than that, we don't do it generally, but it can come to the point where we have to borrow.
>
> *(Before Interview 10/05/2015)*

Queenie's electricity bills increased by $320 per year, which matches with her increased energy use. When we spoke with her the second time, Queenie actually thought that her bills had gone down. The data collected from the energy supplier suggests this is not the case. Queenie was someone who paid her electricity bills via Pay As You Go. Queenie would have been able to see weekly peaks and troughs, but would not have had an overall tally of use over the year. It is possible that her extra energy use was not that noticeable because the extra cost came from occasional spikes in the regular use.

Interestingly, as with a number of other houses, Queenie and her family used a noticeable chunk of their energy on heating the water of tropical fish tanks. Queenie had noticed the extra use of energy each time a new fish tank had been set up. She rated it as a high energy user, under the heat pump, when she spoke with us. This highlighted how pets could be prioritised in homes too.

Personal and community change

Queenie spoke often of living with her partner along with her four children, but did not mention her partner in GBS surveys. Queenie and the family had moved into this house because their old house had been too cold and was not effectively heated. They found this house much better. The family had an excellent relationship with their current landlord who, at Queenie's request, replaced ('freezing') tiles with carpet in the living areas.

Queenie left her heat pump on all the time as she was told by someone she trusted that turning it on and off was likely to cost her more money (it is worth noting here that this is not necessarily true). Queenie carefully managed home comfort explaining that:

To keep it warm in the winter I found if I shut my blinds about half past three it would stay warmer, then if . . . it was a really cold day I just would not open them. And same with the summer, like, if it was too hot I'd keep them down. But days like today I've got them all open, my heat turned down and it's not cold in here. *(After Interview 09/09/2015)*

Queenie liked to make sure that she kept the home reasonably warm (not too hot or too cold) as her children's, especially her daughter's health was affected by temperature. She said:

My daughter suffers epilepsy, so that sets her off a lot if she gets too hot. *(After Interview 09/09/2015)*

As a result, keeping the house at a good temperature was a priority.

Queenie felt that having carpet had really changed how warm her house was:

Yeah, it [the heat pump] gets put down to like 17 or something overnight. Depending on the weather, like, today I think I've got [the heat pump] down on 15. If it's a cold, cold day we'll have it on maybe 22. We used to have it up near 30 with the tiles.
(After Interview 09/09/2015)

With the installation of carpet, the room is likely to heat up faster once the heater is turned on as the tiles will not be soaking up the heat. While this may not affect air temperatures (which we measured), it could affect physiological comfort when touching the surface of the floor.

In her before and after surveys Queenie reported consistently high levels of confidence that she lived in a strongly connected community. She also thought that there were people within the community who could help her with thermal comfort and energy efficiency.

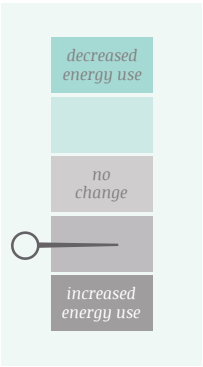
Queenie was unable to attend any of the Get Bill Smart workshops because she was busy looking after her four children. Despite a lack of attendance, she demonstrated increased awareness of power use and energy efficiency in her home which she said came from being part of the GBS research.

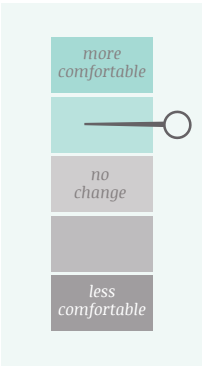
Yeah, I'm more aware and I'm more careful, I suppose, about what I'm doing, yeah. Since I've been doing this, and it just made me think, oh, especially with girls in the shower and stuff, you know, hot water.
(After Interview 09/09/2015)

Queenie informed us she is best friends with a woman who received upgrades through GBS. She also met local Energy Champions when they knocked on her door. She did not engage much with the Champions explaining that she already had the sensors in' (that she was part of the GBS project already and being monitored). She did not know that the Champions had other tips to offer. It is interesting that increased awareness has not yet translated into a decrease in energy. Queenie also listened to other people she knew and because of this had taken on the problematic advice about the heat pump.

Queenie and her family were close to the median of energy use for the Clarendon Vale no upgrade group of households but they were above average and above median for the project overall. Queenie felt confident in her management of the house. She listened to others about home management advice. The house was at temperatures that kept her children healthy but which meant the house was above 18°C for 3/4 of the day. The family's energy use increased over the GBS project period. There were times when Queenie had to ask her mum to help pay energy bills.

CASE STUDY 21
Frank and family





Occupants

Own or rent

Bedrooms

House type

Heating

What did we do?

COMMUNITY CAPACITY BUILDING

> [To reduce power we'd need to] Get rid of teenage kids! ... They use more power than Harvey Norman does!
>
> *(After Interview 09/09/2015)*

What was the result?

Frank was a competent handyman around the home and was constantly working to improve the performance of the house.

Thanks to a higher income than many in this study and a greater capacity to make change, Frank and his family enjoyed relatively high levels of comfort.

Frank attended some community engagement activities but saw himself as attending as a mentor rather than someone needing information.

✗	Energy use increased by 2.82kWh (7.1%) from 39.71kWh/day to 42.53kWh/day.
✓	Energy costs reduced by ~$125 per year ($1,971-$1,846).
✓	Time spent in the comfort zone increased from 56.3% to 61.4%.
✗	Heating efficiency decreased from 0.70 to 0.63 (8.9%) – remains good.
✓	Displayed improved confidence that he could find information on energy efficiency if needed.
✓	Self-reported draughts reduced.
✓	Self-reported reduction in moisture and mould.

Existing physical conditions of the house

Skylights in the kitchen, laundry and bathroom enabled natural light into the house and reduced the need for lighting.

A large deck at the back of the house (south east) also contributed to the liveability of the home (used as a space for clothes drying, cooking and socialising).

The orientation of the house, the higher levels of insulation and Frank's capacity to make changes to the house mean that this home performs thermally much better than most others in this study. We consider Frank's house as near to standard.

Type	Stand alone, suburban, standard block.
Age	50-59 years.
Construction	Weatherboard, timber framed, corrugated metal roof, under floor enclosed with brick, suspended timber floor (.9m above ground), (carpet, timber, cork).
Insulation	Well insulated ceiling with batts, polystyrene floor insulation under living spaces.
Windows	Single glazed timber frames, retrofitted double glazing in bedroom.
Window coverings	Lightweight vertical blinds.
Access to sun	All day access to sun, living room access to sun, eastern sun coming in to living room, well oriented.
Heating	Heat pumps (living, bedroom).

Changes to the home

Other changes to the home:

- Frank had retro-fitted double glazed windows into his daughter's north facing bedroom.

GET BILL $MART UPGRADES

Not relevant for this participant.

Overview

Frank and his family live in a well maintained house. Frank utilised his construction skills to make the home a comfortable place to live. Frank had built high quality double glazed windows for his daughter's bedroom and had insulated both the ceiling and the accessible parts of the floor.

Frank's professional skills and a slightly higher family income means that he had a higher capacity for creating a comfortable and efficient home than others in this study.

Frank and his family increased their total energy use by 2.82kWh/day (7.1%). Most of this increase can be attributed to greater use of the heat pumps (and subsequent increase in time spent in the comfort zone) which may have been used more due to the colder winter. The heat pumps were left on 16°C all day and all night.

Power use on the Other Light and Power circuit decreased. Frank was constantly retrofitting and changing energy use practices in the home which may have contributed to this change.

Frank and his family were well connected in the community. Frank contributed a lot of time to the local men's shed and felt that he had helped to train some of the Energy Champions in energy efficient retro-fits in the home. Frank's wife had also begun to participate in activities at the men's shed and was also quite knowledgeable.

Frank attended several Get Bill Smart community events. He said he attended in order to support the Energy Champions and while he didn't learn anything he said that they were enjoyable social events.

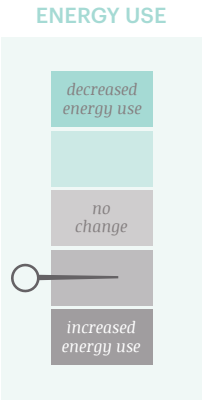
Average daily energy use and heating efficiency during winter conditions

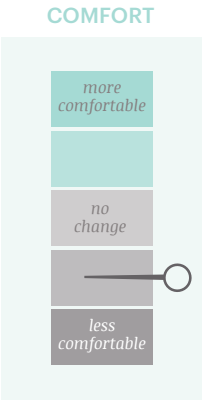
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.00	0.00	0.00	0.0%
T 41 Heating (hard wired heating)	14.19	17.75	3.57	25.1%
Total Heating	14.19	17.75	3.57	25.1%
Other Light and Power (T31)	9.33	8.12	-1.22	-13.0%
Hot Water	16.18	16.66	0.47	2.9%
Total Household Electricity	39.71	42.53	2.82	7.1%
House Heating Efficiency (degree-hours/kWh/day)	0.70	0.63	-0.06	-8.9%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	22.6	15.4	9.0	9.9	56.3%
After	23.0	17.4	8.5	11.3	61.4%
Difference between before and after	0.4	2.0	-0.6	1.4	5.2%

CASE STUDY 22
Stacey and family





Occupants	Own or rent	Bedrooms	House type	Heating
	RENTER		FREESTANDING ONE STOREY	HEAT PUMP

What did we do?

COMMUNITY CAPACITY BUILDING

> The real estate. The door used to whistle. All my windows. I'd say they must have had security things up on the windows or maybe even fly nets, because all the bottom, they've all got a hole that you can just about fit a 20 cent piece in. So you get all the dust and stuff from the... *(After Interview, 9 Sep 2015)*

What was the result?

Stacey and her family increased their energy use while at the same time decreased the time they spent in the comfort zone.

While at first glance it appears that Stacey reduced her heating, tables show that she increased the temperature the house was heated to. In the after period she spent more time above the comfort zone of 24°C.

Stacey hung new curtains and actively zoned areas of her house which contributed to her ability to stay warm.

✗	Energy use increased by 5.01kWh (11.4%), from 43.9kWh/day to 48.91kWh/day.
✗	Energy costs increased by ~$228 per year (from $2070 to $2298).
✗	Time spent in the comfort zone decreased from 50.1% to 44.1%.
✓	Heating efficiency increased from 0.49 to 0.60 (23.8%).
✓	Displayed improved confidence that she could find information on thermal comfort and energy efficiency if needed.

Existing physical conditions of the house

The whistling made by the wind coming through the front door was unbearable and Stacey convinced her real estate to install draught-proofing. Despite significant improvement in curtain coverage and draught-proofing, the lack of insulation, poorly positioned living room and single glazing means this house continues to perform poorly.

Type	Stand alone, suburban.
Age	30-39 years.
Construction	Brick veneer, tile roof, suspended timber floor (carpet, vinyl).
Insulation	None.
Windows	Single glazed, aluminium frame.
Window coverings	Lace curtains and light curtains, improved to medium to heavy curtains throughout house.
Access to sun	Long access north west to south east, slightly blocked on the north east but otherwise all day sun, south corner living area.
Heating	Heat pump, electric blankets (5).

Changes to the home

Other changes to the home:

- Stacey had curtains that she finally got around to hanging.
- Door snakes used to stop draughts.
- At Stacey's request, real estate agent draught-proofed her 'whistling' front door.

GET BILL $MART UPGRADES

Not relevant for this participant.

Overview

Stacey and her children appear to have significantly changed their heater use over the course of the project. The time they spent in the comfort zone decreased (from 50.1% to 44.1%) while at the same time heating costs went up. On closer examination this is due to the increase in time Stacey and her family spent above the comfort zone of 24°C. The average winter temperature in their living room was ~28°C.

Living room temperatures increased significantly while bedroom temperatures increased only slightly. This suggests that Stacey and her family changed their zoning practices, closing doors to the living room, hanging blankets in doorways and using door snakes and draught stoppers. The draught-proofing on the doors would have also helped reduce heat loss.

Stacey explained that she had hung new curtains in the house. This would have contributed to the improved house heating efficiency – windows were the weak point of the home and thus coverings would be beneficial. Stacey noticed moisture on the bedroom windows and this is likely due to the high temperatures in the house rather than being a dew point issue. The high heat pump use is likely to be helping to keep humidity down. The significant increase in the house heating efficiency may also have been because some plug-in heating went through Other Light and Power without a heater sensor attached.

While Stacey liked to keep herself to herself, she was clearly an important person in the community with neighbours frequently dropping in to borrow items or ask for a favour. Stacey was well connected with the community and did have a home visit from one of the Energy Champions. Stacey said this was helpful but she did not attend any community events.

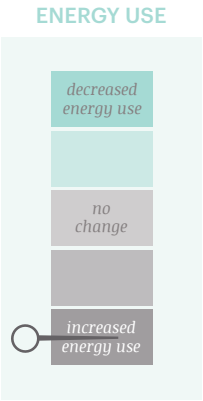
Average daily energy use and heating efficiency during winter conditions

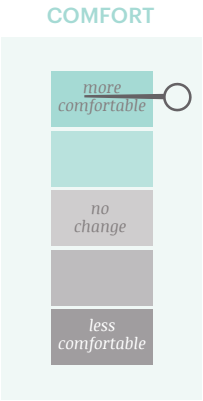
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	1.66	0.67	–0.99	–59.6%
T 41 Heating (hard wired heating)	17.45	20.50	3.06	17.5%
Total Heating	19.10	21.17	2.07	10.8%
Other Light and Power (T31)	13.50	15.76	2.27	16.8%
Hot Water	11.30	11.97	0.67	5.9%
Total Household Electricity	43.90	48.91	5.01	11.4%
House Heating Efficiency (degree-hours/kWh/day)	0.49	0.60	0.12	23.8%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	24.6	18.6	12.3	9.3	50.1%
After	28.4	19.1	11.0	12.8	44.1%
Difference between before and after	3.8	0.5	–1.3	3.5	–6.0%

CASE STUDY 23
Monique and children





Occupants	Own or rent	Bedrooms	House type	Heating
	RENTER		FREESTANDING ONE STOREY	HARDWIRED RESISTIVE

What did we do?

COMMUNITY CAPACITY BUILDING

> I just rug him up more, and put the heaters on; there's not really much more you can do, give him an asthma pump. I mean, maybe you could heat up less if he wasn't sick, possibly, maybe.
>
> *(After Interview, 9 Sep 2015)*

What was the result?

Monique had high energy bills but did spend a significant amount of time in or above the comfort zone. While she did not have much financial capacity to change her home, she drew on the resources available from community organisations and her existing relationship with an Energy Champion. As a result she did make some changes to the comfort of her home through zoning, draught-proofing and a new hot water cylinder.

✗	Energy use increased by 7.41kWh/day (9%), from 82.75kWh/day to 90.16kWh/day.
✓	Energy costs reduced by ~$220 per year (from $3056 to $2836).
✗	Time spent in the comfort zone decreased from 76% to 64.8% (but time above 24°C increased in living room from 22% to 44% of time).
✓	Heating efficiency increased from 0.21 to 0.22 (2.1%) but remains fairly low.
✓	Displayed improved confidence that she could find information on thermal and energy efficiency if needed.
✗	Draughts remained problematic.

Existing physical conditions of the house

The back door has a gap underneath it of about 3cm. This contributes significantly to draughts. The house has a poor thermal performance due to single glazing and aluminium frames, limited solar access from the north, lack of effective insulation and draughts.

Type	Stand alone, suburban.
Age	30-40 years.
Construction	Brick veneer, timber frame, tiled roof, concrete floor (carpet, tiles).
Insulation	Ceiling only (batts) – unknown quality.
Windows	Single glazed, aluminium frame.
Window coverings	Curtains throughout house (heavy and lace), none in kitchen or bathroom.
Access to sun	House runs north/south axis, morning sun to living room, close neighbour on the north west, kitchen/dining west side of house.
Heating	Hard-wired radiant and fan (living), hard-wired radiant (hall).

Changes to the home

Other changes to the home:

- Sealed around the front door (by real estate agent).
- New hot water cylinder (old one was leaking).
- Windows sealed.
- Talked with the kids about saving money by reducing energy use – there is now a new household routine around this.
- Shower timer from Energy Champions.
- Hung a blanket between open dining/kitchen and living area.

GET BILL $MART UPGRADES

Not relevant for this participant.

Overview

Monique kept her house warm in order to help her son, who had problems, with asthma. In summer, however, the house was too hot, and she and the kids would go into the bathroom to cool down and eat icy poles. She had good community connections and used other services, such as Anglicare's kids' camps program. Her energy bills had been very high; they had been based on estimates only by the power supplier.

Monique was proactive about energy efficiency and attempted to act on the information she was given. She said her first port of call in looking for information would be Google, but one of her cousins was an Energy Champion, and she came around with a box of goodies and gave her advice. Monique also had another organisation provide advice to her about the house and as a result asked the landlord to fix the draughts around the windows. Given that she had been in the house a long time and was a 'good' tenant the landlord was happy to help.

During the GBS project, Monique increased her heating use by 11.4%. She thought this might be because she had been working from home more and also because the winter had seemed a lot colder than usual. Monique's time in the comfort zone decreased from 76% to 64%, however this was because of a substantial increase in time spent above 24° (from 22% of time to 44%). The average temperature in the living room in mid-winter was 23.9° which is very close to the upper edge of the comfort zone and comparatively high for this study. A new hot water cylinder probably contributed to the small reduction in hot water usage. Monique also made use of the shower timer to encourage her kids to have shorter showers. There is also some evidence that Monique changed her zoning practices between the sensor swap.

Average daily energy use and heating efficiency during winter conditions

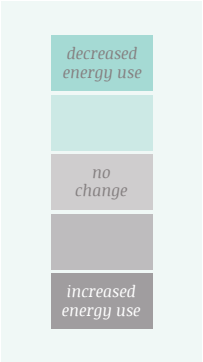
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.00	0.00	0.00	0.0%
T 41 Heating (hard wired heating)	61.84	68.86	7.02	11.4%
Total Heating	61.84	68.86	7.02	11.4%
Other Light and Power (T31)	12.00	12.51	0.50	4.2%
Hot Water	8.91	8.79	-0.12	-1.4%
Total Household Electricity	82.75	90.16	7.41	9.0%
House Heating Efficiency (degree-hours/kWh/day)	0.21	0.22	0.00	2.1%

Average daily temperatures and time in comfort zone during winter conditions

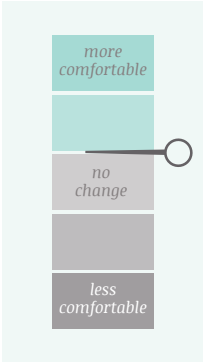
	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	22.5	20.7	8.5	13.1	76.0%
After	23.9	23.2	8.7	14.9	64.8%
Difference between before and after	1.4	2.5	0.1	1.8	-11.2%

CASE STUDY 24
Joe and Beth

ENERGY USE



COMFORT



Occupants	Own or rent	Bedrooms	House type	Heating
	OWNER WITH MORTGAGE		FREESTANDING ONE STOREY	HEAT PUMP

What did we do?

COMMUNITY CAPACITY BUILDING

Researcher: did [the Power Ranger] talk to you about any of the stuff [energy efficiency activities and ideas] that went on at all?

Joe: She told me- she told me about a few things. I can't remember exactly what was said now.

(After Interview 7/9/15)

What was the result?

Joe and Beth's house had poor thermal performance and they lived outside the comfort zone for significant lengths of the day.

Joe and Beth had access to thermal comfort and energy information through a daughter who was an Energy Champion.

It seems that Joe and Beth were not particularly interested in learning from her or participating in the program beyond the basic study. This couple had significant health problems during the project and it is likely that there simply was not the capacity to engage in any kind of education or change processes in their home.

✗	Self reported increase in energy use. (GBS was not able to conduct in-house electrical monitoring here.)
~	Time spent in the comfort zone remained fairly constant moving from 23.4% to25.8% (a 2.4% change). They also spent 26.1% of time in living above comfort zone which then reduced to 8.7% above comfort zone.
~	Heating efficiency could not be calculated from this participant.
✓	Displayed improved confidence that they could find information on thermal comfort and energy efficiency if needed.
✗	Draughts and moisture remained problematic. Moisture levels medium and mould in bedroom and bathroom.

Existing physical conditions of the house

Temperature near dew point at intermittent points June to Sept in the living area (but with a peak of 65% humidity). This may be due to the moisture coming from the kitchen, which is open plan with the living area. The bedroom had intermittent points where temp near dew point with peaks of 75% humidity. Temp in the bedroom low in winter. Mould reported in the end bedroom (had to move the bed) and bathroom.

Joe and Beth's house's single glazing and limited insulation, and mould issue lead to it having a poor thermal performance. The heat pump did assist somewhat to improve performance.

Type	Stand alone, suburban.
Age	30-39 years.
Construction	Brick veneer, timber frame, tile roof, suspended timber floor (1.0m off ground) (carpet, vinyl) , solar panels.
Insulation	Ceiling batts (2009).
Windows	Single glazed, aluminium frame.
Window coverings	Lace and curtains (medium) in dining, curtains/venetian blinds (bedrooms).
Access to sun	All day access to sun, main living room on north west but no north window (only afternoon sun).
Heating	Heat pump (living).

Changes to the home

Other changes to the home:

- No changes made.

GET BILL $MART UPGRADES

Not relevant for this participant.

Overview

Joe and Beth were the parents of one of the Energy Champions. They had lived in the house for many, many years and had regular practices of zoning, heating only the areas they used.

Joe and Beth noted damp windows at the back of the house and continued to have medium levels of mould and moisture.

Energy use in the house was affected by Joe being ill and the presence of grandchildren in the home.

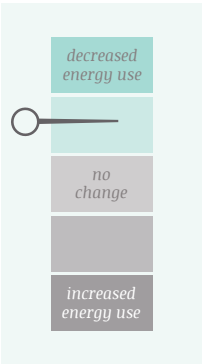
Joe and Beth had strong networks in the area and would have been able to access information on energy efficiency and thermal comfort if needed. That they didn't utilise these networks indicates both their long term residence in the home and their established domestic patterns and also reflects their poor health; they simply did not have the capacity to make changes and continue to work and pay the bills.

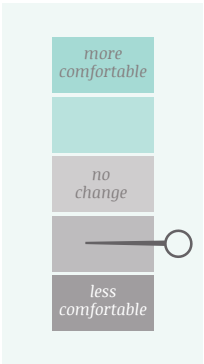
Prior to the second interview, Joe and Beth hung curtains in their home that they had had sitting around for some time.

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	20.8	11.4	11.3	4.8	23.4%
After	19.4	10.0	10.8	3.9	25.8%
Difference between before and after	-1.4	-1.4	-0.5	-0.9	2.4%

CASE STUDY 25
Nancy and partner





Occupants	Own or rent	Bedrooms	House type	Heating
	OWNER WITH MORTGAGE		FREESTANDING TWO STOREYS	WOOD FIRE

What did we do?

COMMUNITY CAPACITY BUILDING

What was the result?

Nancy and her partner have decreased their energy use and decreased the time they spend in the comfort zone. Given that they use a wood heater to heat the home these two things are not necessarily related. It is unclear why their energy use declined. Nancy has been very ill and she and her husband are always looking for ways to improve the home – it is likely this has led to a dynamic energy use within the home.

- ✔ Energy use decreased by 0.65kWh/day (2.9%), from 22.66kWh/day to 22kWh/day.
- ✔ Energy costs reduced by ~$6 per year (from $1244 – $1238).
- ✘ Time spent in the comfort zone decreased from 50.5% to 44.7%.
- ~ Given the wood heater, heating efficiency is not accurately measured for this home.
- ✔ Displayed improved confidence that she could find information on energy efficiency and remained confident that she could access information on thermal comfort if needed.

> Oh yeah, I'm very methodical with information.
>
> *(After Interview, 8 Sep 2015)*

Existing physical conditions of the house

Nancy and her partner had installed solar panels and solar hot water so that in the future as they got older they would have smaller electricity bills. This house was well maintained and had good solar access. However, in summer, despite insulation in the ceiling and sisalation in the walls, the upstairs rooms of the house were very hot and the single glazed aluminium frames and the lack of insulation in the older part of house meant the thermal performance of the house was poor and was particularly problematic in summer.

Type	Stand alone, suburban.
Age	30-40 years.
Construction	Brick veneer, timber suspended floor, floorboards (tiles, carpet), corrugated metal roof.
Insulation	Ceiling, sisalation in upper walls.
Windows	Single glazed, single tinted, aluminium frame.
Window coverings	Vertical blinds/thick curtains throughout, venetian blind (kitchen).
Access to sun	All day sun to living room/kitchen/sun, hedge on the north blocked some sun.
Heating	Wood heater

Changes to the home

Other changes to the home:

- New curtains.
- Changed many light bulbs to LEDs.
- Ecoswitch that Nancy got from the newsagent in a small country town.

GET BILL $MART UPGRADES

Not relevant for this participant.

Overview

Nancy and her partner were in control of how they managed their home and were careful forward planners. They had chosen to install solar panels and solar hot water so that in the future, they would have reduced electricity bills. They were also contemplating installing a heat pump or another kind of electric heater because Nancy's husband was increasingly less able to keep up with the demands of a wood fire (currently their wood supply came from a second property and so there was lots of work involved). If they had the money, Nancy said they would also put in under-floor insulation.

Nancy had a strong local community, although a serious illness had prevented her from attending any Get Bill Smart activities. However, an Energy Champion had knocked on her door and she said this had made a difference to her level of energy consciousness.

The data showed that the average indoor temperature in the home fell by about 1°, although it remained within the comfort zone. The time spent in the comfort zone overall also fell, although it remained relatively high at 44.77%, and time spent above the comfort zone reduced as well. The reason for the 7.7% reduction in other light and power usage is not clear, although it may be related to the solar panels.

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.00	0.00	0.00	0.0%
T 41 Heating (hard wired heating)	0.00	0.00	0.00	0.0%
Total Heating	0.00	0.00	0.00	0
Other Light and Power (T31)	14.36	13.26	–1.10	–7.7%
Hot Water	8.30	8.75	0.45	5.4%
Total Household Electricity	22.66	22.00	–0.65	–2.9%
House Heating Efficiency (degree-hours/kWh/day)				

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	22.7	17.4	11.6	7.6	50.5%
After	21.8	16.6	10.8	7.5	44.7%
Difference between before and after	–0.9	–0.9	–0.8	–0.1	–5.8%

CASE STUDY 26

Robert and partner/ Selena and family

(2 families using the same house consecutively)

ENERGY USE	COMFORT
decreased energy use	*more comfortable*
no change	*no change*
increased energy use	*less comfortable*

Occupants	Own or rent	Bedrooms	House type	Heating
	RENTER → OWNER WITH MORTGAGE		FREESTANDING ONE STOREY	HEAT PUMP

What did we do?

COMMUNITY CAPACITY BUILDING

> I mean we're a bit concerned about how much moisture there is like whether it's going to start growing mould or not because in the bedroom it was quite you could actually see the wall. It was all glossy and shiny. That's not good.
>
> *(Robert, Before Interview 20/05/2014)*

What was the result?

Robert and partner and Selena and family both occupied this house at different times.

They had very different energy use and very different thermal comfort. Robert's household was rarely in the comfort zone and used very little energy. Selena's household was sometimes in the comfort zone and used significantly more energy. The comparison of different people in this home shows how poorly the house performed in terms of thermal comfort and energy efficiency.

Moisture and mould was a huge problem for both households.

- Energy use changed from 13.08kWh/day to 41.77kWh/day.
- Time spent in the comfort zone changed from 3.8% to 27.2%.
- Heating efficiency changed from 3.39 to 0.79.
- Robert and partner were slightly more confident than Selena and family that they could find information on thermal comfort and energy efficiency if needed.
- Draughts were problematic for both Robert and partner and Selena and family.

Existing physical conditions of the house

From the evidence from the householders and observation of the poor thermal performance of the building materials this house performs at a very poor level. The suspended timber floor is just above ground and as a result significant moisture is likely coming up from below. This moisture has led to problematic levels of mould in the bedrooms.

Robert and his partner suspect that prior to them renting the house the landlords simply painted over the mouldy walls.

Type	Stand alone, suburban.
Age	30-39 years.
Construction	Weatherboard, corrugated metal roof, suspended timber floor (polished floorboards, tiles, carpet), old brick chimney, small block skirt around underfloor.
Insulation	Possible ceiling.
Windows	Single glazed, wood frame.
Window coverings	Curtains (heavy), venetians (kitchen).
Access to sun	Main living access to northern sun, all day sun, long axis is east west.
Heating	Heat pump.

Changes to the home

Other changes to the home:

- This house went from being occupied by a young couple (renters), to being occupied by a couple with two young children (owners with a mortgage).

GET BILL $MART UPGRADES

Not relevant for these participants.

Overview

It is interesting to look at how one house performs with two different occupants. Robert and his partner were in their early twenties. They were both new to the area and found it hard to integrate into the community. Both spent significant amounts of time at home studying.

Selena and her partner were in their late twenties with two small children. They were also relatively new to the area and had found it difficult to connect with the community. Selena and the kids spent significant time at home.

While both households were at home for many hours of the day, their energy use differed substantially. Selena and her family reported spending more than twice as much on electricity than Robert and his partner; ~$50 per week compared with ~$20 per week. While some of this can be attributed to the extra people in the home, it also reveals the different priorities, capacities and management strategies of the householders.

Robert and his partner were often at home during the day but they would be in the small bedroom with blankets, computers and occasionally a small plug in heater. The computers generated some heat in the small space and it was easy to contain the warmth. Selena would have had much more trouble containing the heat as her two young children could not just be kept in one small room all day.

Both households made use of blankets and rugs.

Selena and her family spent considerably more time in the comfort zone (27.2%) than Robert and his partner (3.8%). This is reflected in energy use. That both households spent such little time in the comfort zone suggests both incredibly poor thermal performance of the house and low financial capacity of householders.

Selena's household also used considerably more hot water than Robert's. It may be that this increase is not just an increase in household numbers but a change in the way hot water is used. For example Selena's family may have taken more baths. The hot water system may also have deteriorated.

The house as occupied by both households often reached dew-point in the living and bedroom areas. Humidity ranged between 40-90% in the living room and 50-95% in the bedroom. This suggests moisture was coming up through the floors. Both households noted the significant mould problem and found moisture difficult to manage.

Average daily energy use and heating efficiency during winter conditions

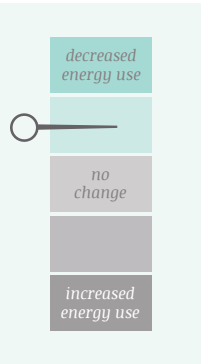
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.46	0.00	-0.46	-100.0%
T 41 Heating (hard wired heating)	0.68	9.71	9.03	1325.0%
Total Heating	1.14	9.71	8.57	750.2%
Other Light and Power (T31)	6.28	14.16	7.88	125.4%
Hot Water	5.65	17.89	12.24	216.6%
Total Household Electricity	13.08	41.77	28.69	219.4%
House Heating Efficiency (degree-hours/kWh/day)	3.39	0.79	-2.60	-76.7%

Average daily temperatures and time in comfort zone during winter conditions

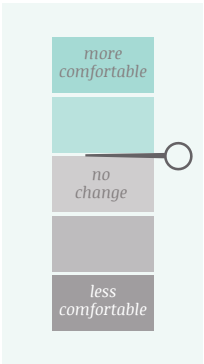
	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	12.8	12.9	9.0	3.9	3.8%
After	17.0	15.1	8.4	7.7	27.2%
Difference between before and after	4.3	2.2	-0.5	3.8	23.4%

CASE STUDY 27
Pam and family

ENERGY USE



COMFORT



Occupants

Own or rent

Bedrooms

House type

Heating

What did we do?

What was the result?

Pam and her family moved into their house in search of a warmer more functional home (see Case Study 14 for previous household experience). The family was much happier in the new home and while the house doesn't actually perform particularly well, thanks to the heat pump they can live relatively comfortably.

Pam's understanding of key energy efficiency and comfort features had helped her choose the new house.

- ✔ Energy use decreased 63.21 to 57.87kWh by 5.34kWh (8.5%).
- ✔ Time spent in the comfort zone slightly increased from 80.0% to 82.0%. This is a high level of time in comfort zone.
- ✔ Heating efficiency increased from 0.32 to 0.35(8.2%).
- ✔ Displayed improved confidence that she could find information on thermal comfort if needed.

> When we moved in, the curtains to keep the draughts out the doors were already up, to keep the heat in. Yeah, so we didn't have to do a lot here, actually, which was really good. It already had the draught stoppers along the bottom of the doors.
>
> *(After Interview 21/09/2015)*

Existing physical conditions of the house

The position of the living area, single glazing and the high uninsulated suspended floor over the garage creates an uncomfortable indoor winter environment.

While the physical house is in better condition than many in the area, it still performs at a poor level.

Type	Stand alone, suburban.
Age	30-40 years.
Construction	Brick veneer walls, corrugate metal roof, floor (height), unused chimney.
Insulation	Unknown, suspected none.
Windows	Single glazed, aluminium frame.
Window coverings	Vertical blinds, blinds and curtains.
Access to sun	Northwest to south east long axis, living to west with afternoon sun access. 1 shed north west blocks a little sun (to kitchen).
Heating	Heat pump in living, radiant fan in hall.

Changes to the home

Other changes to the home:

- No changes.

GET BILL $MART UPGRADES

Not relevant for this participant.

Overview

Pam and her family moved into this house in search of a more comfortable home. So confident was she that the house would be functional that she turned down the GBS in home education and upgrade.

The house worked well and Pam explained that they felt comfortable in winter with the heating on. Pam's family spent 82% of their time in the comfort zone (a slight increase from 80%). While time in the comfort zone increased, overall energy use decreased. House Heating Efficiency decreased by ~8% from 0.32 to 0.35.

Use of the heat pump decreased by 16% (from 22.1kWh/day to 18.44kWh/day) while use of the plug in heater increased from 6.12kWh/day to 9.2kWh/day (50.3%).

All other energy decreased.

Pam and her family were energy conscious and were careful in how they zoned and heated their home. This was a household who had previously received an in home education and upgrade as a part of the GBS project. As a result they were likely to have retained some knowledge of energy efficient practices. Indeed, Pam spoke directly about energy features in regards to the new house.

This was not a house that performed well but it did perform better than Pam's previous home. The family was comfortable for a good period of time and felt confident in their management practices. They did also manage to reduce their energy consumption over the after winter period.

Pam did not attend any community run GBS events as she was pregnant and then had a new born baby as well as looking after her other children.

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	6.12	9.20	3.08	50.3%
T 41 Heating (hard wired heating)	22.10	18.44	-3.66	-16.5%
Total Heating	28.22	27.64	-0.58	-2.0%
Other Light and Power (T31)	21.15	17.42	-3.73	-17.7%
Hot Water	13.84	12.81	-1.03	-7.4%
Total Household Electricity	63.21	57.87	-5.34	-8.5%
House Heating Efficiency (degree-hours/kWh/day)	0.32	0.35	0.03	8.2%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	20.4	18.4	10.3	9.1	80.0%
After	20.8	18.4	10.0	9.7	82.0%
Difference between before and after	0.4	0.0	-0.3	0.5	2.0%

Cases 28–39

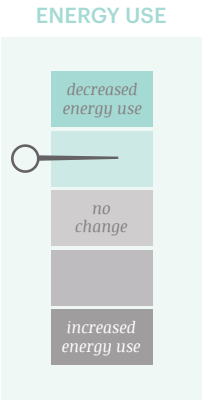
HOME ENERGY UPGRADES

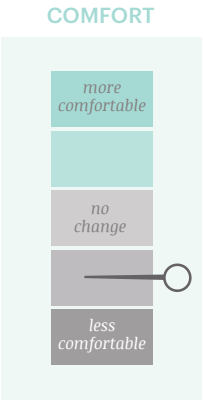
GBS support activities for these cases were:

1. Home energy upgrade/ education visits by experienced home energy helpers.

Houses in this case group were all living in suburbs of the Greater Hobart region. None of these households had homes in the suburbs of Clarendon Vale and Rokeby and none of these households were directly exposed to community capacity building activities held.

CASE STUDY 28
Gabrielle and daughter





Occupants	Own or rent	Bedrooms	House type	Heating
	RENTER		FREESTANDING ONE STOREY	HARDWIRED RESISTIVE + HEAT PUMP

What did we do?

IN HOME EDUCATION & UPGRADES

What was the result?

Gabrielle and her daughter reduced their energy use and costs but their thermal comfort also decreased.

Gabrielle's household was dynamic over the project as her mother came to visit for long periods, the sensors were moved around the house and she recovered from a broken leg.

Gabrielle felt that little changed as a result of her participation in the project but the tips were helpful reminders of what she could do around the home.

✔	Energy use reduced by 1.60kWh/day (10.2%) from 15.71kWh/day to 14.1kWh/day.
✔	Energy costs reduced by ~$195.
✘	Time spent in the comfort zone decreased from 12.6% to 7.5%.
✘	Heating efficiency decreased from 0.40 to 0.34.
~	Maintained confidence that she could find information on thermal comfort.
~	Maintained lack of confidence that she could find information on energy efficiency.
✘	Self-reported moisture levels increased (medium – high) and mould appeared. Home Energy Helpers reported mould issue in bedroom. Occasional high humidity measured (higher in bedroom).
~	Draughts reduced but remained problematic.

> I'm always thinking, turning lights off when they're not being used, and yeah, just being careful I guess.
>
> *(After Interview 31/08/2015)*

Existing physical conditions of the house

Gabrielle and her daughter live in one story suburban stand alone house that is approximately 60 years old. The house receives sunlight, with best access in the morning. The living area is on the north east and mainly receives sunlight from the northeast through a window. The house is timber framed with weatherboard cladding, has a corrugated iron roof and a suspended timber floor (covered with carpet, vinyl and tiles).

The house has thin loose fill insulation in the ceiling. Heating is provided by a fan heater, electric blankets (2) and a heat pump.

In winter without heating the house is reported as never comfortable with draughts. With little insulation and only some solar access this house has poor thermal performance.

Insulation	Loose fill thin ceiling only.	POOR
Windows	Single glazed, old timber frames, pelmets.	NEAR STANDARD
Window coverings	Curtains and venetians. Backing on curtains in living.	NEAR STANDARD
Under floor space	Timber suspended 1.0m high, enclosed with block, no insulation.	POOR
Mould and moisture	Self-reported medium moisture levels in living area reported and some mould appeared in the bedrooms in the after period. Intermittent points where temp comes near or would reach dew point. Winter humidity in bedroom got to 90% and in living to 80% which is very likely to cause condensation on cold surfaces.	POOR
Other conditions of note	Noticeable draughts. Generally uncomfortable indoors.	POOR
	Generally maintained to a reasonable standard.	

Changes to the home

Other changes to the home:

- Gabrielle bought a plug in heater to take chill off bedrooms and so her mother was warm when visiting.
- Gabrielle called a plumber to turn the hot water down.
- Gabrielle bought 2 electric blankets July 2014.

GET BILL SMART UPGRADES

- ✔ Draught proofing of doors
- ✔ Small fridge thermometer
- ✔ Draught proofing of windows
- ✔ Stay Warm education booklet
- ✔ Lights changed
- ✔ Eco-switch
- ✔ Shower timer
- ✔ Door snakes

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.06	0.13	0.07	110.3%
T 41 Heating (hard wired heating)	5.95	4.35	-1.60	-26.8%
Total Heating	6.01	4.48	-1.53	-25.4%
Other Light and Power (T31)	4.75	5.16	0.41	8.7%
Hot Water	4.95	4.46	-0.49	-9.8%
Total Household Electricity	15.71	14.10	-1.60	-10.2%
House Heating Efficiency (degree-hours/kWh/day)	0.40	0.34	-0.07	-16.7%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	17.2	11.6	12.0	2.4	12.6%
After	13.6	11.2	10.9	1.5	7.5%
Difference between before and after	-3.6	-0.4	-1.1	-0.9	-5.1%

Referring to the tables and graphs presented, changes were observed in energy use and comfort. Overall electricity reduced from 15.71 to 14.10kWh/day which was a 1.60kWh/day saving (10.2%). Both before and after total energy use is much lower than average or median use in the Greater Hobart upgrades group. The percentage change in electricity use is higher than the average but less than median for this same group.

House heating efficiency decreased by 16.7% from 0.40 to 0.34. This decrease was caused by changes to the way Gabrielle was using her heaters and where they were positioned. The change in heater use is apparent on the example before and after graphs when compared.

Time spent in the comfort zone also decreased, from 12.6% to 7.5% (-5.1%) with no time spent above 24°C meaning Gabrielle and her daughter spent little time above 18°C during winter. The average temperature of the living room in the after period was 13.6°C, a drop of 3.6°C when compared to the before period. The bedroom temperature remained at ~11°C.

The before/after data shows there was a change in heating practices which was likely inspired by the cold temperatures Gabrielle and her daughter are living in. Living room heat pump use decreased slightly from 5.95kW/day to 4.35kWh/day (a decrease of 26.8%). In addition, Gabrielle bought 2 electric blankets in July 2014 and then also got a plug in heater to use in the hallway (to warm bedrooms) and to keep her mother comfortable when visiting. The before graph shows that the bedroom tracks with, or even below, outside temperatures and that the only room kept warm is the living area (using

the heat pump). The temperature in the bedroom tracking with outside temperatures indicates very poor thermal resistance in the house. In the after graph while part of each day in the living and the bedroom still tracks just above outside, the bedroom temperature is now being heated for part of the day as is the living room. In the after graph heating in the living room is not being sustained for as long as it was in the 2014 winter and both the bedroom and living are going through cycles of peaks and troughs.

The before period heating was likely affected by the fact that Gabrielle had a broken leg at that time and was spending a lot of time in the at home in the living room. Gabrielle's concern over her mother being ill when at her house motivated changes in the after period.

Sensors were installed on the electric blankets and registered as the (0.7 kWh/day, 110%) increase in plug in heating. The Get Bill Smart team was not aware of the new plug in heater, and it is therefore only registered as part of the Other Light and Power, which increased 0.41 kWh/day.

The light on one of the temperature and humidity sensors bothered Gabrielle's daughter and so Gabrielle moved the sensor to a different room. This means the data collected on temperature in the bedrooms will not necessarily correlate to use in the daughter's bedroom, but does give an idea of how cold these rooms can get.

On her mother's advice Gabrielle employed a plumber to lower the thermostat on her hot water heater. Hot water decreased by 9.8%, from 4.95kWh/day to 4.46kWh/day (a reduction of 0.49kWh/day).

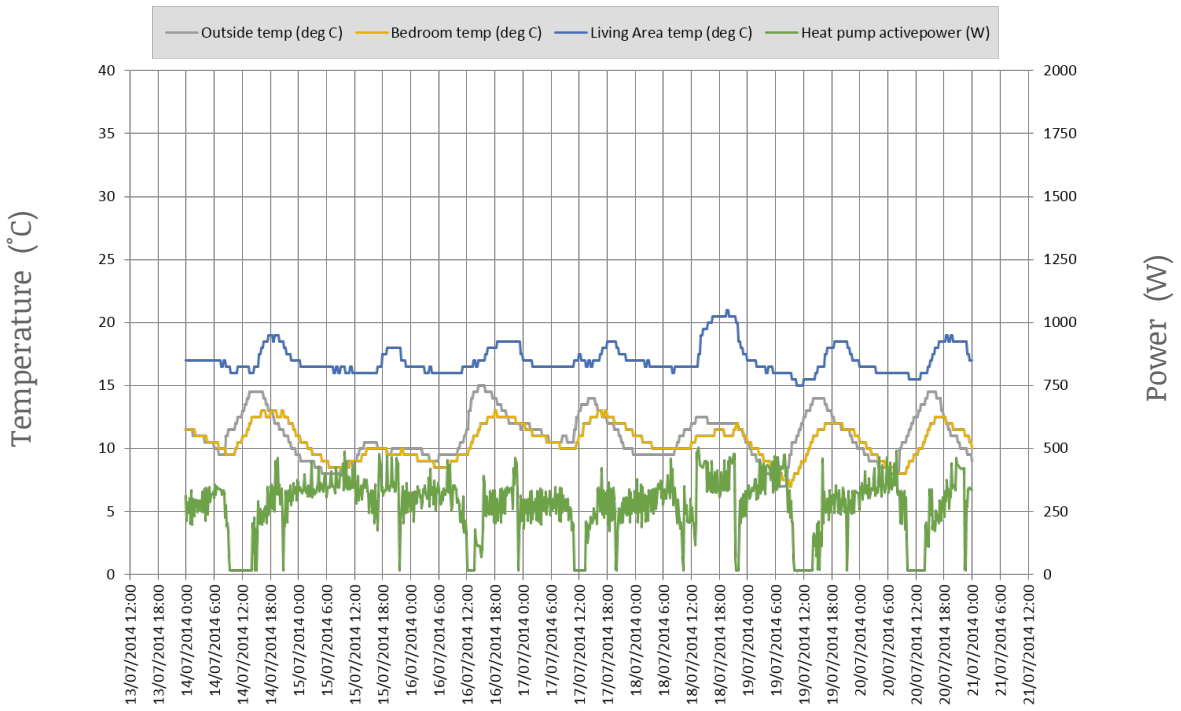
Condensation appeared to be a developing problem in the house. Gabrielle originally reported medium moisture levels in the living area and later reported increased moisture levels and some mould in the bedroom. HEHs visiting during the upgrade also reported mould in the bedroom. Measurements taken in the living and bedroom show there were intermittent points where temp came near, or reached dew point. While these were only intermittent points, winter humidity in bedroom got to 90% and in living to 80% in the after period. This high level of humidity was controlled for periods in the living room by the use of the heat pump. Humidity levels of around 80%–90% can cause surface condensation even when the measured air temperature does not reach dew point. Single glazing is most vulnerable, but walls and ceilings can also become wet. Indeed living room winter humidity was better constrained in the before (2014) winter because of the way the living room heater was being used at the time.

Changes to room use, movement of the unmonitored plug in heater and the moved bedroom sensor have made it harder to capture the heating and temperature patterns in this house. However, it is clear that Gabrielle changed her patterns of heating and lived in a cold thermal environment in a house that had little heat resistance.

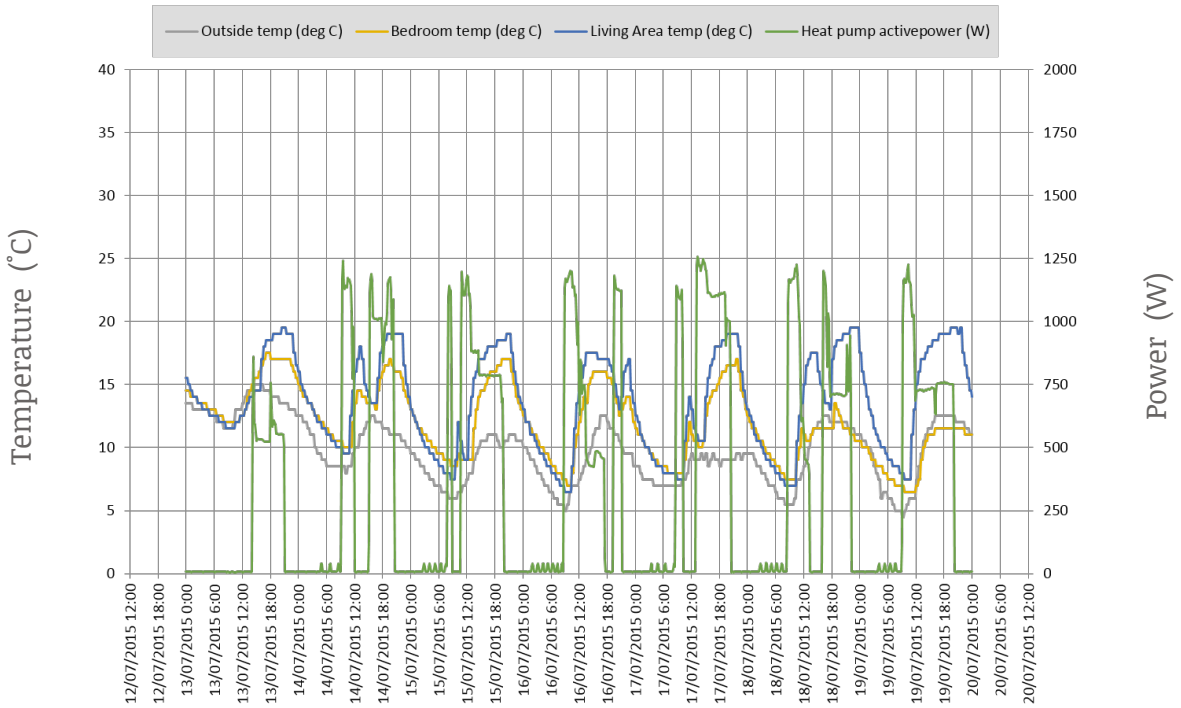
> We had my mum over in, I think July... What I was doing was having this heater on and closing off the lounge room door. But the rest of the house was absolutely freezing, and when mum came over, she actually got an upper respiratory tract infection. *(After Interview 31/08/2015)*

> [With the heater we are] comfortable in the lounge room, because we close the door off, but uncomfortable in the rest of the house.
> *(Before Interview 20/05/2014)*

Before period: example week in winter showing selected energy use and temperature readings



After period: example week in winter showing selected energy use and temperature readings



Personal and community change

As a single mother Gabrielle had a limited income and was very conscious of her energy use. When we first met she said,

> I must admit, I'm a bit, not paranoid, but concerned when I do put the heater on, like sometimes I've got to have it on all day and I'm just thinking, what's going to happen when the next bill comes through? I mean it's got an economy cycle and that to it but it's just when money's tight, you know, you do get concerned.
>
> *(Before Interview 20/05/2014)*

Billing data from the electricity retailer indicates that Gabrielle reduced her annual energy bills by approximately $195 per year.

The second time we spoke to Gabrielle she was still concerned about her bills but felt that she was on track with her energy usage saying,

> My bill, I think the last one was about $200 and something.... I think it's pretty good. Yeah because what did they say, you know how they have a one person household, two person, stuff like that. I think ours was like equivalent to a one person household or something *(After Interview 31/08/2015)*.

Gabrielle's bills decreased as expected by her decreased energy use.

Personal and community change

When we met Gabrielle she had recently broken her foot. She and her daughter were new to Tasmania and did not have established networks. Gabrielle's mother visited to help out with her broken foot, staying for long periods of time at intervals over the course of the GBS project.

Given her restricted mobility, Gabrielle was likely to have felt the cold more than usual and this may have informed how she heated her home in the before period. Gabrielle did not feel she had full control of the thermal comfort and energy efficiency of her home and thought the house was poor performing. She connected illnesses they had to their cold house. Certainly, the house was cold, with temperatures often sitting under 18°C. Being ill would have, in turn, affected how they managed the home. We saw Gabrielle trying to adjust winter heating practices in the after period to try and improve comfort. She also bought electric blankets and a plug in heater to heat the other end of the house.

Prior to the visit by the Home Energy Helpers Gabrielle was energy conscious not only because she needed to be financially, but for environmental reasons as well. She said,

> We all play a part don't we, in the big global impact.
>
> *(After Interview 31/08/2015)*

Personal and community change

While Gabrielle had some upgrades to her home as a part of the Get Bill Smart project, she did not feel like much had changed afterwards. She noted that the draughts had improved slightly but were still problematic. In fact she removed some of the draught proofing around the doors because it made the door catch as it opened and closed.

While the upgrades did not make a huge difference to the home for Gabrielle, she felt the HEHS had helped to reinforce her prior awareness and consciousness around energy efficiency and thermal comfort. She said,

> There was a few sort of handy hints, which sort of I guess helped a bit.
> *(After Interview 31/08/2015)*

Gabrielle pointed out that other needs could get in the way of efficient behaviours. She knew, for example, that closing the curtains helped to keep the heat in, but explained that it was also important to her that the room was light. She said,

> I mean I know I should have the curtains closed, because the heats going out with that, but I like to have light in. *(After Interview 31/08/2015)*

Gabrielle's sense that there were people in her community who could help her with energy efficiency and thermal comfort declined over the course of this project. This decline may have been due to her increased isolation for the period she was stuck inside with her broken foot and the persistent discomfort she felt in her house even after the Home Energy Helper visit.

When we first met, Gabrielle noted that many people in her street had lived there a long time and as such were a bit wary of newcomers. Her status as a renter she felt also affected how welcome she was in the community.

She explained,

> The trouble is too, when you rent sometimes they don't want to... [They think] oh they're going to shift out sometimes too. *(Before Interview 20/05/2014)*

Gabrielle noted in the after period that she had not made a huge effort recently to engage with the community but that this was something she planned to do. She said,

> I don't know, I guess I just sort of more or less keep to myself, I don't reach out to the community.
> *(After Interview 31/08/2015)*

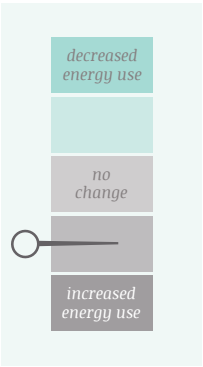
Gabrielle was keen to live in a warmer house but was limited by her rental status and her income. Prior to the GBS project she was already attempting to improve energy efficiency and keep her energy bills low. The design of her house was such that it was difficult to heat and felt very draughty.

While Gabrielle herself did not get a huge amount out of her participation in Get Bill Smart, she recognised it might be of great value to others saying,

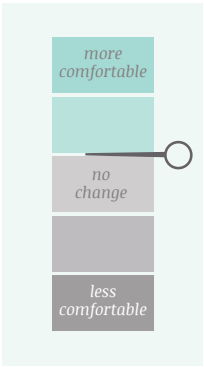
> I just think it's a great program. I think it could definitely help a lot of people in lower income households. And it's just a way of making people aware of how to save energy and be more energy efficient. *(After Interview 31/08/2015)*

CASE STUDY 29
Patricia

ENERGY USE



COMFORT



Occupants	Own or rent	Bedrooms	House type	Heating
1	RENTER	4	FREESTANDING ONE STOREY	PLUG-IN ELECTRIC + WOOD FIRE

What did we do?

IN HOME EDUCATION & UPGRADES

What was the result?

Patricia used minimal energy to heat her home and her home performed very poorly. As a result she was very uncomfortable for most of the time.

While temperature data collected shows minimal changes to comfort, Patricia was very clear that she felt more comfortable after the home upgrade visit.

- ✗ Energy use increased by 1.75kWh/day (18.5%), from 9.48kWh/day to 11.23kWh/day.
- ✓ Energy costs reduced from by ~$35 per year (likely due to reduced tariff).
- ✗ Time spent in comfort zone remained at 1.1% (self-reported increase in comfort).
- ~ Heating efficiency increased from 13.33 to 18.29, but this only looks good because Patricia went from NEVER heating to only occasionally heating. These figures are NOT indicative of a good house performance.
- ~ Confidence that she could find information on energy efficiency and thermal comfort remained low.
- ✓ Self reported moisture levels decreased.

> It makes it harder to breathe [when it is cold]. That some nights, you know, I'm fully dressed and I have two dressing gowns on too, [but this has] improved.
>
> *(After Interview, 07/09/2015)*

Existing physical conditions of the house

The position of the living area, single glazing, aluminium frames and lack of insulation, along with Patricia's practice of leaving a door slightly open for her animals, means this house has a very poor thermal performance. However the thermal performance was improved slightly by an upgrade.

Type	Stand alone, suburban.
Age	40-49 years.
Construction	Concrete blocks, tile roof, suspended timber floor (carpet).
Insulation	Unknown (suspect none).
Windows	Single glazed, aluminium frame.
Window coverings	Vertical blinds (added curtains to living and bedroom during project).
Access to sun	Some morning and afternoon sun however living room only receives late afternoon sun.
Heating	Has wood heater which smokes too badly to use, rare use of a plug-in heater, electric blanket.

Changes to the home

Other changes to the home:

- New curtains around the house.
- Curtains in doorways to retain heat.
- A new plug-in electric heater in living area.

GET BILL $MART UPGRADES

- ✔ Draught-proofing of doors
- ✔ Hot water pipes insulated
- ✔ Hot water valve cosy
- ✔ Lights changed
- ✔ Shower timer
- ✔ Door snakes
- ✔ Small fridge thermometer
- ✔ Stay Warm education booklet
- ✔ Ecoswitches (2)
- ✔ Curtains

Overview

Patricia is in her 60s and lives with her dogs, cats, birds and chickens. The animals are very important to Patricia and she manages her home with their comfort in mind. She leaves the doors open slightly so the cats can come and go and sacrifices her own well-being in order to afford the cost of pet ownership.

Prior to the Get Bill Smart upgrades Patricia was extremely cold. Her wood heater is dysfunctional as it leaks large amounts of smoke into the house and thus it goes unused. Patricia now occasionally uses a new plug in heater in the living room because she has learnt to zone off areas to contain the heat. As a result she occasionally is slightly warmer. The Home Energy Helpers managed to significantly improve Patricia's draught problems which she has noted has helped her comfort levels.

The energy use table below highlights how little Patricia heated her home. The average indoor and outdoor temperatures are only a couple of degrees above the average outdoor temperatures. Patricia is spending 99% of her time in temperatures below 18°C. Indeed, the average indoor temperature for the living room in mid-winter remained at 11.7°C.

Patricia did not feel that there were people in her community whom she could talk to about thermal comfort and energy efficiency. Similarly she did not feel she lived in a strongly connected community. Both these measures did improve slightly over the course of the project.

Patricia sits well below both the median and the average in terms of energy use for both the group receiving Home Upgrades and Community Capacity Building, and all participants in the project.

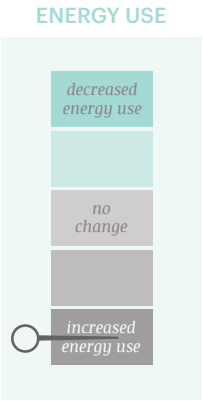
Average daily energy use and heating efficiency during winter conditions

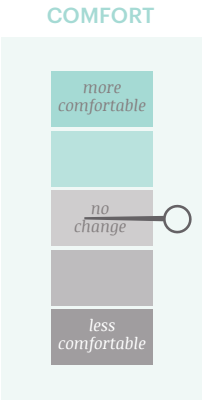
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.21	0.14	–0.07	–32.4%
T 41 Heating (hard wired heating)	0.00	0.00	0.00	0.0%
Total Heating	0.21	0.14	–0.07	–32.4%
Other Light and Power (T31)	5.91	6.79	0.88	14.9%
Hot Water	3.35	4.29	0.94	28.0%
Total Household Electricity	9.48	11.23	1.75	18.5%
House Heating Efficiency (degree-hours/kWh/day)	13.33	18.29	4.96	37.2%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	11.7	11.0	8.6	2.8	1.1%
After	11.7	10.7	8.6	2.6	1.1%
Difference between before and after	0.0	–0.4	0.0	–0.2	0.0%

CASE STUDY 30
Yvette and Gerard





Occupants	Own or rent	Bedrooms	House type	Heating
	OWNER		FREESTANDING ONE STOREY	HARDWIRED RESISTIVE + HEAT PUMP

What did we do?

IN HOME EDUCATION & UPGRADES

What was the result?

Yvette and Gerard managed their home for energy efficiency and thermal comfort as well as they could, given the physical limitations of the house.

Gerard's health issues influenced the way they heated their home and their capacity to make use of sunlight.

Their energy use increased primarily due to an increase in hot water usage – likely due to an increasingly faulty hot water system.

- ✗ Energy use increased by 9.8kWh (21.1%), from 34.81kWh/day to 44.61kWh/day.
- ✗ Energy costs increased by ~$232 per year ($2157 – $2389).
- ~ Time spent in the comfort zone remained constant at 14.7-14.1%.
- ~ Heating efficiency remained constant at 0.85-0.86.
- ✓ Displayed improved confidence that they could find information on thermal comfort if needed.
- ✓ Draughts reduced (some to none).

And we put these shutters down too. They keep a lot of the cold out. And the warmth in and, yeah. And they're good in summer too. When it's roasting hot we put them down sort of two-thirds of the way and it keeps a lot of the heat out as well.

(After Interview, 2 Sep 2015)

Existing physical conditions of the house

The position of the living area, single glazing and the need to keep curtains and blinds closed means this house performs at a poor level. Temperatures in the home are able to reach dew point and this is likely to the house being closed up to keep internal spaces dim coupled with the open plan living/kitchen space. Use of the heat pump however seems to have kept humidity to only 75% which is lower than many houses in this study.

Type	Stand alone, suburban.
Age	30-39 years.
Construction	Brick veneer, corrugated iron roof, suspended timber floor (vinyl, carpet).
Insulation	Ceiling (cellulose, old), some floor insulation (batts, kitchen/living).
Windows	Single glazed, aluminium frame.
Window coverings	Lace curtains, curtains (living room – medium weight), venetian blinds, external shutters.
Access to sun	Long access north to south, sheds on north and west mean only morning sun.
Heating	Heat pump (living), plug-in heater (study), wired-in heater (shed), electric blanket (2).

Changes to the home

Other changes to the home:

- Installed three internal draught stoppers on doors (prior to the upgrade).
- Replaced some energy efficient lights with original globes.
- Yvette and Gerard bought a new fridge in Jan 2015 when their fridge of twenty years broke.

GET BILL $MART UPGRADES

- ✔ Draught-proofing of doors
- ✔ Stay Warm education booklet
- ✔ Hot water valve cosy
- ✔ Lights changed
- ✔ Shower timer
- ✔ Door snakes
- ✔ Small fridge thermometer

Overview

Yvette and Gerard had lived in their home since it was built in 1980. Retired now, they spent a lot of time at home in the living room, Yvette's craft room or Gerard's shed out the back.

Gerard had a chronic illness that affected how they managed their home. Key symptoms included sensitivities to both light and cold. As a result Yvette explained that they rarely opened the curtains in the living room in order to keep a comfortable home environment for Gerard. Similarly they felt it was important to maintain a warm living space to keep Gerard comfortable.

Yvette and Gerard spent 14% of their time in the comfort zone (temperatures between 18°C and 24°C). The average peak winter temperature of the living room was 19.2°C. Yvette explained that they used the heater when they needed to but also made an effort to use blankets and warm clothing before resorting to heating.

The House Heating Efficiency is quite good at ~0.85. The multiple layers of window coverings – curtains, blinds and external shutters – would have improved the thermal resistance of the living area. The insulated nature of the shutters may also have helped to reduce window condensation which was noted as only being a minor problem.

Hot water use increased significantly (by 60%). When we first spoke to Yvette she explained that their hot water system was just about to blow up. Detailed energy use data shows the hot water turning on and off again and unusual high frequencies indicating that it is likely faulty.

Gerard was a handyman and during times of better health had insulated underneath the open plan living area with batts. While it would have been a financial squeeze, he wanted to insulate the ceiling of the house but was physically no longer able to do so.

Yvette and Gerard appreciated the home upgrades but did change some of their light bulbs as they found the energy efficient ones too dim.

Yvette and Gerard were involved in the local community but did not think that there were people they could ask about energy efficiency or thermal comfort. They said that they would talk to their daughter, get an electrician or look on the internet.

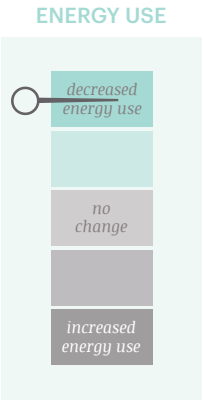
Average daily energy use and heating efficiency during winter conditions

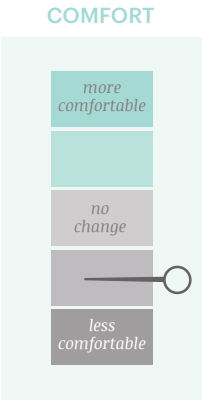
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.93	0.57	–0.36	–39.0%
T 41 Heating (hard wired heating)	5.24	6.88	1.64	31.2%
Total Heating	6.17	7.44	1.27	20.7%
Other Light and Power (T31)	15.07	15.40	0.32	2.1%
Hot Water	13.56	21.76	8.20	60.5%
Total Household Electricity	34.81	44.61	9.80	28.1%
House Heating Efficiency (degree-hours/kWh/day)	0.86	0.85	0.00	–0.1%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	18.3	13.0	10.3	5.3	14.7%
After	19.2	13.1	9.8	6.4	14.1%
Difference between before and after	0.9	0.1	–0.6	1.1	–0.7%

CASE STUDY 31
Hazel





Occupants	Own or rent	Bedrooms	House type	Heating
	OWNER		FREESTANDING ONE STOREY	HARDWIRED RESISTIVE + HEAT PUMP

What did we do?

IN HOME EDUCATION & UPGRADES

What was the result?

Hazel decreased her energy use partially as a result of the in home education and upgrades and partially due to the departure of her daughter and grandson who had been living with her.

Hazel was pleased to have regained control of energy use in her home and found the educational components of the program useful for managing the heat pump.

- ✔ Energy use decreased by 10.94kWh/day (36.5%) from 29.97kWh/day to 19.40kWh/day.
- ✔ Energy costs reduced by ~$317 per year ($1439-$1122)
- ✘ Time spent in the comfort zone decreased from 19.4% to 13.3%.
- ✘ Heating efficiency decreased from 0.71 to 0.64 (10%).
- ✔ Displayed improved confidence that she could find information on thermal comfort and energy efficiency if needed.
- ✔ Draughts reduced.

> Oh yes, yes, I am more up with it now. You know, I just was power's power, but now I can see how you can save. See because I've also got a new shower thing, so that's saving too.
>
> *(After Interview 31/08/2015)*

Existing physical conditions of the house

The position of the living area, single glazing and the high uninsulated suspended floor over the garage creates an uncomfortable indoor winter environment.

While the physical house is in better condition than many in the area, it still performs at a poor level.

Type	Stand alone, suburban.
Age	40-49 years.
Construction	Brick veneer, tile roof, suspended timber floor (carpet), under house garage.
Insulation	Ceiling (batts).
Windows	Single glazed, aluminium frame.
Window coverings	Vertical blind, pelmets.
Access to sun	All day sun, living room on the east corner and kitchen on north corner, skylight in the hallway.
Heating	Heat pump, wired panel heater, electric blanket.

Changes to the home

Other changes to the home:

- Hazel has begun to turn her heat pump off overnight (unless it is below 10°C).
- Hazel's daughter and adult grandson moved out.

GET BILL $MART UPGRADES

- ✔ Insulation
- ✔ Shower timer
- ✔ Draught proofing of doors
- ✔ Door snakes
- ✔ Hot water pipes insulated
- ✔ Small fridge thermometer
- ✔ Hot water valve cosy
- ✔ Water saving shower head
- ✔ Lights changed

Overview

When we first met Hazel she shared her house with her daughter and adult grandson. Her family had moved in with her following relationship breakdowns. Hazel found living with her family difficult as they were less aware of the cost of energy use as they were not contributing to bills and as a result were more likely to leave doors open and appliances on.

With the departure of her family members Hazel's bills decreased along with her energy use. Noticeably her hot water use reduced by 64% from 10.36kWh/day to 3.64kWh/day. Other Light and Power use also decreased substantially by almost 40%. There may have been an unmonitored electric plug in heater on this circuit.

Worth noting is that Hazel's heater use increased. This may be because she felt more comfortable heating her home knowing her bill would be generally less. The increase was only slight so this may have also been due to the colder winter.

Hazel was fairly energy conscious prior to participation in the project. She was nervous about the cost of her electricity bills saying that when these were too high she had to reduce how much she spent on groceries. Hazel used a plug in turbo oven for her cooking which helped keep costs down.

Hazel did not spend very long in the comfort zone. Indeed despite an increase in heater use, her time in the comfort zone decreased from 19.4% to 13.3%. This also suggests someone was using an unmonitored plug in heater in the house in the before period.

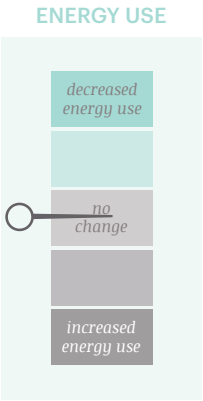
Average daily energy use and heating efficiency during winter conditions

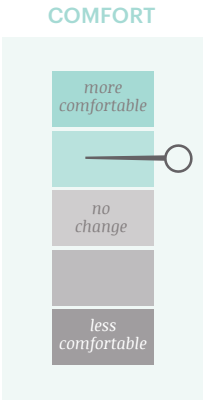
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.07	0.09	0.01	18.8%
T 41 Heating (hard wired heating)	7.85	8.21	0.36	4.6%
Total Heating	7.93	8.30	0.37	4.7%
Other Light and Power (T31)	11.68	7.10	-4.58	-39.2%
Hot Water	10.36	3.64	-6.72	-64.9%
Total Household Electricity	29.97	19.04	-10.94	-36.5%
House Heating Efficiency (degree-hours/kWh/day)	0.71	0.64	-0.07	-10.0%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	17.1	12.7	9.2	5.7	19.4%
After	16.0	11.7	8.5	5.3	13.3%
Difference between before and after	-1.1	-1.0	-0.7	-0.3	-6.1%

CASE STUDY 32
Hamilton and Isabel





Occupants	Own or rent	Bedrooms	House type	Heating
	OWNER		FREESTANDING ONE STOREY	HEAT PUMP

What did we do?

IN HOME EDUCATION & UPGRADES

What was the result?

Hamilton and Isabel's home was of a better quality than many others in this project. They managed their household budget tightly and kept an immaculate house. They learned a lot from the upgrades and education, and reported a significant improvement in their comfort levels due to draught-stopping. Hamilton was very interested in the technical side of the upgrade and had plans to further improve their thermal comfort and energy efficiency once they had the money.

- ~ Energy use decreased by 0.19kWh (0.9%), from 21.71kWh/day to 21.52kWh/day.
- ✔ Energy costs reduced by ~$76 per year (from $1306 to $1230).
- ✔ Time spent in comfort zone increased from 31.2% to 34.2%.
- ✘ Heating efficiency decreased from 1.68 to 1.45 (14.1%).
- ✔ Displayed improved confidence that they could find information on thermal comfort if needed.
- ✔ Draughts reduced.

Hamilton thinks he and Isabel are pretty careful with their energy consumption so he wasn't sure it would be easy to reduce energy use further 'how it is, is how it is'. They are already managing it carefully, so couldn't think what they could do to reduce it. *(After Interview 2/9/15)*

Existing physical conditions of the house

Overall, the house performs near or to standard, helped by insulation in ceiling and walls and solar gain in the living room. Single glazing aluminium windows and single glazing were recorded as giving some discomfort.

Type	Stand alone, suburban.
Age	5 – 9 years
Construction	Brick veneer, corrugated metal roof, concrete floor (carpet and tiles)
Insulation	Ceiling and walls (batts)
Windows	Single glazed, aluminium frame.
Window coverings	Curtains (medium)
Access to sun	Living room faces north but close eastern neighbour, so mainly midday and afternoon sun.
Heating	Heat pump (living), hard-wired panels (hall, kitchen), electric blanket.

Changes to the home

Other changes to the home:

- Replaced down-lights with LEDs
.

GET BILL $MART UPGRADES

✔ Draught proofing of doors	✔ Door snakes
✔ Hot water system insulated	✔ Small fridge thermometer
✔ Hot water pipes insulated	✔ Stay Warm education booklet
✔ Hot water valve cosy	✔ Ecoswitches (3)
✔ Lights changed	
✔ Shower timer	

Overview

Hamilton and Isabel's home was of a better quality than many in the GBS project, and performed near or standard. However, Hamilton and Isabel learned a lot from the project. They were very grateful for their upgrade and receptive to the education — it triggered a lot of ideas for them about how they could improve the thermal comfort and energy efficiency of their home. The installation of draught-proofing, especially on the internal door to the garage, had made a massive difference and was much more effective than their previous use of door sausages. They also thought the Ecoswitches were great.

They had installed LEDs in place of down-lights themselves, because LED lights used less electricity and emitted less heat.

Hamilton in particular was interested in the technical side of the upgrades and had a number of ideas about what he could do with his new knowledge.

He was thinking of installing pelmets and other draught-proofing to reduce the cold in the living room, and floor insulation to block the cold that he thought was coming up through the floor. However, lack of money was the biggest barrier to making significant changes.

Hamilton and Isabel said their hot water supply ran out less these days, and the data confirms there was a 14.5% reduction in hot water heating, likely partly because of insulation upgrades made to the hot water system. Their use of light and power also decreased somewhat, likely due to the switch to LED bulbs.

Heating use increased (and efficiency decreased), but this may be due to the longer, colder winter during the study period; Hamilton said that this year, he and Isabel had used the heater more than usual over winter. There was still some moisture on the windows at times.

Average daily energy use and heating efficiency during winter conditions

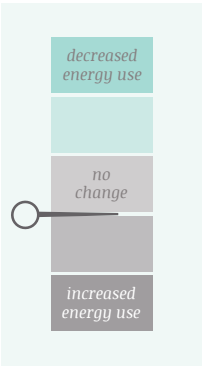
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.05	0.05	–0.01	–12.5%
T 41 Heating (hard wired heating)	5.01	6.50	1.48	29.5%
Total Heating	5.07	6.54	1.47	29.1%
Other Light and Power (T31)	9.47	8.85	–0.62	–6.6%
Hot Water	7.17	6.13	–1.04	–14.5%
Total Household Electricity	21.71	21.52	–0.19	–0.9%
House Heating Efficiency (degree-hours/kWh/day)	1.68	1.45	–0.24	–14.1%

Average daily temperatures and time in comfort zone during winter conditions

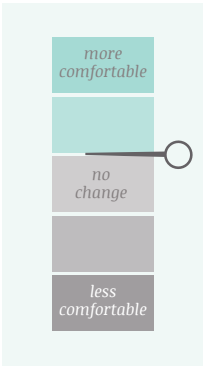
	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	18.4	14.9	8.1	8.5	31.2%
After	19.2	14.8	7.5	9.5	34.2%
Difference between before and after	0.8	–0.1	–0.6	0.9	3.0%

CASE STUDY 33
Ingrid

ENERGY USE



COMFORT



Occupants	Own or rent	Bedrooms	House type	Heating
	OWNER		FREESTANDING ONE STOREY	PLUG-IN ELECTRIC

What did we do?

IN HOME EDUCATION & UPGRADES

What was the result?

Ingrid did not feel that much had changed around her home. She continued to live in a cold house and use minimal energy. Ingrid maintained meticulous records about her energy use, there was very little she could have done to reduce use further. Ingrid slightly increased her energy use as she became more sensitive to the cold.

- ✗ Energy use increased by 0.96kWh (17.1%).
- ✗ Energy costs increased by ~$192 per year (self-reported bill increase).
- ✓ Time spent in the comfort zone increased from 0.8%–0.9% – this time is still incredibly low.
- ✓ Heating efficiency increased from 1.67 to 1.78 (6.6%).
- ✓ Displayed improved confidence that she could find information on energy efficiency.
- ✓ Self-reported moisture levels decreased (medium – none).
- ✗ Self-reported draughts remained present.

> Because you see, when it's cold I go to bed. I got the TV in there and I switch my blanket on and that's it. That's all I can do, you see. That's how I save electricity and the [electric] blanket doesn't really use much.
>
> *(After Interview 01/09/2015)*

Existing physical conditions of the house

Ingrid lived in a standalone suburban house on a standard sized block. Approximately 55 years old, the house is constructed of rendered brick veneer, with a corrugated metal roof and a suspended timber floor (with carpet and vinyl). With a square house plan and siting on a slope it is well positioned for all day solar access. The living room (most used) sits on the east corner of the plan and receives morning sun. Another living area sat on the north corner of the house but was not used very often and the curtains were generally closed in that area.

Heating is provided by living room column/fan heater, an electric blanket, a small fan heater. There is a fireplace that is never used.

Overall this well maintained house has poor thermal performance because of a lack of insulation, single glazing, thin curtains, window draughts and the lack of solar gain to the most commonly used sitting room.

Insulation	Ceiling only (batts).	POOR
Windows	Single glazed, aluminium frames, pelmets.	POOR
Window coverings	Thin curtains and lace.	VERY POOR
Under floor space	Suspended floor 0.4-1.5m off ground, underfloor enclosed with brick, no insulation.	POOR
Mould and moisture	Temp intermittently reaches dew point in living and bedrooms. Humidity peak in winter is 85%.	POOR
Other conditions of note	Well maintained. Draughts.	

Changes to the home

Other changes to the home:

- Ingrid replaced her curtains as the old ones fell apart when washed.

GET BILL SMART UPGRADES

- ✔ Temperature turned down on hot water system
- ✔ Door snakes
- ✔ Draught proofing of doors
- ✔ Small fridge thermometer
- ✔ Hot water system insulated
- ✔ Stay Warm education booklet
- ✔ Hot water pipes insulated
- ✔ Lights changed
- ✔ Shower timer

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.79	0.81	2.7%
T 41 Heating (hard wired heating)	0.00	0.00	#DIV/0!
Total Heating	0.79	0.81	2.7%
Other Light and Power (T31)	2.51	3.59	43.1%
Hot Water	2.30	2.16	-6.1%
Total Household Electricity	5.61	6.57	17.1%
House Heating Efficiency (degree-hours/kWh/day)	1.67	1.78	6.6%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Kitchen Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	11.1	10.9	9.7	9.7	1.3	0.8%
After	10.5	10.1	8.8	8.8	1.5	0.9%
Difference between before and after	-0.6	-0.8	-0.9	-0.9	0.1	0.1%

Referring to the tables and graphs presented, changes were observed in energy use and comfort. Total Household Electricity average per day increased by 0.96 kWh/day from 5.61 to 6.57 (17.1%). Both before and after consumption was very low.

Housing heating efficiency was high at 1.67 before and 1.78 after. This was because Ingrid used minimal heating, rather than her heaters being super-efficient. In uninsulated houses such as these the more heating used means the less efficient the heating efficiency will become.

Ingrid also noted that she kept at least some windows open, even during winter, to ensure fresh air. This is shown through the very low temperatures recorded in Ingrid's house. The indoor temperature of Ingrid's house tracked very closely with the outside temperature (approximately only 1.5.°C above outside). This means the house was uncomfortably cold most of the time. For most of the time (99.2-99.1% of time) the temperature levels in the house were below the comfort zone of 18-24 degrees. Ingrid reported feeling cold a lot of the time.

Total heating increased by 2.1% (from 0.79kWh/per day to 0.81kWh/per day). At the same time Ingrid's Other Light and Power use increased by 43.1% (from 2.51kWh/per day to 3.59kWh/per day). Ingrid noted at the After Interview that she had begun to use a new plug in heater that was not recorded by this project. Also contributing to the increase in power use on this circuit may have been the purchase of a new stove. Ingrid explained that her old stove had been replaced because it did not work. Ingrid may have begun to cook more and the new stove may have used more energy as well.

Energy and comfort

Hot water use decreased by 6.1%. Ingrid noted that the Home Energy Helpers had given her a hot water upgrade which likely contributed to this reduction.

Example temperature graphs showing before and after the GBS visit highlight some key points. Indoor and outdoor temperature consistently track near each other before and after. On occasion the outdoor temperature spikes, this may be due to a problem with the sensor but may also be something being laid over it for a short period (it was on a shelf). The after graph shows slightly increased temperatures inside and this is likely due to Ingrid's increased use of a non-monitored plug in heater. She did confide in our second interview that she had found the cold much harder to bear in the 2015 winter and had 'cracked' and used the heater a little more.

Ingrid's use of the electric blanket is visible in both the before and after graphs. As discussed in the interviews with her she turns the blanket on sometimes as early as 4pm when the temperatures in her house are getting colder. She also uses the electric blanket in the early mornings.

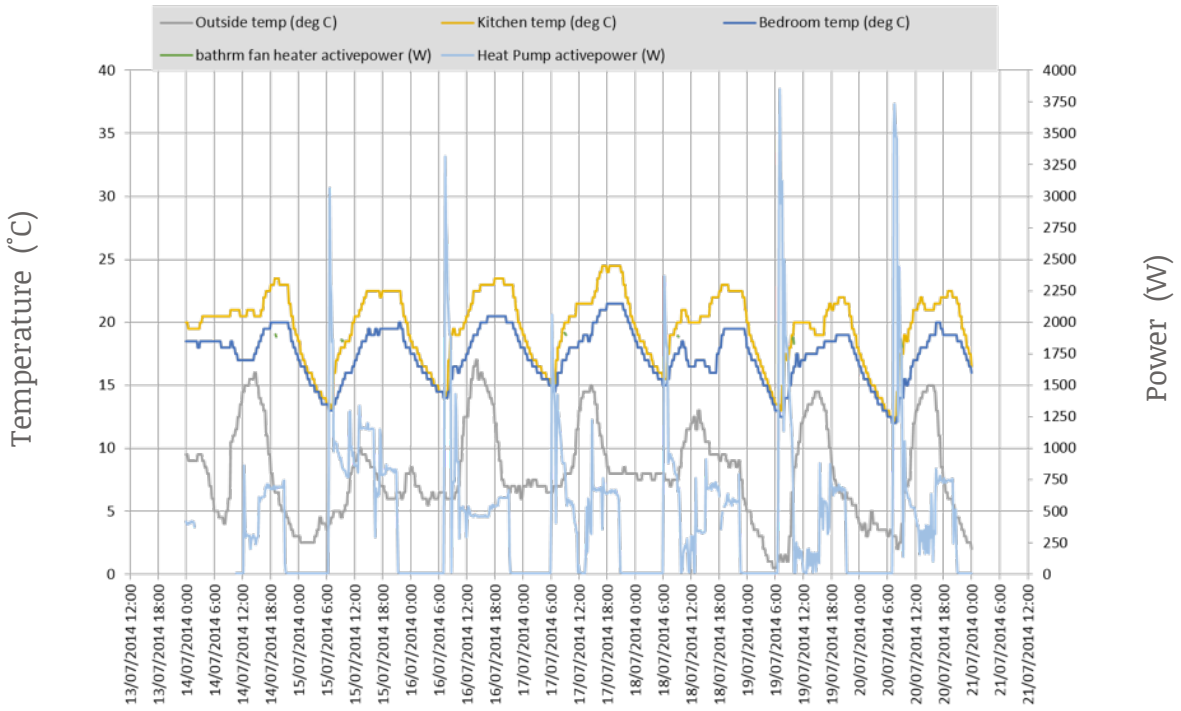
Both before and after graphs show occasional spikes in the use of the living room heater. It is likely that at these times she had guests as she explained in her interviews that this was the only time she usually used the heater. Ingrid reported that she never heated the bedroom and the graphs confirm this as the bedroom generally tracks outside temperatures.

Moisture problems in the house reportedly reduced, but measure show that temperature intermittently reaches dew point in living and bedrooms in before and after with humidity peaks in winter at 85%. This may mean Ingrid deals with some surface condensation issues. The living room humidity patterns are like many people's bedrooms humidity (due to the lack of heating). Ingrid's airing of the house is likely what keeps the moisture under control.

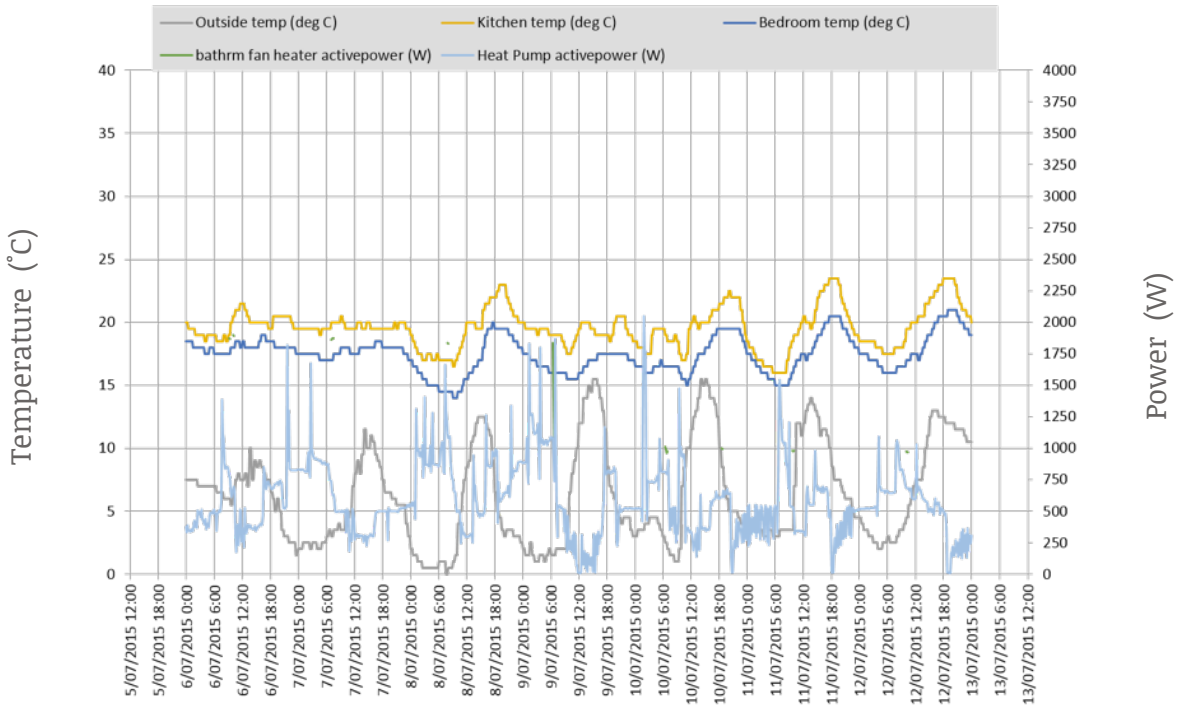
> I have to improve the comfort of home because I can't reduce it. You see this, you see where it is. I don't use-I mean with $1.50 a day, I think that's the lowest that anyone can. And I can show you that it's only a $1.50 a day.
>
> *(Before Interview 19/05/2014)*

> Yes I would like that my house to be more comfortable. But I am too scared to put the heaters on because all the costs you see. Because there's too many costs involved you see. The house insurance went up by $99 in one year so I rang them up and they said they have to because they had all these bushfires in Victoria and we all have to pay for it.
>
> *(After Interview 01/09/2015)*

Before period: example week in winter showing selected energy use and temperature readings



After period: example week in winter showing selected energy use and temperature readings



Energy affordability

Ingrid was extremely careful with her energy use and monitored her costs very closely. So concerned was she about the costs that she explained:

> Sometimes you like to don't go to bed so early you see and you just think, ah I'd better go, use too much electricity and then you go [to bed] you see.
>
> *(After Interview 01/09/2015)*

Ingrid's energy use increased and according to her records her bills also increased by ~$16 per month. This was different to the billing data from the supplier which indicated she had reduced costs by $67 per year. Ingrid's records were meticulous and these differences in cost may have been due to problems with some of the billing data.

Personal and community change

Ingrid lived alone in a house that she and her husband had built over 50 years ago. Her house was immaculately kept and very carefully managed. Ingrid knew that she spent approximately $1.50 per day on energy and had detailed records of all her household bills. She explained that she was conscious of the energy use because of the cost:

Yes, financial reasons. You see it's Pay As You Go. When I have money I put it in and then, I can show you the book. The first day I came here in this country, I use the book, and I have it every money, everything, and I put it in. This is the second book now. You see every year.... You see, what I have to spend, how much electricity I use. You see '12, '11, '13 and it goes on and on, and this is this year. *(Before Interview 19/05/2014)*

Ingrid's house was very cold. It was uninsulated brick veneer and was hard to heat up. She used such minimal energy that she was almost never within the comfort zone.

While Ingrid lived alone she had was a part of a functional community network. When the research team visited, her neighbours came out to make sure she was safe. Ingrid also explained her involvement with the community, she cut the hair of one man who lived nearby, made craft for local charities and looked out for her neighbours.

Ingrid was a very self-sufficient person who was unwilling to complain about the discomfort in her home. She explained,

> Yeah. I mean, you do what you can you see. So it's all right. I am not a person who complains. I do my own thing. *(After Interview 01/09/2015)*

Personal and community change

In keeping with this independent streak Ingrid also explained that she did not want to seek help from the community to make her home more comfortable she said,

> I be my own person, you see. I don't like to ask, I think what I can and what I do is right. *(After Interview 01/09/2015)*

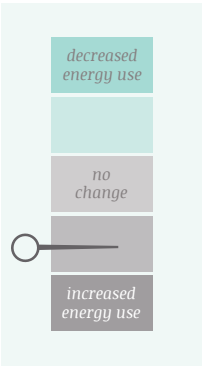
An example of this was her strategy of putting old Christmas cards in the cracks in the window frames to stop the draughts.

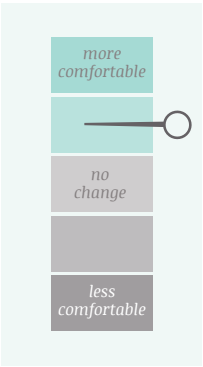
It is worth noting that Ingrid wanted to assist the greater Get Bill Smart project, but was quite annoyed by some of the interventions. For example installation of monitoring equipment in her meter box made the meter box door much harder to close. This was a problem for Ingrid as she regularly checked her energy use.

While Ingrid was very stoic about her frugal lifestyle, in our second visit to her home she opened up more about the stresses and difficulties of living in such a cold and uncomfortable house.

Overall the thermal performance of Ingrid's house was very poor. This was exacerbated by her need to keep the windows open for fresh air. It was Ingrid's impressive stoic nature that allowed her to manage when she couldn't afford to pay more for energy, for example she would simply go to bed with the electric blanket (and a good book) at 4pm when it began to get cold. Ingrid was the lowest energy user and had the coldest house of all participants in this study.

CASE STUDY 34
Cassie and partner





Occupants	Own or rent	Bedrooms	House type	Heating
	OWNER		FREESTANDING ONE STOREY	HEAT PUMP

What did we do?

IN HOME EDUCATION & UPGRADES

What was the result?

Cassie and partner's overall household energy use increased along with the time she spent in the comfort zone (of 18°C to 24 °C) and above the comfort zone. The increase in energy use Cassie reported as being from extra heating used because her partner had a serious illness and needed to be kept warm.

✗	Energy use increased by 1.45kWh/day (7.1%) from 20.43 – 21.88 kWh/per day.
✗	Energy costs increased by approximately $281 per year ($905–$1,186).
✓	Time spent in the comfort zone increased from 68.8% to 72.9%.
✗	Heating efficiency decreased from 0.91 to 0.84 (7.5%).
✓	Maintained a high level of confidence that she could find information on energy efficiency and comfort.
✓	Self-reported moisture levels remained the same (low) and mould was eradicated. Temperature did not reach dew point. Humidity max only 70%.

I chose a pretty good block. I mean I get sun in here don't I? Through that window, sun in that window.

(Before Interview 26/05/2014)

Existing physical conditions of the house

Cassie and her partner live in a small standalone house on a small suburban block that is part of a retirement lifestyle complex. It was built in 2011. The long axis of the house is southwest to northeast. The house has a carport on the northwest and a close neighbour also on the north west but still receives morning and midday sun. The living room is on the north corner of the house and is open plan with a dining area, which is on the east corner – these areas catch sun from the east and the north. The house is constructed of prefabricated vinyl weatherboard cladding, a suspended floor (with carpet and vinyl), a corrugated iron roof, and fibre cement skirt. The house is insulated to 2011 standards and so wall and floors and ceiling are insulated. Heating is provided by a heat pump in the living room, a fan heater in the bathroom and an electric blanket.

Overall, despite the single glazing and limited window covering, the insulation, airtightness, and solar gain in critical spaces this house performs to a NEAR STANDARD.

Insulation	Ceiling (batts), walls (batts and wrap), floor (polystyrene with reflective foil).	TO STANDARD
Windows	Single glazed, aluminium frames, no pelmets.	NEAR STANDARD
Window coverings	Vertical blinds all through.	POOR
Under floor space	Suspended floor, underfloor enclosed with fibre cement sheeting, insulated.	TO STANDARD
Mould and moisture	Temperature never near dew point problems. Humidity in winter peaks at 65 and 70%.	TO STANDARD
Other conditions of note	New house, well maintained.	
	Heat pump hot water system.	

Changes to the home

Other changes to the home:

- Cassie ran her heat pump at 27°C, rather than the usual 19°C as her partner was very sick.
- Cassie and her partner also used the electric blanket more regularly.
- The couple's occupancy patterns changed due to long hospital stays for Cassie's partner.

GET BILL SMART UPGRADES

- ✔ Draught proofing of doors
- ✔ Small fridge thermometer
- ✔ Hot water valve cosy
- ✔ Stay Warm education booklet
- ✔ Lights changed
- ✔ Hot water pipes insulated
- ✔ Shower timer
- ✔ Door snakes

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (%)
T 31 Heating (plug in heating)	1.06	1.13	7.2%
T 41 Heating (hard wired heating)	9.67	11.32	17.0%
Total Heating	10.73	12.45	16.1%
Other Light and Power (T31)	6.68	6.66	-0.3%
Hot Water	3.03	2.78	-8.4%
Total Household Electricity	20.43	21.88	7.1%
House Heating Efficiency (degree-hours/kWh/day)	0.91	0.84	-7.5%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	20.1	17.8	9.2	9.8	68.8%
After	20.5	18.2	8.8	10.5	72.9%
Difference between before and after	0.4	0.3	-0.3	0.7	4.1%

Referring to the tables and graphs presented, changes were observed in energy use and comfort. Total Household Electricity increased 1.45kWh/day from 20.43kWh/day to 21.88kWh/day (7.1%). Total heating increased by 16.1% from 10.73kWh/day to 12.45kWh/day. This increase was primarily due to increased use of the heat pump, but plug in electric heaters also went up. Cassie explained that her heating use had increased primarily because her partner had been very sick during the after period and required substantially more heating.

Time in the comfort zone was high in the before data (68.8%). This time increased to 72.9% over the project. There was also an increase in the time spent above a 24°C average in the living room — from 0.3% to 4.9% of the time. This means that a lot of the time in the after period Cassie and her partner were targeting heating to somewhere between 18°C and 24°C. Cassie reports of using higher heater temperatures and the increase in time heating above the comfort zone correspond. Cassie reported that in the after period they had been setting the heat pump to 27°C rather than their usual 19°C.

Cassie's hot water use decreased by 8.4% (from 3.03kWh/day to 2.78kWh/day). This may have been due to the time her partner spent in hospital. Hot water heating was provided by a heat pump-hot water system, which is a reverse cycle air conditioner heater and is typically 4 times more efficient than a standard electric storage hot water system. Energy used for hot water heating was very low overall before and after.

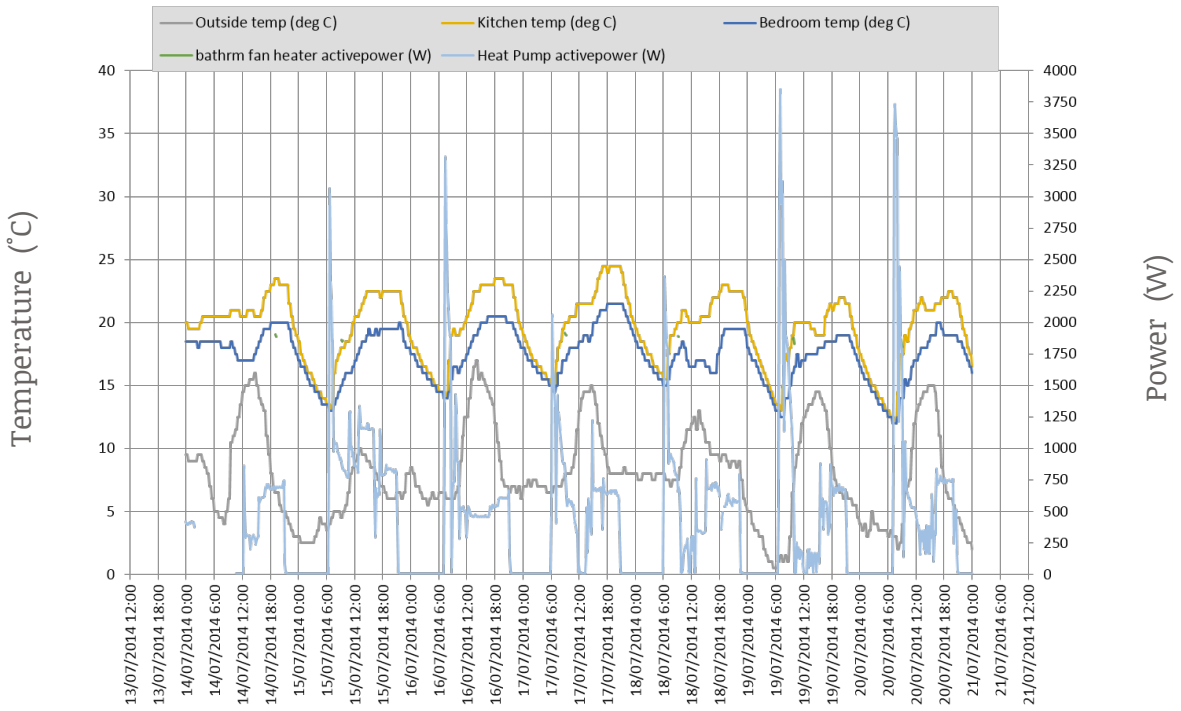
Energy and comfort

There was no issue with temperatures reaching dew point in this home and humidity peaked at 70% in winter. This great performance was in large part due to the well-insulated building shell and the use of the heat pump/air conditioning, which dries out the air.

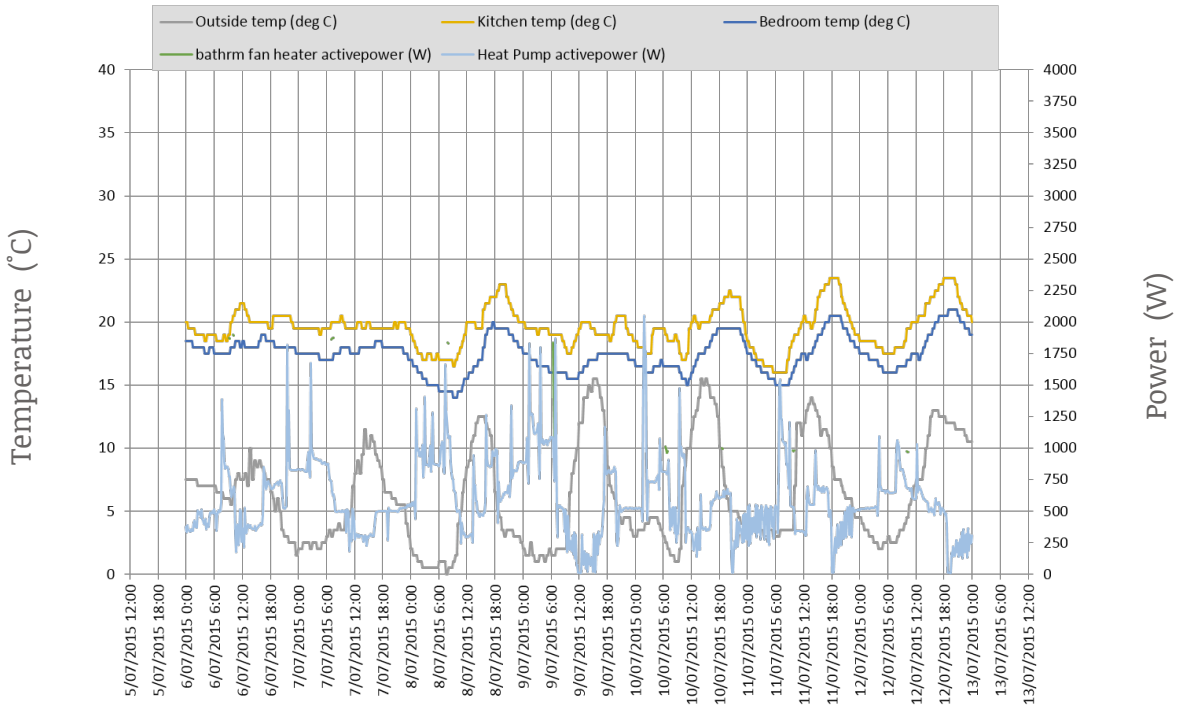
Cassie's house was reasonably efficient. While efficiency decreased (from 0.91 – 0.84), her house was relatively effective at maintaining heat. This is primarily due to its 5 star energy rating (the house was built in 2011), its living room orientation and the presence of good insulation. Overall energy use in this house sits just under the greater Hobart upgrades group average energy use. Cassie intentionally chose this house because of its position in the landscape and the solar gain to the house. She noted a good level of sun and how pleased she was to have bought in a good position.

> Just vertical blinds to get the sun in the winter and to keep it out in the summer for coolness. I very seldom have a jacket on like I have today, only I've put that on because of the door being opened but normally I wouldn't have that on. *(Before Interview 26/05/2014)*

Before period: example week in winter showing selected energy use and temperature readings



After period: example week in winter showing selected energy use and temperature readings



Energy affordability

Cassie was very careful with her energy use and was concerned about her bills. When her partner got sick she was conscious of changing her heating practices to keep the house warmer for him. She was quite concerned about what this would mean for her bills as the heater was run much higher and doors were left open. She was pleased to note that the increase in bills was less than anticipated and she was able to keep her partner warm without additional financial stress:

> Yeah, well see I haven't kept the bedroom doors closed or anything, because I think, well he doesn't want to go from a hot room to a cold type of thing. So I was very pleased with [the bill]. I think it was about $20 more than last year. It was only a smidgen on the graph. Just a smidgen. *(After Interview 02/09/2015)*

Personal and community change

Cassie and her partner are in their 70s and live in a retirement lifestyle community. All the accommodation in this community was built to five star energy efficiency standards (required by law since 2003). Cassie's house has gained efficiency from being built under these standards. This is not always the case. In some instances, like for Nonie (case study #03), even recently built houses can perform poorly.

Cassie's house was relatively small and therefore easy to heat and maintain she also observed certain practices to ensure she was using heating effectively. She explained that

> When we go out through the day in the winter with the heater going, I do close the bedroom two doors and the bathroom door. So that helps the warmth in here, so you're not running the heater on as high as you would with the doors open.
> *(After Interview 02/09/2015)*

Cassie's partner moved in with her just after GBS monitoring on the house began. Cassie's partner became ill after GBS Home Energy Helpers had visited and the couple found the house was more comfortable for him if they increased the heating. She was worried that this would dramatically increase her electricity bills but noted being pleasantly surprised that although it was more expensive it was not as bad as she had anticipated. We have found in other cases that increasing heating for sick occupants can increases energy use much more than in this case. The effect of increase of heating here was limited by the efficient building shell and the efficient appliances in use.

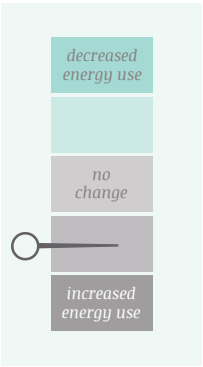
Cassie chose to live where she did so as to be relatively close to family. She made it clear that while she liked to live nearby friends and family she did not want friends living in the same street and tended to keep to herself.

While Cassie knew that the Get Bill Smart team could provide her with information on energy efficiency and thermal comfort she did not feel that there was anyone else in her community who could.

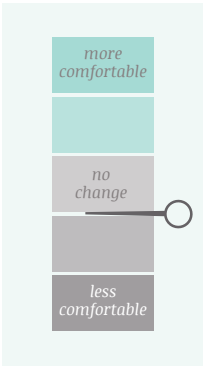
Cassie received an upgrade, but her house was reasonably new and was built to modern energy efficiency standards so Cassie reported there was little for Home Energy Helpers to do. Changes in energy use and heating were due to the illness of her partner.

CASE STUDY 35
Danielle and family

ENERGY USE



COMFORT



Occupants	Own or rent	Bedrooms	House type	Heating
	RENTER		FREESTANDING TWO STOREYS	PLUG-IN ELECTRIC + HEAT PUMP

What did we do?

IN HOME EDUCATION & UPGRADES

What was the result?

Danielle improved her knowledge of energy efficiency and thermal comfort. She made some changes to how she used and heated her house and found the advice from Home Energy Helpers useful. Her power use increased but not significantly given that she began working from home between the before and after periods.

✗	Energy use increased by 7.2kWh (16.8%), from 42.97kWh/day to 50.18kWh/day.
✗	Energy costs increased by ~$168 per year (some data based on estimates from the supplier).
✗	Time spent in comfort zone decreased by 0.7% (from 17.5% to 16.8%).
✓	Heating efficiency increased from 0.39 to 0.41 (4.0%) – median for group.
✗	Displayed decreased confidence that she could find information on energy efficiency and comfort.
✓	Self-reported reduction in moisture (low – none).
✓	Danielle displayed an increased sense of community and a greater awareness that there might be people in her community who could help with energy efficiency and thermal comfort.

Well just your lifestyle really, it's horrible to be too cold or too hot. And I'm just a Mrs Fix It person, I always just like to make sure that things are working and good, and it really is the cost of the bill that has motivated me to do the things like the curtains and light globes and that sort of thing. *(Before Interview 25/05/2014)*

Existing physical conditions of the house

Danielle and her children live in a standalone suburban house that is approximately 40 years old. Her son lives in a bed-sit underneath the main house. The house is timber framed, with weatherboard-clad walls, a sheet metal roof, and suspended timber floors (with carpet and vinyl). Positioned with an east to west long axis and high on a steep hill, the house receives sun through the morning and the middle of the day. The bedsit is tucked under, so receives less sun. The upstairs living area sits on the east of the house and receives morning through midday sun.

Bedrooms to the west receive some afternoon sun. The kitchen is open plan with the living area. Heating is provided by a heat pump in the living, a fan heater in the bed-sit, a water bed heater in the bedroom and a column oil heater in the study (office).

With some solar access to the living area this house tends to capture critical warmth, but the lack of insulation still limits thermal performance to a poor level.

Insulation	Ceiling only, poor condition.	POOR
Windows	Single glazed, aluminium frames.	POOR
Window coverings	Vertical blinds (living and bedrooms), roller blind (kitchen), heavy curtains study.	POOR
Under floor space	Suspended timber floor with unit under, unknown insulation status.	POOR
Mould and moisture	Temp did not reach dew point and humidity under 75% all year. In winter in living humidity under 65%.	NEAR STANDARD
Other conditions of note	Generally well maintained house.	

Changes to the home

Other changes to the home:

- Danielle now works from home and has begun to use a plug in oil heater (with thermostat) in her home office.
- Following advice from the Home Energy Helpers, Danielle bubble wrapped the glass door between her lounge and foyer area.
- Danielle reduced showering because she knows it saves energy.
- Danielle decreased the temperature the heat pump is set to (now 22°C).
- The kitchen has a new stove.

GET BILL SMART UPGRADES

- ✔ Hot water valve cosy
- ✔ Small fridge thermometer
- ✔ Hot water pipes insulated
- ✔ Stay Warm education booklet
- ✔ Lights changed
- ✔ Water saving showerhead
- ✔ Shower timer
- ✔ Door snakes

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	9.02	10.28	1.26	14.0%
T 41 Heating (hard wired heating)	7.24	6.75	-0.49	-6.8%
Total Heating	16.26	17.03	0.77	4.7%
Other Light and Power (T31)	19.35	26.58	7.23	37.4%
Hot Water	7.36	6.56	-0.79	-10.8%
Total Household Electricity	42.97	50.18	7.20	16.8%
House Heating Efficiency (degree-hours/kWh/day)	0.39	0.41	0.02	4.0%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	17.5	14.3	9.0	6.4	17.5%
After	16.9	14.6	8.3	6.9	16.8%
Difference between before and after	-0.6	0.3	-0.6	0.6	-0.7%

Referring to the tables and graphs presented, multiple changes were noted. Total Household Electricity increased by 16.8% (from 42.97kWh/day to 50.18kWh/day).

Total heating increased by 4.7% from 16.26kWh/day to 17.03kWh/day. This increase is likely related to Danielle working from home in the after period (a change from the before period). As she reported she tended to heat her office space with a plug in heater and not use the heat pump until she had finished work. The plug in heater was not mentioned to the GBS team until the end of the monitoring period and hence was not monitored. Increased use from this plug in appears in Other Light and Power where there was a big increase from 19.35 to 26.58kWh/day. Increase noted in the plug in heating of 1.26kWh/day is from increased use of the downstairs heater in the bed-sit.

> I wouldn't feel very good that, say, my daughter or her friends if they were here, I'd feel really bad for my kids really if they had to suffer being cold.
> *(Before Interview 23/05/2014)*

Energy and comfort

In the living area after the Home Energy Helpers visit Danielle reported that she turned the temperature of the heat pump down. The example before/after charts show this reduction as does the hard wired heating decrease of 6.8%. Example graphs also show the heat pump energy use moving up and down in the after period rather than staying at constant levels suggesting Danielle has gone from leaving it on to turning it on and off as needed.

Time spent in the comfort zone decreased from 17.5% to 16.8%. No time was spent above 24°C. Both the before and after percentages are low. Temp/humidity was measured in the living and a bedroom, not in the room Danielle set up as the home office. Temperatures there may have been substantially warmer than the averages recorded.

Bedroom temperatures seem to respond to the outside temperature but tend to stay a little warmer than outside (a regular distance from outside temperatures on the graph). This temperature buffer is likely due to the presence of a waterbed and the continual heating of the water which constantly holds the room temp slightly higher than outside.

> Life's too short to be down about things like a cold house. Like I said, we started working out, we go for an afternoon walk and you can always count on a good walk to warm you up even if it's freezing outside.
> *(After Interview 07/09/2015)*

Danielle's Other Light and Power increase of 7.23kWh/day (37.4%) is related to the plug in heater in the study but may also be attributed to a new stove that was installed partway through the project.

The heating efficiency of Danielle's house increased by 2.4%, from 0.0.39 to 0.41. This is a small difference and does not indicate the house's energy changes well because of the use of the plug in heater in the study.

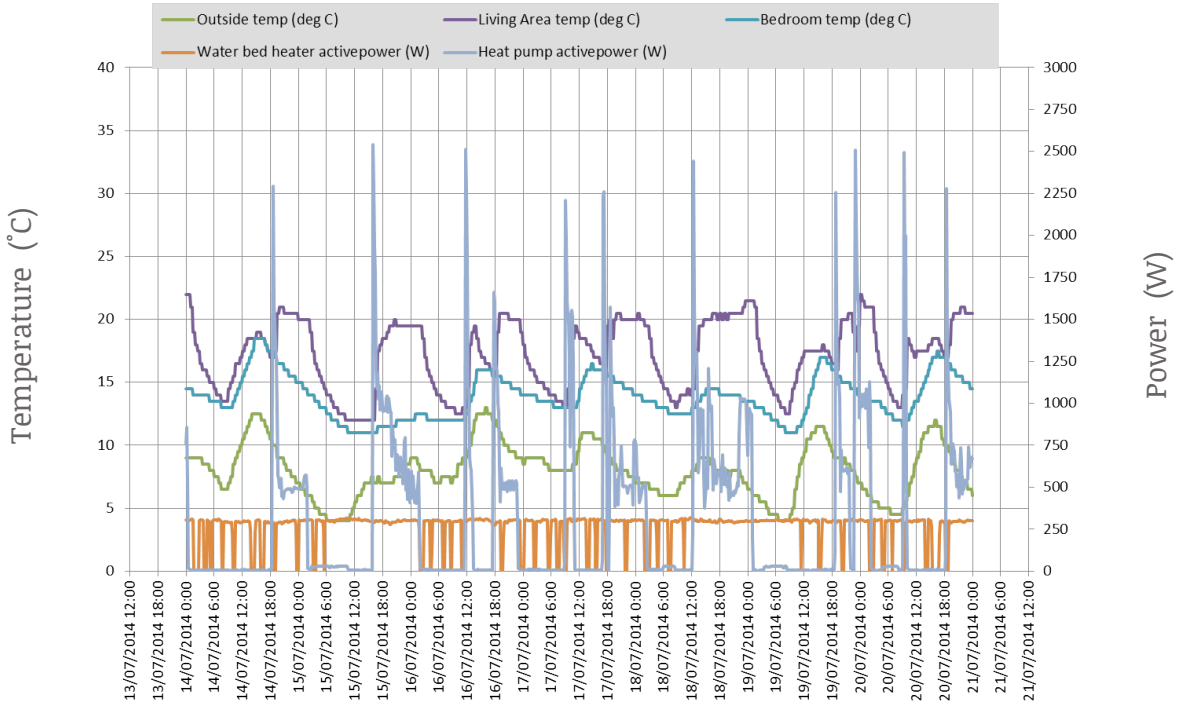
Consistent with Danielle's comments that she had reduced the number of showers she had, is the decrease in energy used by her hot water system (from 7.36kWh/day to 6.56kWh/day). GBS upgrades at her house involved measures that would have also helped to improve hot water use.

Measurements show moisture was manageable in this house. The living and bedroom area temperature did not reach dew point during winter and winter humidity peaked at 75%. Moisture was reported as a significant issue by Danielle. In the living area the heat pump limited humidity to peaks of 65%, indicating a reasonably dry living room.

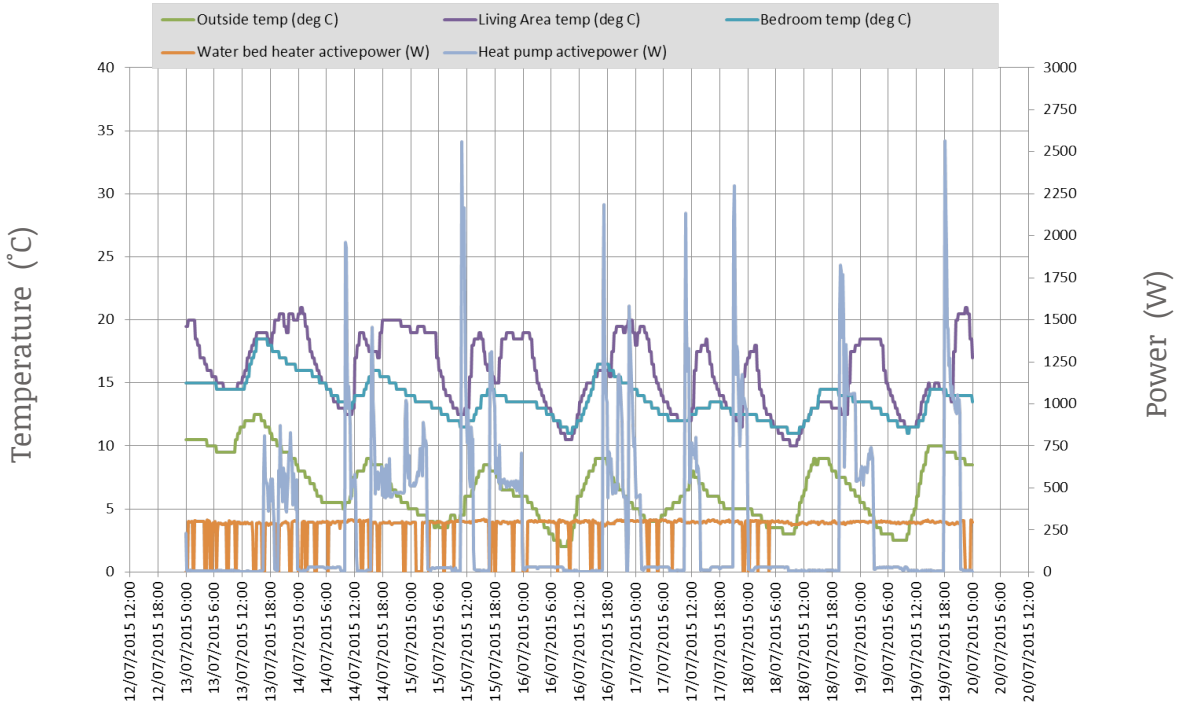
Much of Danielle's energy use and corresponding comfort is hard to monitor as she began heating an area in which we did not have sensors.

Temperature and energy use was also logged in Danielle's son's unit. His heater use went up slightly.3.16 to 4.51kWh/day and room temperature also went up so comfort slightly increased.

Before period: example week in winter showing selected energy use and temperature readings



After period: example week in winter showing selected energy use and temperature readings



Energy affordability

Danielle was very careful with her power bills. Prior to the GBS program felt that she would like to reduce costs but wasn't sure how,

> Because my power bills are high so it just makes you really conscious of what you're doing, everything is electrical isn't it, for me cooking and preparing meals to making a coffee to my son's got computer equipment down there ... I mean it's a shame it's like buying petrol isn't it, petrol's expensive but you can't live your life on how expensive petrol is and say we're not going there or not going there, so it's the same with power, you don't want it to affect your lifestyle.
>
> *(Before Interview 23/05/2014)*

After participation in the Get Bill Smart project Danielle's bills seem to have increased. The data we have from the energy supplier were based on estimates and so are likely to be inaccurate (the estimate was an annual increase of ~$164). Working from home will have contributed to this increase.

Despite the bigger bills Danielle felt a lot more in control explaining that,

> This is probably the first time that I've been up-to-date with my power bill, I haven't had to make a payment plan but then I've got my son contributing to that too. I've got his whole living area downstairs with fridge and microwave and his computer gaming stuff and he's got a heater downstairs which he's been using as well, but I only let him have it on one bar, so it's right next to him, might as well be in his jacket. *(After Interview 07/09/2015)*

Personal and community change

Danielle lives with her two children. Danielle's son is late teens and lives in the small bedsit underneath the house. In his room he has a radiant plug in heater, a fridge, a microwave and lots of computer gaming equipment. Danielle had limited success getting him to reduce his use. Because he uses so much power and often has the heater on very high, he now contributes to the power bill.

Danielle had a fantastic relationship with her landlady. Danielle had asked whether she could make some changes to the kitchen and the landlady was delighted with the final product. As a result Danielle felt valued and respected as a tenant and considered the rental to be very much her home. She explained,

> Up until a little while ago this bench here was like the other side, it had a really high wall on it and I asked my landlord could I do it because to let the light and the warmth, because it was like a freezing little icebox in here, and the heat would if anything go right up there. *(Before Interview 23/05/2014)*

The landlord was so pleased that she offered to pay Danielle's water bill.

In her after survey Danielle displayed an increased sense of community and a greater awareness that there might be people in her community who could help with energy efficiency and thermal comfort.

Even prior to the project Danielle was clearly proactive when it came to energy efficiency and comfort. She had a strong network of friends whom she was able to turn to:

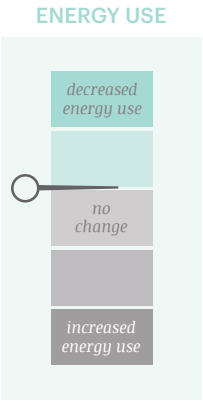
> Like I had a friend here and he was telling me about how the heater, for example, I just said to him some people run these heaters 24/7 because they reckon it takes more energy to turn them on and off, and he said no, yours is a whatever he said it was, geared up that you can turn it on and off anytime and it doesn't matter, because I can't justify that blowing. *(Before Interview 23/05/2014)*

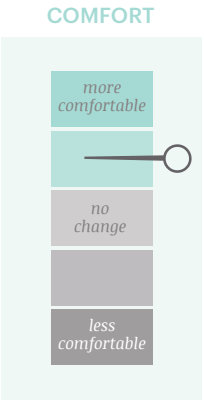
Danielle had also installed her own door seals, blocked off areas of the house with curtains and thought about how she used different appliances in the home. She used her strong network of friends to work through ideas and issues explaining,

> I discuss my power bill with a few of my friends, we can't believe what sort of power bills that they have also, so we discuss it and I've said to a couple of my friends ring up Aurora and get them to explain that cost. One of my friends has got one of those off-peak heat bank things in their hallway, costs her an absolute fortune but it's on off-peak, she can't understand it. *(After Interview 07/09/2015)*

Danielle found the home energy education and upgrade helpful and had changed some of her habits as a result. Her power use increased but not significantly given that she began working from home between the before and after periods. The thermal performance of Danielle's house was poor but she made the most of the good sunlight.

CASE STUDY 36
Patti and son





Occupants	Own or rent	Bedrooms	House type	Heating
	RENTER		FREESTANDING ONE STOREY	HEAT PUMP

What did we do?

IN HOME EDUCATION & UPGRADES

What was the result?

Patti increased her energy use slightly, however due to electricity price decrease she actually saved money on her bills. With the increase in energy use her time in the comfort zone also increased.

Patti was confident in her ability to find information and make changes to her home and was limited only by her rental status and financial capacity.

- ✗ Energy use increased by 1.02kWh/day (8.9%) from 11.47kWh/day to 12.5kWh/day.
- ✓ Energy costs reduced by ~$67 per year ($660-$593)
- ✓ Time spent in the comfort zone increased from 18.4% to 21%.
- ✗ Heating efficiency decreased from 1.01 to 0.97 (4.5%).
- ✓ Displayed improved confidence that she could find information on thermal comfort and energy efficiency if needed.
- ✓ Draughts reduced.

> Oh, you know, no one told me anything that I didn't already know but I salute the fact that they were so relentlessly diligent, you know, running through the whole booklet and I mean I kept saying "Yep, yep, yep, yep," all over it, you know. But okay, everyone's not so...
> *(After Interview 01/09/2015)*

Existing physical conditions of the house

Patti's house was in relatively poor condition. Despite acceptable orientation, thick curtains and multiple layers of carpet, he single glazing and lack of insulation contributed to poor thermal performance.

Type	Stand alone, suburban.
Age	40-49 years.
Construction	Weatherboard with timber frame, suspended timber floor (carpet, multiple layers of carpet in living, vinyl and tiles in bathroom/toilet/kitchen), corrugated metal roof, garage under living room.
Insulation	None.
Windows	Single glazed, timber frame.
Window coverings	Curtains (mostly heavy), pelmets (living and one bedroom).
Access to sun	All day access to sun in living room.
Heating	Heat pump.

Changes to the home

Other changes to the home:

- Patti upgraded her curtains to a heavier weight.
- Patti had multiple layers of carpet in the living room to which she continued to add during the course of the GBS project.

GET BILL $MART UPGRADES

- ✔ Draught proofing of doors
- ✔ Door snakes
- ✔ Hot water system insulated
- ✔ Small fridge thermometer
- ✔ Hot water valve cosy
- ✔ Stay Warm education booklet
- ✔ Hot water pipes insulated
- ✔ Water saving shower head
  Lights changed
- ✔ Shower timer

Overview

Patti had lived in her home for several years with her young son. When we first met she also had a boarder staying with her briefly.

Patti's overall energy use increased by 8.9% from 11.47kWh/day to 12.50kWh/day. The table below shows slightly increased energy use across the board. Heating and hot water increased the most in terms of kWh/day, while Other Light and Power increased more in terms of percentage.

When speaking with Patti in the After Interview she explained that while she had enjoyed the home education and upgrades she hadn't learnt much that she didn't already know. It did however make her feel confident in her own practices. Patti acknowledged that because she felt in control prior to the home visit and because that visit reinforced this message, she "might have been a bit more profligate with the heating just because of the psychological..." (After Interview 01/09/2015). This may explain the small generalised increase in energy use.

Heating efficiency decreased as is to be expected with increased heater use, however it remained very good. This is because of the hard work Patti put into managing her home.

Patti found the draught stoppers in her house frustrating as they necessitated the slamming of doors in order for them to close. She was however grateful for their presence.

Patti was very energy conscious and felt confident in her knowledge and ability to control her home which was only limited by her rental status.

Patti was active in her community although recently had felt somewhat isolated from her community due to some personality clashes. Patti was confident in her own ability to find information that she needed.

Average daily energy use and heating efficiency during winter conditions

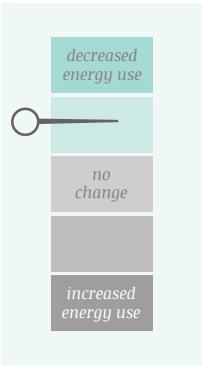
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.00	0.00	0.00	0.0%
T 41 Heating (hard wired heating)	5.19	5.73	0.53	10.2%
Total Heating	5.19	5.73	0.53	10.2%
Other Light and Power (T31)	2.30	2.72	0.41	17.9%
Hot Water	3.98	4.05	0.08	2.0%
Total Household Electricity	11.47	12.50	1.02	8.9%
House Heating Efficiency (degree-hours/kWh/day)	1.01	0.97	-0.05	-4.5%

Average daily temperatures and time in comfort zone during winter conditions

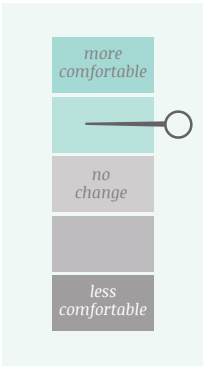
	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	16.0	11.9	8.7	5.3	18.4%
After	16.1	11.6	8.3	5.5	21.0%
Difference between before and after	0.1	-0.3	-0.4	0.3	2.6%

CASE STUDY 37
Alice

ENERGY USE



COMFORT



Occupants	Own or rent	Bedrooms	House type	Heating
	RENTER		ONE STOREY TOWNHOUSE	HARDWIRED RESISTIVE

What did we do?

IN HOME EDUCATION & UPGRADES

What was the result?

No major changes were made to Alice's house through the upgrade, but she did think she had learned a lot during the process. She had changed her practices at home and was proud of her new skills. Thermally the house was of a reasonable standard and so changes she made to her practices (heater use, zoning) had a noticeable impact.

- ✔ Energy use decreased by 1.32kWh (6.1%), from 21.69kWh/day to 20.37kWh/day.
- ~ Energy costs reduced by ~$1 per year (from $1015 to $1016).
- ✔ Time spent in the comfort zone increased from 7.6% to 11.1%.
- ✘ Heating efficiency decreased from 0.48 to 0.46 (4.9%).
- ✔ Displayed improved confidence that she could find information on thermal comfort and energy efficiency if needed.
- ✔ A recently built house with insulation and solar hot water.

> The cost, of course, cost, yeah, and comfort, yeah, both of course. I feel quite proud of being aware; I've lived all these years, because I'm in my 70s and I've lived all these years and I really haven't been aware, I realise that now. And all of this is important, very important
>
> *(After Interview, 1 Sep 2015).*

Existing physical conditions of the house

This home is a one storey unit that was recently constructed with double glazing and solar hot water. Alice reported that the western sun in the living area could get far too hot in summer, but was good in winter. The temperature did not reach dew point indoors. The living room humidity stayed under 70%, but the bedroom moved from a peak of 80% (before) to 75% (after). Overall, despite poor window coverings and a difficult living room orientation, the insulation, double glazing and solar hot water mean this house performed to standard.

Type	Conjoined unit, one storey in townhouse complex.
Age	0-5 years.
Construction	Brick veneer and fibre board walls, corrugated metal roof, concrete floor on ground (vinyl and carpet cover), solar hot water.
Insulation	Ceiling (batts), walls (batts).
Windows	Double glazed, aluminium frame.
Window coverings	Metal venetians all through house, no pelmets.
Access to sun	Conjoined neighbour sits on north east, main living area receives afternoon sun.
Heating	Wired-in radiant heater, upright radiant plug-in.

Changes to the home

Other changes to the home:

- New curtains.
- Changed heating practices.
- Changed zoning practices in both winter and summer.

GET BILL $MART UPGRADES

- ✔ Lights changed
- ✔ Water-saving shower head
- ✔ Shower timer
- ✔ Door snakes
- ✔ Small fridge thermometer
- ✔ Stay Warm education booklet
- ✔ Hot water valve cosy

Overview

Alice was retired and lived happily in her conjoined unit with her dog. She had a strong sense of community and often visited her neighbours and the nursing home across her drive. She was a bit of a 'go-to' person, and had a good feel for how other people were managing energy use in their homes.

As a result of GBS, Alice felt a lot more in control and proud of herself for the changes she had made to her heating practices. The home energy helpers assisted her to think through zoning off unused, draughty parts of her house, and this gave her more freedom to move around rather than hide in one room. She also learned to effectively capture summer breezes, and to use her heater more efficiently (she felt she had been using it wrongly before). She now offers advice to others about energy use issues. She indicated that there are still some gaps in one of the doors that weren't sealed properly by the home energy helpers and these still admit draughts.

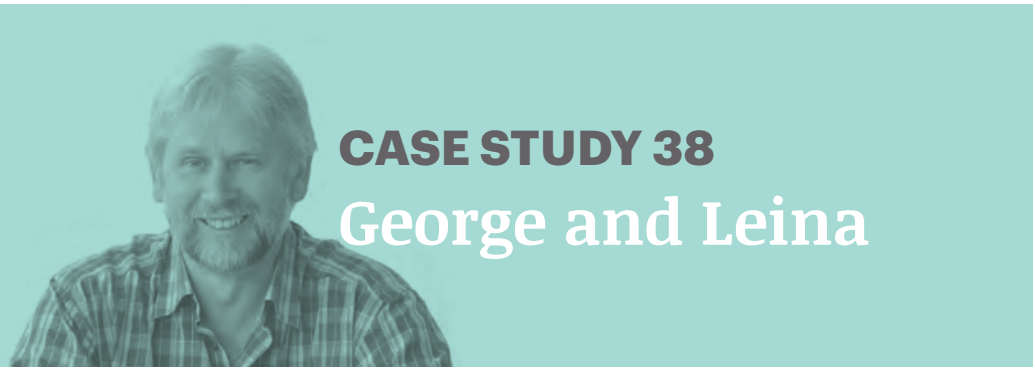
The solar hot water system in her home helps to keep her bills down. However, summer remains her biggest problem and so she has plans to invest in a screen door to help with this.

Average daily energy use and heating efficiency during winter conditions

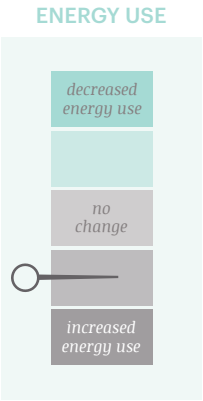
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	3.07	0.52	–2.55	–83.1%
T 41 Heating (hard wired heating)	6.63	8.90	2.27	34.3%
Total Heating	9.70	9.42	–0.28	–2.9%
Other Light and Power (T31)	5.26	4.63	–0.63	–12.0%
Hot Water	6.73	6.33	–0.41	–6.1%
Total Household Electricity	21.69	20.37	–1.32	–6.1%
House Heating Efficiency (degree-hours/kWh/day)	0.48	0.46	–0.02	–4.9%

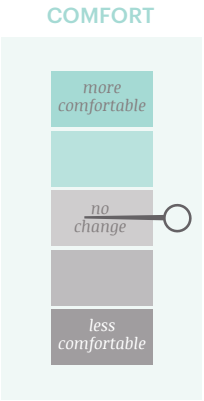
Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	15.1	12.7	9.2	4.7	7.6%
After	15.2	12.3	9.4	4.3	11.1%
Difference between before and after	0.1	–0.4	0.2	–0.4	3.5%



CASE STUDY 38
George and Leina





Occupants	Own or rent	Bedrooms	House type	Heating
	OWNER WITH MORTGAGE		FREESTANDING ONE STOREY	HEAT PUMP

What did we do?

IN HOME EDUCATION & UPGRADES

What was the result?

George and Leina reduced energy costs at the same time as increasing their energy use slightly. This is because energy prices went down and their increase in use was through the cheaper T41 power tariff. The upgrade was reported as helpful and despite already being aware of some suggestions made by the home energy helpers, they found the minor adjustments to the heat pump suggested were very useful and reduced heating draughts.

- ✗ Energy use increased by1.61kWh/day (5%), from 32.31kWh/day to 33.92kWh/day.
- ✓ Energy costs reduced by ~$271 per year (from $1894 to $1623).
- ✗ Time spent in the comfort zone decreased from 29.5% to 28.2%.
- ✗ Heating efficiency decreased from 0.33 to 0.1 (4.4%).
- ✓ Maintained confidence that they could find information on thermal comfort and reported improved confidence that they could access information on energy efficiency if needed.
- ✓ Draughts reduced.

With the heat pump systems, we had one on the floor many years ago and it was more efficient than the one on the wall. Having said that, we chose on the wall because it gave us more room in the lounge room, it was just taking up a little bit of room. So therefore we had it put on the wall and I will say that there is a downward draught when it's on. If I had a bigger room I'd probably go back to the floor system again, but this way it gives us a bit more room.

(After Interview, 2 Sep 2015)

Existing physical conditions of the house

Despite some insulation, the overshadowing from the house to the north and the eastern deck and the single glazing means that the thermal performance of this house is only poor to near standard level.

Type	Stand alone, suburban.
Age	50-59 years.
Construction	Brick veneer, tile roof, suspended timber floor (0.2m-0.4m off ground) (tiles, vinyl, carpet).
Insulation	Ceiling (batts), some walls (batts).
Windows	Single glazed, timber/aluminium frames.
Window coverings	Vertical blinds (kitchen and living), heavy curtains (living and bedrooms).
Access to sun	Northwest to southeast long axis, neighbouring house close to north corner, covered deck on north east of house, so little east and north sun, living room midday to afternoon sun.
Heating	Heat pump, radiant panel heater, electric blankets (2), hard-wired resistive circuit (garage – unmonitored).

Changes to the home

Other changes to the home:

- Daughter and grandson moved out.
- Started using small portable gas oven inside.

GET BILL SMART UPGRADES

- ✔ Ceiling insulation
- ✔ Small fridge thermometer
- ✔ Draught-proofing of doors
- ✔ Stay Warm education booklet
- ✔ Hot water pipes insulated
- ✔ Lights changed
- ✔ Shower timer
- ✔ Door snakes

Overview

George and Leina's household was very dynamic with changes in occupancy that led to fluctuations in energy use. In the before period the couple had an adult daughter and their grandchild stay with them. After the extra occupants left energy use actually went up a bit. Leina thought that they might have used more heating during 2015 because of the colder winter. Perhaps also there might have been some 'comfort creep' after the extra occupant left.

They had previously chosen to replace a floor-mounted heat pump with a wall-mounted heat pump to give them more floor space in their living room, although there were less happy with the effectiveness of the wall-mounted one.

Although George and Leina's energy use increased during the GBS project, their bills decreased. This was probably because of a reduction in energy costs and because their increase was mainly on the cheaper T41 heating tariff. Their heating efficiency and time in the comfort zone both reduced slightly, but the average temperature in both bedroom and living room increased slightly.

George and Leina found the physical changes made by GBS helpful, and even though they were already aware of some of the information provided, other information was helpful in assisting them to make minor changes (e.g. to heat pump use) that made them feel more comfortable. They now closed doors and windows when cold, and opened windows in closed-off rooms to keep the air fresh. They had recently started using a portable gas oven rather than an electric oven, and this may have related to the reduced Other Light and Power energy use.

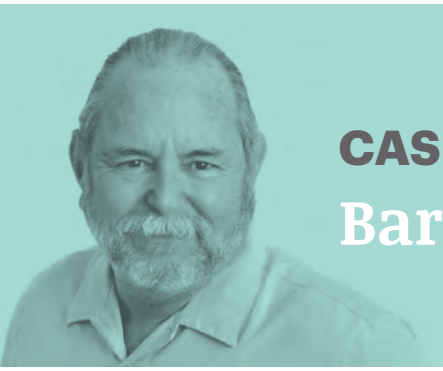
They felt more in control of their energy consumption, but said to improve this they would like to move to a smaller house. George and Leina also wanted solar power but said they could not currently afford it. Leina reported strong community connections, and said that there would always be new ideas and sources of help available. She would feel comfortable calling either GBS or Aurora for help.

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	1.71	1.92	0.22	12.6%
T 41 Heating (hard wired heating)	14.71	16.17	1.46	9.9%
Total Heating	16.42	18.09	1.67	10.2%
Other Light and Power (T31)	9.02	8.65	–0.37	–4.1%
Hot Water	6.88	7.18	0.31	4.5%
Total Household Electricity	32.31	33.92	1.61	5.0%
House Heating Efficiency (degree-hours/kWh/day)	0.33	0.31	–0.01	–4.4%

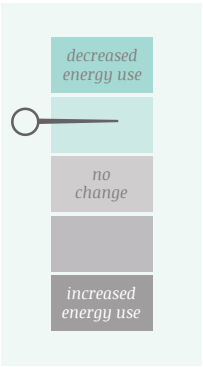
Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	18.0	9.6	8.4	5.3	29.5%
After	17.9	9.9	8.3	5.6	28.2%
Difference between before and after	–0.1	0.3	–0.2	0.3	–1.3%

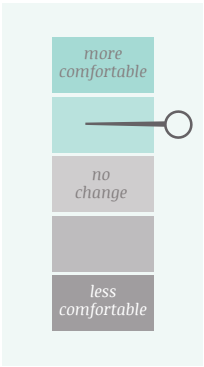


CASE STUDY 39
Barry and Mary

ENERGY USE



COMFORT



Occupants	Own or rent	Bedrooms	House type	Heating
	OWNER		FREESTANDING ONE STOREY	WOOD FIRE

What did we do?

IN HOME EDUCATION & UPGRADES

What was the result?

Barry and Mary experienced a minor improvement in their comfort levels and a small decrease in their energy use and electricity costs after the GBS home visit. The couple relied heavily on their wood heater for comfort in the home. During the GBS study period the couple had got solar power installed, but had had problems with the tariff rate they received and so weren't sure what benefit it would provide. The couple were involved in their community and had a caring attitude toward their neighbours but appeared not to need to ask for help from others much.

- ✔ Energy use decreased by 1.65 kWh (9.8%), from 16.81kWh/day to 15.16kWh/day.
- ✔ Energy costs reduced by ~$356 per year (from $1430 – $1074).
- ✔ Time spent in the comfort zone increased from 37.7% to 39.5%.
- ~ Given the wood heater, heating efficiency is not accurately measured for this home.
- ✔ Displayed improved confidence that they could find information on thermal comfort and energy efficiency if needed.
- ✔ Draughts reduced.

> The fridges would be the thing that would suck the power, there's not a lot I can do. We did ask [the Home Energy Helpers] about that and they said there was a thing you could do but it was a lot of mucking around and I thought "No we'll just continue on the way we're going". *(After interview, 2 Sep 2015).*

Existing physical conditions of the house

No moisture issues were measured in this home. Humidity peaked at a fairly low 65% in the living room in winter and, in the bedroom, at 75% before and 70% after. Draughts were a problem, likely amplified by heating from wood fire and balancing of temperatures across the house. While the reasonable curtain coverage and the use of radiant wood heat supported Barry and Mary's comfort, having the sun blocked for big chunks of the day, single glazing and only ceiling insulation led to the thermal performance of this house being poor.

Type	Stand alone, suburban.
Age	30-40 years.
Construction	Brick veneer wall, tile roof, suspended timber floor (0.5-2.0m off ground) (vinyl, carpet), photo voltaics on roof.
Insulation	Ceiling (batts, 5 years old).
Windows	Single glazed, aluminium frame.
Window coverings	Curtains with thermal backing plus lace in all rooms, one blind in kitchen and bathroom.
Access to sun	Overshadowed by neighbour and shrub close and uphill on north east so living (on eastern corner) only receives morning sun, kitchen and dining (open plan with living) receive midday and some afternoon sun but roofed deck on western side blocks lots of sun.
Heating	Wood heater with fan, electric blankets (2).

Changes to the home

Other changes to the home:

- New hot water cylinder.
- House sitters for a total of about 12 weeks overall (some in winter periods).

GET BILL $MART UPGRADES

- ✔ Hot water pipes insulated
- ✔ Stay Warm education booklet
- ✔ Hot water valve cosy
- ✔ Water-saving shower head
- ✔ Lights changed
- ✔ Shower timer
- ✔ Door snakes
- ✔ Small fridge thermometer

Overview

Barry and Mary are retired and live is a comfortable a well maintained home. Barry and Mary's overall energy use decreased because of a reduction in their hot water usage. They had a new hot water system installed in late 2014 which probably contributed to this. In the after period their time spent in the comfort zone increased, as did the average bedroom temperature, and the average living room temperature remained the same. Unusually, although Barry and Mary have a wood heater, they did not spend any time above the comfort zone cut-off point of 24° (wood heaters were normally heating to higher temperatures). This indicates they managed their wood heater outputs whenever they were using it.

Barry and Mary had had solar panels installed over the GBS study period. They had some trouble with the installation of these in relation to tariff charges (many others had similar issues with this at the same time). The solar panels affected the billing data, which means the apparent savings in energy costs are probably too high.

They were frustrated by the new light bulbs installed through GBS, which they reported as flickering (this was followed up on by SLT), and disliked the flashing of the sensor lights that recorded energy and temperatures. They were given advice about further changes by the home energy helpers, but decided that implementing them would mean too much trouble mucking around, and that they would just keep doing what they were already doing. They came from a strong church community which had an ethic of helping others who needed it.

Barry and Mary had house sitters in their home for two weeks during July 2014 and then at several other times throughout the study period, adding up to 12 weeks overall.

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.31	0.41	0.10	31.1%
T 41 Heating (hard wired heating)	0.00	0.00	0.00	0.0%
Total Heating	0.31	0.41	0.10	31.1%
Other Light and Power (T31)	3.98	4.12	0.14	3.6%
Hot Water	12.52	10.63	–1.89	–15.1%
Total Household Electricity	16.81	15.16	–1.65	– 9.8%
House Heating Efficiency (degree-hours/kWh/day)	26.85	21.98	–4.87	–18.2%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	18.6	14.7	8.3	8.3	37.7%
After	18.5	15.7	8.2	8.9	39.5%
Difference between before and after	– 0.1	1.0	– 0.2	0.6	1.8%

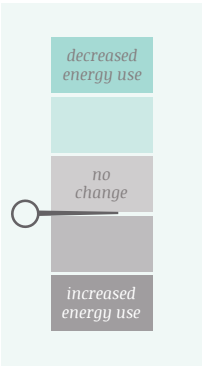
Cases 40–51

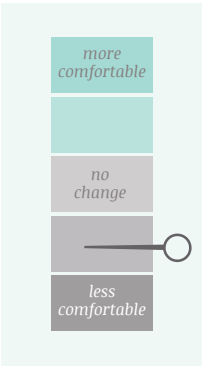
REPRESENTATIVE HOUSEHOLDS

There were no GBS support activities undertaken with these households. These households provided representative information and were not exposed to GBS activities.

Houses in this case group were all living in suburbs in the Greater Hobart region. None of these households had homes in the suburbs of Clarendon Vale or Rokeby and none of these households were directly exposed to community capacity building activities held.

CASE STUDY 40
Naomi and family





Occupants	Own or rent	Bedrooms	House type	Heating
	RENTER		FREESTANDING ONE STOREY	WOOD FIRE + HEAT PUMP

What did we do?

REPRESENTATIVE GROUP

> We're pretty frozen this year, because we haven't had any wood ... I just put extra blankets and that on their beds. I've got two dogs that keep us warm. It's nice and warm in here, because that's basically on 25°C, but you walk around the rest of the house and it's freezing.

What was the result?

Naomi stopped using her wood fire due to cost. The temperatures in her house decreased to sit within the comfort zone of 18-24°C. While her comfort rating increased, this was mainly due to a reduced amount of overheating that was occurring due to the use of the wood fire. Naomi actually felt colder.

The radiant heat from the wood fire was important to Naomi's comfort and thus, while the air temperature of the comfort zones improved, Naomi reported feeling less comfortable. It is well understood that radiant heat is a more comfortable form of heat.

When Naomi stopped using a wood heater and the heat pump usage stayed roughly the same, but overall household heating increased and the temperatures dropped.

✗	Energy use increased by 2.2kWh (5.5%) from 40.01–42.21 kWh/day.
✓	Energy costs decreased by ~$300 per year (much of this due to no longer purchasing wood to burn).
✓	Time spent in the comfort zone increased from 56.9% to 80.1% (had been consistently above the comfort zone of 24 degrees in the before period).
✗	Heating efficiency decreased from 0.60 to 0.40 (34%) (due to the ceasing of use of the wood fire).
✓	Displayed improved confidence that she could find information on energy efficiency and comfort.
✗	Self reported moisture levels increased and mould noticed for the first time. Temperature not shown reaching dew point, but large temperature differences between inside and outside could cause significant condensation.

Existing physical conditions of the house

Naomi and her children rent a stand-alone suburban home. Sitting in the middle of a standard sized block the house is open to sunlight, The long axis of the house sits northwest to south west. The living room sits to the south and only receives some afternoon sun. The construction is weatherboard cladding with timber frame sitting on a concrete block skirt, roofed with corrugated iron with a timber suspended floor (covered in carpet and vinyl).

The house had no known insulation. Heating is provided by a wood fire and a heat pump in the living room and a radiant plug in heater in bathroom.

Due to the lack of available sunlight to the living area, the poor level of maintenance, the significant draughts and the lack of insulation this house is described as having very poor thermal performance.

Insulation	None known.	VERY POOR
Windows	Steel framed, single glazed, no pelmets.	POOR
Window coverings	Curtains of various weights.	NEAR STANDARD
Under floor space	Suspended timber floor .2-1.5m, underfloor enclosed with concrete blocks, no insulation.	POOR
Mould and moisture	Moisture levels reported to have increased, reported mould noticed for the first time.	POOR
Other conditions of note	House maintained in working order, but only just.	POOR
	Gaps under most doors and significant drafts.	POOR

Changes to the home

Other changes to the home:

- Blocked fan vent in bathroom with cardboard.
- Stopped draughts with rolled up towels.
- Used extra blankets and doonas.
- Hung curtains and sheets in doorways (kitchen and front door).
- Turned the heat pump down slightly.
- Stopped buying wood for the fire.

GET BILL SMART UPGRADES

Not relevant for this participant.

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (%)
T 31 Heating (plug in heating)	2.88	6.58	128.7%
T 41 Heating (hard wired heating)	18.94	18.01	-4.9%
Total Heating	21.81	24.60	12.7%
Other Light and Power (T31)	9.65	7.99	-17.2%
Hot Water	8.55	9.63	12.6%
Total Household Electricity	40.01	42.21	5.5%
House Heating Efficiency (degree-hours/kWh/day)	0.60	0.40	-34.0%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	25.9	22.3	11.0	13.2	56.9%
After	21.7	18.8	10.5	9.8	80.1%
Difference between before and after	-4.2	-3.5	-0.5	-3.4	23.2%

Referring to the tables and graphs presented, multiple changes were noted. Total household energy use increased by 2.2 kWh/day, from 40.01kWh/day to 42.21kWh/day (5.5%). Total heating went from 21.8kWh/day to 24.6kWh/day, an increase of 12.7%. The use of the heat pump declined by 4.9%0.9kWh/day(4.9%), while plug in heating use increased by over 3.7kWh/day (128%).

Not captured in the data above is that Naomi stopped purchasing wood for their wood heater in the after period because it was difficult to source and she had been finding the wood was often green (other households also had these issues). Reducing the use of the wood fire saved her approximately $500 but increased the pressure on her electrical heating and caused a shift in heating practices. The extra plug in heating may have also been used to counteract the lack of radiant heat from the fire. Heating efficiency reduced by 34% (from 0.60 to 0.40). The reduction in heating efficiency is because the heat from the wood fire being used in the before period is not available in the after period. The electrical heating is being used approximately the same amount and providing approximately the same amount of heat, but the extra 'free' heat from the wood fire is not there in the after period.

Time spent inside the comfort zone (of 18-24°C) increased from 56.9% to 80.1%. The family had actually spent more time over 24°C (over the comfort zone) in the before period with the wood heater. During the after period they more frequently spent time in the comfort zone, rather than above it. As is shown in the table and charts, average temperatures did reduce somewhat. The living room was the only place where the temperature had an average comfort that exceeded 24°C in the after period. In the living room time spent above the comfort zone reduced from 75.5% to 9.2% of the time. In the bedroom time spent above the comfort zone reduced from 10.6% of the time to 0%.

Energy and comfort

Example charts show that in the before period bedroom and living room temperatures follow each other when the wood fire is on. The heat pump may have been used to blow heat down the hallway and perhaps to kick start the heating in the house while the fire was being lit. The after chart shows that the heat pump was used more continuously once the wood fire was no longer in use. The temperature is maintained at a more consistent but cooler level and there are no large spikes in temperature.

The example before/after charts also show how much the house responds to the outside temperature cycles. In the before chart this response is less visible as the heat from the wood fire is intense enough to partly overrides the outdoor cycles. This response to outside temperatures indicate poor thermal resistance in the building shell.

Naomi was a shift worker (and a student in the after period), so tended to need heating at irregular hours. Naomi had said that she had been more onto the teenager children about keeping the temperature of the heat pump down in the after period.

Hot Water use increased 1.08 kWh/day from 8.55 kWh/day to 9.63 kWh/day (12.6%). Other light and power decreased by 17.2% (from 9.65kWh/day to 7.99kWh/day).

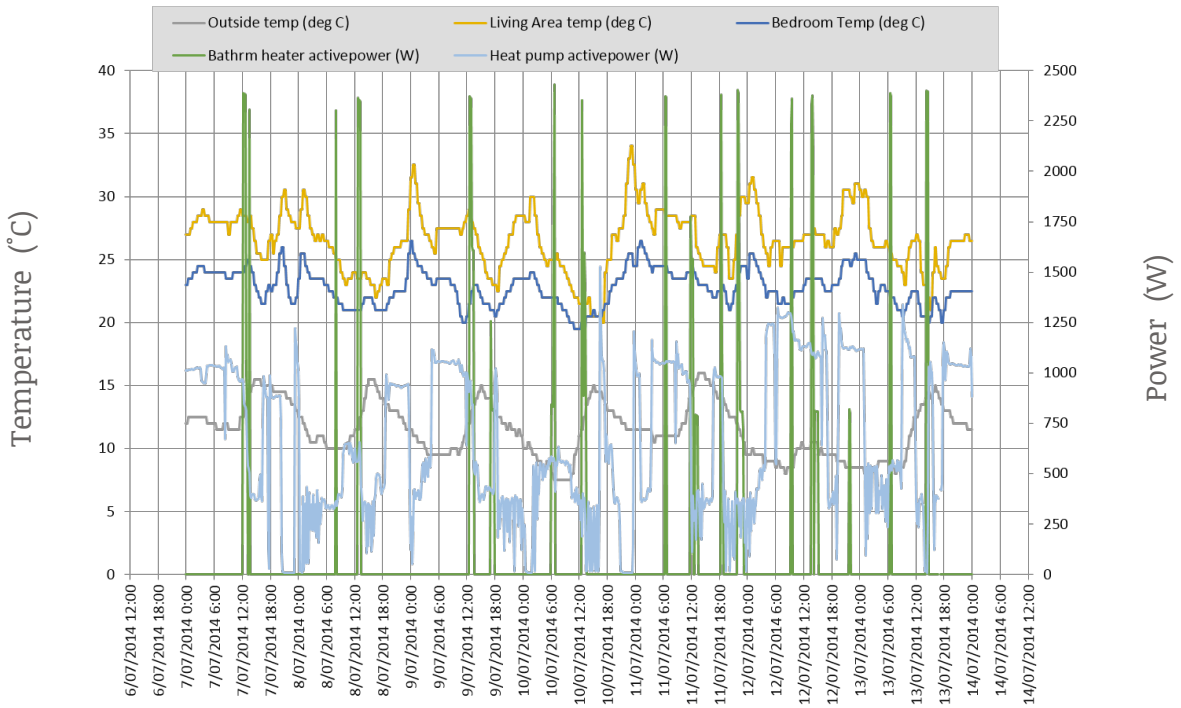
Likely linked to changes in heating is the change in moisture/mould where mould was noticed by Naomi for the first time in the after period. The house measurements showed that temperature did not meet dew point in the bedroom or living area and that peak humidity before was 75% and after was 70% and most often did not peak above 60%, so these measure show no regular issues. However it is important to note that condensation on cold surfaces can be more likely to occur, where there is a large temperature difference between inside and outside as is the case in this household. The higher internal air temperature allows more water vapour to me stored in the air. This, in combination with the poor thermal resistance of the building skin which leads to cold window and external wall surfaces, could lead to condensation occurring on those surfaces, even though our air temperature measurements make it seem that it would be unlikely.

When we first moved in to this house, I kept the heating up on 21 thinking that 21 was like optimum... a good temperature to have it... So anyway, I discovered after getting—I think the first bill was $600, so we turned it down to 18. And then the next bill was $900. But see, it was on 24/7. *(Before Interview 4/6/14)*

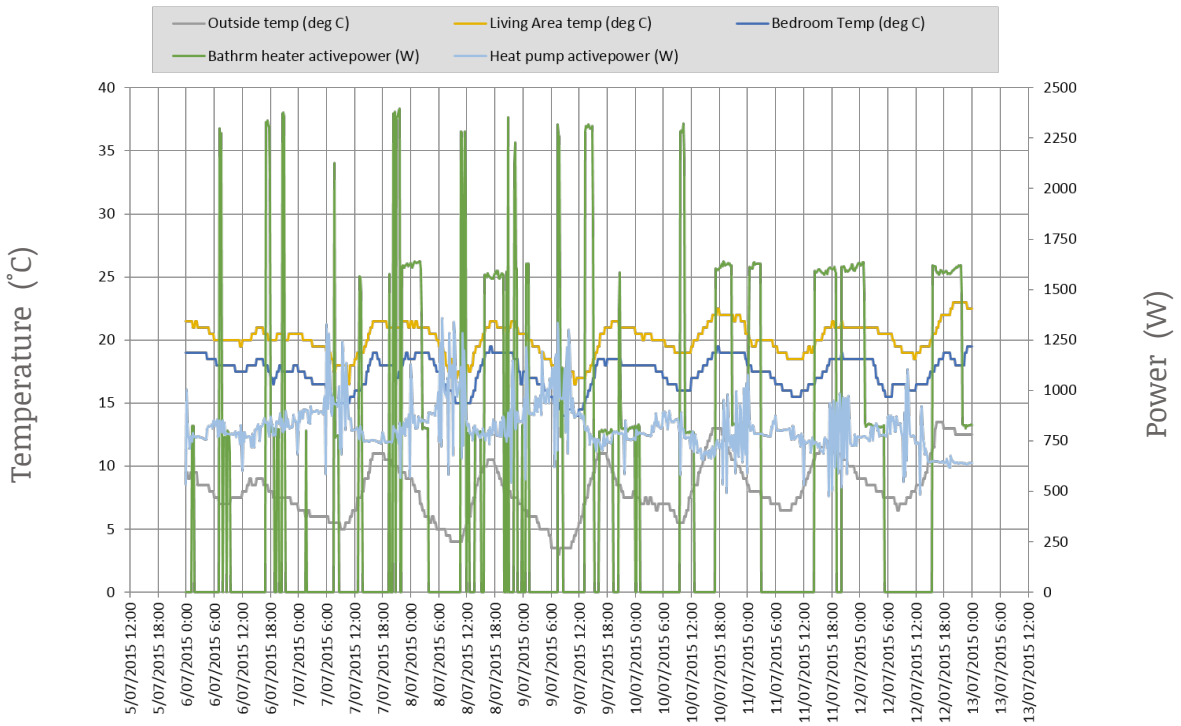
We've got a fan in the bathroom, it has a lot of cold air coming through it. So I pulled the cover off one day to clean it, and I had a look up there. I thought I'm going to cover it up, so I cut out a piece of round cardboard and popped it in there, to stop the... cold coming through. Because it's right above the shower, and when we get in the shower, and you can feel all this cold air coming through and it was really cold.

(After Interview 31/09/2015)

Before period: example week in winter showing selected energy use and temperature readings



After period: example week in winter showing selected energy use and temperature readings



Energy affordability

Unsurprisingly, with her increased electricity use, Naomi also increased her power bills. Naomi stopped purchasing wood because it was too expensive and estimated that this saved her approximately $500-$600 per year. Offsetting these savings was some increase in heater usage which increased her power bill by approximately $200 per year. Overall, although Naomi's house was not as warm she had a very high percentage of time within the comfort zone, and she saved approximately $300 per year in heating costs.

Prior to participating in the Get Bill Smart program Naomi explained how stressed she was financially:

Last year I was struggling with the hydro [electricity bill] because I was unemployed for three months as a temporary.....That's when I copped the [huge] bill and I was just, you know, with Centrelink money, Hydro's getting most of it, it was ridiculous. I was getting someone delivering a food hamper to me every week, just with fruit and veggies and stuff...

If I hadn't had that we would have starved, I reckon.
(Before Interview 4/6/2014)

When we spoke with Naomi a second time she was thankful her bill had decreased:

I've only just got the winter bill, which was $800 something last year and it was only $700 this year. Only $700 is still a lot.
(After Interview 31/09/2015)

Much of this decrease she put down to the general decline in energy price as set by the electricity provider.

Personal and community change

Naomi, her two children, their two dogs and a cat manage to heat their home most of the time. Naomi is a shift worker and has irregular hours, making heating and home management more difficult. The move from using the wood fire to the heat pump and plug in heaters has changed the way she heats her home, comfort levels and also changed her overall heating costs. While the house is most often in the comfort zone, Naomi acknowledged how cold the place would be without heating:

It'd be freezing. [With the heater on it improves] a little....It takes a lot. You need the fire going for two or three hours at night time for the lounge room and hallway to warm up, so that's nice and comfortable. And if I'm cooking tea in here at night time this room will warm up.
(Before Interview 04/06/2014)

Naomi's house was not in very good condition and she had trouble getting the landlord to address some of the problems. For example, the toilet leaked on and off during her tenancy and there had been trouble with the wood heater.

Given that both Naomi and the landlord had very little money (as noted by Naomi) available for things, like accidentally broken windows, became long term problems. As Naomi explained,

We've got a broken window in the main bedroom, so there's only a piece of cardboard on there at the moment. That was just a random; that was really windy one night and the window just pulled open and broke. We can't afford the excess to get it fixed just yet. *(Before Interview 04/06/2014).*

Personal and community change

Such problems contributed to the discomfort she felt in the house – the window making things particularly cold and draughty.

Despite the challenges of the home, Naomi did her best to keep herself and her family warm. She had blocked up vents, used bits of material to zone areas of the house and had made door snakes using rolled up towels held together with hair ties. She kept the house very clean and this helped to reduce the mould and moisture problems. She said,

> Actually when I first moved in there was mould all over the windows and everything. But see, I keep it clean so... I clean a couple of times a week because we've got dogs and the fluff and hair that goes everywhere. *(Before Interview 04/06/2014).*

When we spoke to Naomi the second time she was renting from a new owner who was acting to improve the house a little. In an attempt to be proactive she had asked the landlord about possibilities for draught proofing but he was fairly dismissive of the problem. Naomi was frustrated by the poor quality and broken curtain and blinds in the home but similarly had no luck getting them replaced by the landlord.

Keeping the home warm was important for Naomi, not only did she want her family to be comfortable but she had carpal tunnel syndrome,

> Yeah, well I've got carpal tunnel too, so I can't stand cold houses. It's one of those, I feel alright at the moment. But sometimes I'd get up in the morning and it's just, they're frozen. Carpal tunnel problem – need to keep it warm. *(After Interview 31/08/2015)*

Naomi felt that she lived in a strongly connected community. Her sense that there were people she could ask for help regarding energy efficiency and thermal comfort increased over the course of the project.

Naomi explained that she didn't have a strong personal community with her neighbours but had a strong connection with the neighbourhood house. At times when Naomi had need for assistance (food hampers etc.) the neighbourhood house really supported her. In turn, Naomi always made sure that when she had extra she passed it on through the community centre so that others who needed help could receive it.

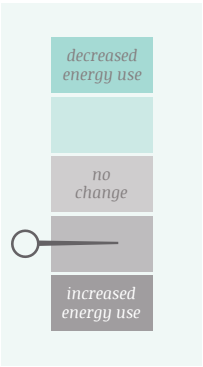
Naomi said,

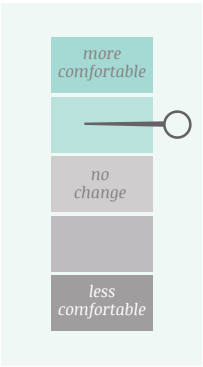
> That's a pretty good community centre, they have a lot of programs going for local people and stuff. There's always people there, and my daughter was actually going through the training program, learning to drive. *(After Interview 31/08/2015)*

Despite this connection, Naomi and her children felt that the suburb they lived in was unsafe and they didn't tend to talk to people in the street or go out at night alone.

Overall Naomi was very proactive but was limited in what she could achieve because of income and her renter status. The house was thermally poor and required lots of heating to maintain comfort.

CASE STUDY 41
Olivia





Occupants	Own or rent	Bedrooms	House type	Heating
	RENTER		ONE STOREY TOWNHOUSE	HARDWIRED RESISTIVE

What did we do?

REPRESENTATIVE GROUP

> You know, I do wear warmer gear and wrap up as much as I can, you know, because that is a power eater.
>
> *(After Interview 01/09/2015)*

What was the result?

Over the course of the project Olivia slightly increased her power use and the time she spent in the comfort zone.

These increases are likely due to the increased severity of her illness and the long periods she was confined to the home.

Olivia added a new plug in heater to the living area and bought a warmer doona for her bed.

On a low income, Olivia had a history of careful home management and was very conscious of energy use and energy saving measures.

✗	Energy use increased by 1.51kWh (5.7%) from 26.6kWh/day to 28.11kWh/day.
✗	Energy costs increased by ~$231per year ($980-$1211).
✓	Time spent in the comfort zone increased from 29.8% to 34.4%.
✓	Heating efficiency increased from 0.38 to 0.41 (6.3%).
✓	Displayed improved confidence that she could find information on thermal comfort and energy efficiency if needed.
✗	Self reported increase in draughts.

Existing physical conditions of the house

Olivia lived in a recently constructed unit with double glazing and solar hot water. No moisture issues found. Temperature did not reach dew point. Humidity peaks reduced (from 65%–55% in living). Bedroom range was 70% before and 75% after.

Type	Conjoined unit, one storey in townhouse complex.
Age	0-5 years.
Construction	Brick veneer and fibre board walls, corrugated metal roof, concrete floor on ground (vinyl, carpet), solar hot water.
Insulation	Ceiling batts, walls batts.
Windows	Double glazed, aluminium frame.
Window coverings	Paired light and heavy curtains in living and dining.
Access to sun	Conjoined neighbours sit on north east and south west, living room receives north eastern sun.
Heating	Wired in radiant heater in living room, radiant heater elsewhere, plug in heater.

Changes to the home

Other changes to the home:

- Olivia was quite unwell and spent a lot more time at home in the winter and more time in the hospital in summer.
- Olivia installed an extra plug in heater into her kitchen area.
- The fridge was replaced and Olivia was given a chest freezer.

GET BILL $MART UPGRADES

Not relevant for this participant.

Overview

Olivia was always looking for ways to save money and energy use. She washed the dishes in a small amount of water, only filled the kettle up with one cup's worth of water, and always chose to put on more clothes or blankets when she first got cold.

While Olivia carefully managed her bills, when she became extremely ill she changed her behaviour. She realised that for her health she needed to be warm and that she would risk very large electricity costs. This increased heating use in both before and after periods.

Olivia increased her heating use in the after period. It is likely that this is due to her purchase of a new plug in heater (we did not have sensors on this heater – plug in heater use captured in Other Light and Power). The energy efficiency of Olivia's house increased which is likely due to slightly lower average temperatures (still above 18°C) but remains good. Double glazing and the ceiling and wall insulation contributes to the efficiency of the home.

As a tenant and on a low income, there were things that she could not do. For example she was frustrated by the draughty rattling of the internal bedroom door. Olivia also wanted fly-screens on her doors to enable her to make the most of cooling summer breezes.

While Olivia didn't get out a lot due to illness, she felt very supported by her local neighbours. Having been given a chest freezer a nearby resident advised Olivia that keeping in part full was the most efficient thing to do (sound advice).

Olivia's house performed to standard thanks to insulation, double glazing and solar hot water. However the heater was not well suited to the space. It was energy hungry and Olivia found it difficult to effectively manage comfort.

Average daily energy use and heating efficiency during winter conditions

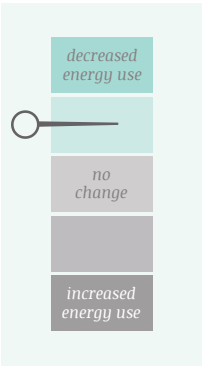
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.00	0.00	0.00	0.0%
T 41 Heating (hard wired heating)	20.22	19.93	-0.28	-1.4%
Total Heating	20.22	19.93	-0.28	-1.4%
Other Light and Power (T31)	3.74	5.27	1.53	41.0%
Hot Water	2.64	2.91	0.27	10.0%
Total Household Electricity	26.60	28.11	1.51	5.7%
House Heating Efficiency (degree-hours/kWh/day)	0.38	0.41	0.02	6.3%

Average daily temperatures and time in comfort zone during winter conditions

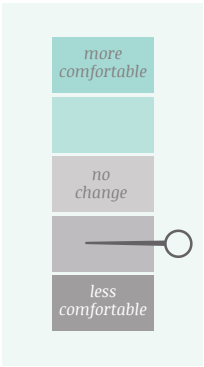
	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	19.9	15.6	9.9	7.8	29.8%
After	19.6	15.6	9.4	8.1	34.4%
Difference between before and after	-0.3	0.0	-0.5	0.4	4.6%

CASE STUDY 42
Teri

ENERGY USE



COMFORT



Occupants	Own or rent	Bedrooms	House type	Heating
	RENTER		ONE STOREY TOWNHOUSE	PLUG-IN ELECTRIC + HEAT PUMP

What did we do?

REPRESENTATIVE GROUP

Well I'm just getting over the flu, I don't know if that had anything to do with it. If I get really cold I go to bed. It's warmer there. *(Before Interview 26/5/14)*

What was the result?

Despite living in a cold house and having little knowledge of heater performance, Teri improved her comfort by switching off the radiant floor heater and switching on the heat pump in her living room. Teri had avoided using the heat pump, which she called 'that thing', until her daughter in law showed her how to use it.

✔	Energy use decreased by 1.85kWh/day (10.6%) from 17.40kWh/day to 15.55kWh/day.
✘	Energy costs increased by ~$139 per year ($1119-$1258).
✘	Time spent in the comfort zone decreased from 34.5% to 32.6%.
✔	Heating efficiency increased from 0.66 to 0.83 (24.5%).
✔	Displayed improved confidence that she could find information on thermal comfort if needed.
~	No change to self-reported moisture levels (no moisture observed).
✘	Draughts continued to be problematic
✔	Self reported comfort increased.

Existing physical conditions of the house

Teri lived in a federation-style, one-storey, timber suburban house that had been converted into two units. The unit received very little sun and the living area sat on the south-western side of the house. No insulation in the ceiling or walls coupled with poor orientation and an old structure meant the house sustained a cold microclimate. No mould or moisture problems noted – likely due to draughtiness.

Teri found the house to be draughty and reported that it was never comfortable in winter and rarely comfortable in summer.

Overall thermal performance was very poor. Teri found the house so uncomfortable that she decided to move again after under a year in the house.

Type	Single story town house, suburban.
Age	Approximately 100 years.
Construction	Weatherboard, corrugated iron roof, suspended timber floor (low – no skirt).
Insulation	Unknown (suspected none).
Windows	Single glazed, timber frames, no pelmets, living room skylight.
Window coverings	Heavy curtains (living, bedroom), blinds (other areas of the house).
Access to sun	Living room on south west side of house, very little solar access.
Heating	Plug in radiant heater with fan booster (living), heat pump (living).

Changes to the home

Other changes to the home:

- On the advice of a family member, Teri began to use her heat pump rather than the radiant floor heater (plug in).
- Teri used more blankets to keep warm.

GET BILL $MART UPGRADES

Not relevant for this participant.

Overview

Teri is in her 60s and lives alone. When we first met, she had lived in her house for less than a year. She found it so uncomfortable that at the last interview she explained that she intended to leave as soon as possible.

Thanks to a tip off from her daughter-in-law, Teri began to use the heat pump rather than the radiant heater. This made a big difference to her home heating efficiency (a shift of 24.5% from 0.66 to 0.83). Teri's time in the comfort zone decreased (from 34.5% to 32.6%), but this is because she spent more time above 24°C (from 12.2% to 15.3%). Teri dramatically reduced the use of her plug in heater in favour of the heat pump.

Average living room temperatures increased by approximately 1°C, while bedroom temperatures decreased by a similar amount.

Teri had a small house, good zoning practices and heavy curtains which meant that she was able to manage her heater use relatively efficiency.

However Teri explained that she was uncomfortable in the house due to draughts, cold surfaces and a lack of sunlight. Due to the discomfort Teri felt in the house she had decided to move out as soon as possible in search of a warmer home.

Teri was somewhat involved with her local community and attended a few local community run activities. She found her daughter-in-law the most helpful source of information regarding energy efficiency and other types of technological problems.

Average daily energy use and heating efficiency during winter conditions

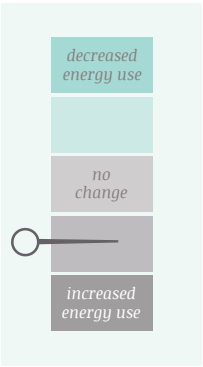
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	4.40	0.22	-4.18	-95.0%
T 41 Heating (hard wired heating)	6.91	9.11	2.20	31.8%
Total Heating	11.31	9.33	-1.98	-17.5%
Other Light and Power (T31)	4.11	4.19	0.07	1.8%
Hot Water	1.98	2.03	0.06	2.9%
Total Household Electricity	17.40	15.55	-1.85	-10.6%
House Heating Efficiency (degree-hours/kWh/day)	0.66	0.83	0.16	24.5%

Average daily temperatures and time in comfort zone during winter conditions

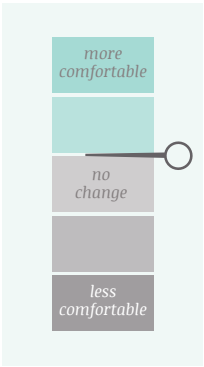
	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	18.8	15.0	9.4	7.5	34.5%
After	19.9	14.2	9.4	7.7	32.6%
Difference between before and after	1.1	-0.8	-0.1	0.2	-1.9%

CASE STUDY 43
Kara

ENERGY USE



COMFORT



Occupants	Own or rent	Bedrooms	House type	Heating
	RENTER		FREESTANDING ONE STOREY	HARDWIRED RESISTIVE

What did we do?

REPRESENTATIVE GROUP

> Well I can't put the heater down any more in the winter when it's cold. I can't keep putting jumpers and jumpers on.
>
> *(After interview, 1 Sep 2015)*

What was the result?

Kara's energy use and comfort practices remained relatively stable over the course of the project. As someone living in NGO-provided housing she had received some basic assistance with draught-proofing which had improved her comfort. Kara wanted more help and would have liked to have received an upgrade. She managed her home well for energy efficiency and thermal comfort given the physical constraints of the house and her financial limitations.

- ✗ Energy use increased by 3.05kWh/day (17.2%), from 17.7kWh/day to 20.75kWh/day.
- ✗ Energy costs increased by ~$54 per year (from $830 to $884).
- ✓ Time spent in the comfort zone increased from 15.8% to 16.9%.
- ✗ Heating efficiency decreased from 0.48 to 0.40 (15.5%).
- ✓ Displayed improved confidence that she could find information on thermal comfort if needed.
- ~ Draughts remained problematic.

Existing physical conditions of the house

Kara's house was well maintained with no sign of mould. Intermittently temperature may have reached dew point and caused surface condensation. Moisture and humidity was not a problem in the living room, but in both the Before and After periods moisture reached 85%. This was a borderline house in terms of moisture problems and the draughts may have actually helped to reduce this. Overall, despite good curtains and solar access, the lack of insulation, single glazing and old inefficient heater meant this house had poor thermal performance.

Type	Stand alone, suburban.
Age	20 – 29 years.
Construction	Brick veneer, corrugated metal roof, suspended timber floor (1m above ground) (vinyl, carpet).
Insulation	Unknown (suspect none).
Windows	Single glazed, aluminium frame.
Window coverings	Heavy curtains (triple layer), vertical blinds in one window for privacy.
Access to sun	Long access north/south, open plan living/dining/kitchen on north end of house, all day sun .
Heating	Rad fan wired-in heater (living), fan heater (bathroom).

Changes to the home

Other changes to the home:

- Used heater more in the winter of 2015.
- Door seals (landlord).
- Attempt to fix heater (landlord).

GET BILL $MART UPGRADES

Not relevant for this participant.

Overview

Kara's house was well-maintained and she had consistent energy use practices. When we first met her, she had just undertaken a substantial change to her routine and was in a transition period. She had significant problems with her heater, which she said 'drove her mad', and didn't think her house functioned in a supportive way. She would have liked to have had an upgrade and some extra help. She had in the past used the local community centre, but she felt less safe in her neighbourhood than she had previously and this stopped her seeking information there.

Kara's use of plug-in heating reduced slightly while her hard-wired heating use increased by 24%. This suggests she was heating her home more than usual, which was consistent with her observation that she used her heater more due to the cold winter. The other changes in her electricity use shown in the energy use table below are likely just due to slight changes in lifestyle patterns and the general dynamic of living in a house.

Although Kara's time in the comfort zone did increase by a small amount, the average temperatures in the living room and bedroom in mid-winter actually fell slightly (by less than 1°).

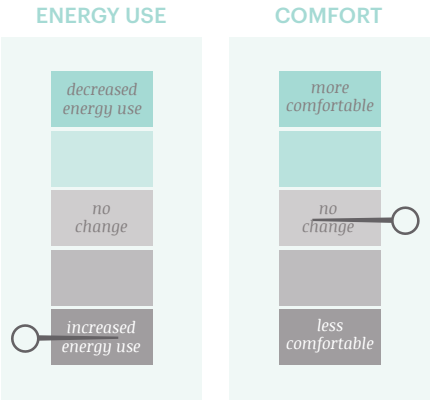
Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.38	0.36	–0.01	–3.2%
T 41 Heating (hard wired heating)	10.32	12.85	2.53	24.5%
Total Heating	10.69	13.21	2.52	23.6%
Other Light and Power (T31)	3.14	3.21	0.07	2.2%
Hot Water	3.87	4.33	0.46	11.9%
Total Household Electricity	17.70	20.75	3.05	17.2%
House Heating Efficiency (degree-hours/kWh/day)	0.48	0.40	–0.07	–15.5%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	16.0	13.0	9.3	5.1	15.8%
After	15.8	12.5	8.8	5.3	16.9%
Difference between before and after	–0.1	–0.5	–0.6	0.2	1.1%

CASE STUDY 44
Martin and Fiona



Occupants	Own or rent	Bedrooms	House type	Heating
	OWNER		FREESTANDING ONE STOREY	HEAT PUMP

What did we do?

REPRESENTATIVE GROUP

> We may have used a little bit more power but that was because it was so cold but overall I don't think, you know, because we've got Pay as You Go I think it's much easier because then you can keep a track of what you get.
>
> *(After Interview 2/9/15)*

What was the result?

Overall, Martin and Fiona thought that they hadn't changed their power use much in the After period because they had not changed their heating practices. The data shows they heated to a higher temperature and thus used more power. The increase may have occurred when their second foster child came to stay during the GBS study period. Despite this change, Fiona had fairly consistent and regular routines for managing comfort and energy in their home. Martin and Fiona foster two children (one a teenager) who, along with Martin, have health issues that Fiona partly manages by keeping the house warm.

- ✗ Energy use increased by 6.51kWh (13.9%), from 46.80kWh/day to 53.31kWh/day.
- ✗ Energy costs increased by ~$55 per year (from $2752 to $2767).
- ✗ Time spent in the comfort zone decreased from 44.9% to 38% (time spent above 24°C in living increased from 76.5% to 86.1%).
- ✗ Heating efficiency decreased from 0.41 to 0.39 (3.3%).
- ✓ Displayed improved confidence that she could find information on thermal comfort.

Existing physical conditions of the house

This home had no moisture issues. In winter the humidity peak was only 45% in the living area (higher in summer, at 70%, when heating was not in use). Humidity in the bedroom was 65% in the Before period and 60% in the After. Overall, even though the house was not well insulated and had single glazing its thermal performance was better than the average in this study (with heat being held inside to some extent) and worked to a poor/near standard level.

Type	Stand alone, suburban.
Age	50-59 years.
Construction	Vinyl with weatherboard under-cladding, cement sheeting under floor skirt, corrugated metal roof, floor (0.6m-1.5m off ground) (timber, tiles, carpet), front and back door deck (both enclosed with plastic blinds).
Insulation	Ceiling (batts).
Windows	Single glazed, aluminium frame, 2 pelmets in kitchen/living.
Window coverings	Vertical blinds and curtains (heavy) in living, all others lace.
Access to sun	North to south long axis, open plan living and kitchen at north end of house, sun into living in afternoon, eastern roofed deck reduces morning sun somewhat.
Heating	Heat pump in old fireplace position.

Changes to the home

Other changes to the home:

- Longer use of heater due to colder winter.
- Extra blankets on the beds.

GET BILL $MART UPGRADES

Not relevant for this participant.

Overview

Martin and Fiona are aged in their 70s. They live in an area of Greater Hobart with a high incidence of fog. They currently care for two foster children, one in high school, who has been living with them for some time, and one in primary school, who arrived during the study period. Their regular heat pump use and consistently-managed home routines meant temperatures and airflow were good and the home was dry with no moisture issues. Martin is a skilled handyman, and he and Fiona have retrofitted their front and back decks with plastic blinds creating a wind block to stop draughts. Prior to the GBS project they had received federally-funded insulation upgrades and had also installed new, heavy curtains that had made a difference. They were already careful in their energy use, cooking outdoors on a gas barbeque because it was cheaper and turning appliances off at the power point when not in use. They reported that their foster children used a lot of hot water in their showers and baths, but hot water usage did decline in the After period.

Martin has previously had a heart attack and so Fiona was careful to use the air-conditioner in hot weather. They use their heat pump to heat the living area in winter; Fiona practices zoning but opens up the bedrooms at night so that heat can flow in. She reported that the heat pump is set on 20, but the average temperatures were much higher than this — in fact, time spent above 24° increased during the study period from an already high 76% to 86%. The average bedroom temperatures, at 19°, were also comparatively high (but actually more healthy than a lot of houses studied). Use of an unmonitored plug-in heater during the study period may have also contributed to the increased energy usage.

Both Martin and Fiona have strong connections in their community. They make regular use of their local community centre and provide assistance and advice to other people in the area. They are actually some of the 'go-to' people in their community. They are also active grandparents and have day to day contact with their children, grandchildren and great grandchildren.

Average daily energy use and heating efficiency during winter conditions

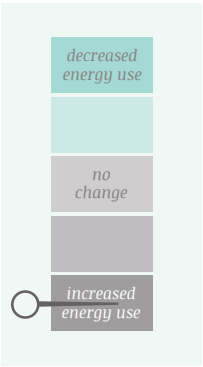
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.00	0.00	0.00	0.0%
T 41 Heating (hard wired heating)	32.53	35.91	3.38	10.4%
Total Heating	32.53	35.91	3.38	10.4%
Other Light and Power (T31)	6.11	9.78	3.67	60.0%
Hot Water	8.16	7.62	–0.54	–6.6%
Total Household Electricity	46.80	53.31	6.51	13.9%
House Heating Efficiency (degree-hours/kWh/day)	0.41	0.39	–0.01	–3.3%

Average daily temperatures and time in comfort zone during winter conditions

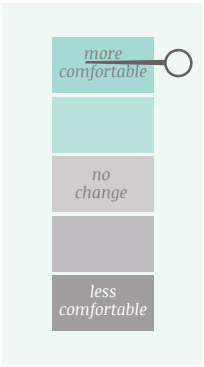
	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	26.3	19.2	9.5	13.2	44.9%
After	26.9	19.0	8.8	14.1	38.0%
Difference between before and after	0.6	–0.2	–0.7	0.9	–6.9%

CASE STUDY 45
Leah

ENERGY USE



COMFORT



Occupants	Own or rent	Bedrooms	House type	Heating
	OWNER WITH MORTGAGE		FREESTANDING ONE STOREY	HEAT PUMP

What did we do?

REPRESENTATIVE GROUP

> I don't even shut my curtains. I just leave them pulled. The only thing I pull down a bit is that blind of a night.
> *(After interview, 7 Sep 2015).*

What was the result?

Leah increased her time spent in the comfort zone as a result of changing her heating practices. Just to see what would happen she began leaving her heat pump on 24 hours a day. As expected this increased her time in the comfort zone, reduced her moisture problems and increased her energy use.

Leah's daughter had suggested she use her curtains, which were of good quality, to reduce heat loss but this was not something Leah had acted on.

✗	Energy use increased by 7.51kWh (24.2%), from 30.96kWh/day to 38.46kWh/day.
✗	Energy costs increased by ~$163 per year (from $1460 to $1623).
✓	Time spent in the comfort zone increased from 50.2% to 79.5%.
✗	Heating efficiency decreased from 0.29 to 0.28 (4.4%).
✗	Displayed reduced confidence that she could find information on thermal comfort if needed.
✓	Displayed improved confidence that she could access information on energy efficiency if needed.
✗	Draughts remained problematic.

Existing physical conditions of the house

This was a well maintained house that, despite insulation, performed poorly due to single glazing, aluminium frames and poor solar access. The house was draughty and had some level of moisture and mould. The dew point was sometimes reached prior to changes in heat pump use but was not a problem in the after period.

Type	Stand alone, suburban.
Age	Unknown
Construction	Concrete block, tiled roof, suspended timber floor (vinyl, carpet).
Insulation	Ceiling only (batts, installed 2009).
Windows	Single glazed, aluminium frame.
Window coverings	Combination lace and curtains, blind (kitchen).
Access to sun	Back covered deck on north-east, living room in south-west, no access to northern winter sun.
Heating	Heat pump, electric blanket (2).

Changes to the home

Other changes to the home:

- Use of heat pump 24/7 as experiment.

GET BILL $MART UPGRADES

Not relevant for this participant.

Overview

In many ways, Leah was not particularly savvy with regard to energy efficiency. Her home was well kept but when we first met her she admitted that she didn't think much about energy use. She started running her heat pump 24 hours a day as an experiment to see what it did to her bill. As expected, her bill increased, but the longer running time also increased her time in the comfort zone — although this was also due to a reduction in time spent above 24°. She seems to have stopped using her plug-in heater in the after period. She did report improved confidence about finding information on energy efficiency and thermal comfort in the after period; although she did not think there was anyone in her community who could specifically help her with these things.

Leah kept her curtains and blinds open all the time. Her daughter suggested that she could make better use of them by closing them at night to keep the heat in, but Leah had not acted on this suggestion.

Leah had a strong sense of community. She was heavily involved with her local community centre, attending classes and recreational activities there. The centre provided transport which made these activities very accessible.

Average daily energy use and heating efficiency during winter conditions

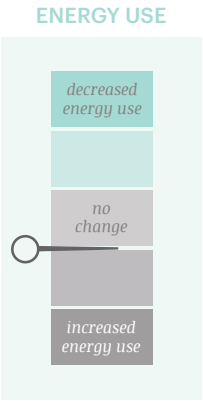
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.96	0.52	–0.44	–45.9%
T 41 Heating (hard wired heating)	20.62	29.42	8.81	42.7%
Total Heating	21.57	29.94	8.37	38.8%
Other Light and Power (T31)	6.51	5.67	–0.84	–12.8%
Hot Water	2.87	2.85	–0.03	–0.9%
Total Household Electricity	30.96	38.46	7.51	24.2%
House Heating Efficiency (degree-hours/kWh/day)	0.29	0.28	–0.01	–4.4%

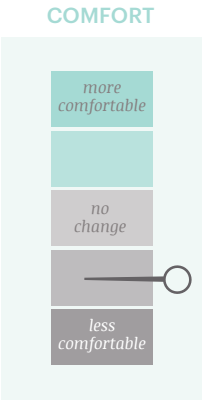
Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	19.8	15.8	11.5	6.3	50.2%
After	22.0	17.9	11.6	8.3	79.5%
Difference between before and after	2.1	2.2	0.1	2.0	29.3%

CASE STUDY 46

Terrance and daughter





Occupants	Own or rent	Bedrooms	House type	Heating
	RENTER		FREESTANDING ONE STOREY	GAS HEATER

What did we do?

REPRESENTATIVE GROUP

I don't know, I'd be interested to find out what the insulation is like. Obviously it's not my house so I don't know how well insulated it is. I reckon probably most of the heat loss comes from the windows, so if it was my house I would consider things like double glazing and stuff like that, but obviously it's not mine so...

(After Interview 24/8/15)

What was the result?

Terrance and his daughter's energy use increased slightly. Because they were renters they did not really consider changing anything and he was happy to pay for the heating they needed. Despite his willingness to do this, they only spent around 30% of time in the comfort zone.

✗	Energy use increased by a slight 0.45kWh/day (1.6%) from 21.66kWh/day to 22.01kWh/day (all gas energy is included here – gas use was converted into kWh for comparison).
✗	Energy costs increased by ~$31 per year ($841-$872).
✗	Time spent in the comfort zone reduced slightly from 33.0% to 30.0%.
✓	Heating efficiency increased from 0.11 to 0.10 (6.7%).
✓	Displayed improved confidence that he could find information on thermal comfort and energy efficiency if needed.
✓	Draughts reduced.

Existing physical conditions of the house

Terrance's house was one story 1930s-style with a split level living room extension added over ten years ago. The house had gas heating, hot water and cooking.
The family had no problems with dew point as temperature clearly stayed away from dew point. Humidity peaked in the living room at 75% before and 70% after GBS activities, but winter tended to be under 65% humidity before and after.

Despite double brick walls, which would assist to slow heat loss down, the southern living room, single glazing, split level open plan (which creates stack effect) and the minimal insulation lead to a poor thermal performance.

Type	Stand alone, suburban.
Age	30-40 (extension) – original approximately 90 years old.
Construction	Double brick walls in original section, weatherboard timber frame in extension, corrugated metal roof, suspended timber floor (0.1-1.0m off ground) (carpet and vinyl cover). Split level between original house and living room extension.
Insulation	Part of ceiling has 100mm cellulose.
Windows	Single glazed, timber frame, skylight in kitchen.
Window coverings	Curtains (heavy) in living areas, blinds in dining, curtains + blinds in bedrooms.
Access to sun	All day sun, long axis northwest to south east, living on south east (3 external walls) so morning sun, living open plan with kitchen.
Heating	Gas ducted heating through house, electric blankets.

Changes to the home

Other changes to the home:

- No changes made.

GET BILL $MART UPGRADES

Not relevant for this participant.

Overview

Terrance and his teenage daughter were renting their house from a friend who was overseas.

Terrance valued a warm home and was happy to heat the house on demand.

Terrance and his daughter relied heavily on gas. Gas was used for heating, hot water and cooking. In the table below, gas was converted to kWh for comparative purposes.

Gas heating was estimated at 73.47kWh/day before and 81.36kWh/day after. Gas ducted heating also used electricity for ignition, fan and thermostats (2.27kWh/day to 2.43kWh/day).

The average temperatures in Terrance's home sit within, or are close to, the comfort zone. Given he has a ducted heating system with thermostat controls he is able to maintain fairly constant temperatures (which he does).

While Terrance had high levels of control over his comfort he also used a huge amount of energy to do so, indeed he is one of the highest energy users in the study.

Total heating energy increased by 10.6% in after period. This may have been because his teenage daughter lived with him more often. Terrance was also studying and this may have increased the time he spent in the home.

Average daily energy use and heating efficiency during winter conditions

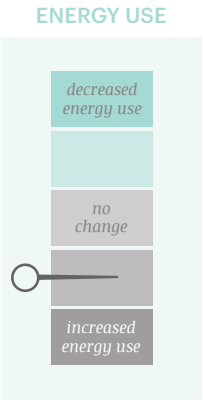
	Before	After	Change
	(kWh/day)	(kWh/day)	(%)
T 31 Heating (plug in heating)	2.35	2.49	6.0%
T 41 Heating (hard wired heating)	0.00	0.00	0.0%
Total Heating	75.82[1]	83.85	10.6%
Other Light and Power (T31)	8.20	8.41	2.4%
Hot Water	11.11	11.11	0.0%
Total Household Electricity	21.66	22.01	1.6%
House Heating Efficiency (degree-hours/kWh/day)	0.11	0.10	-6.7%

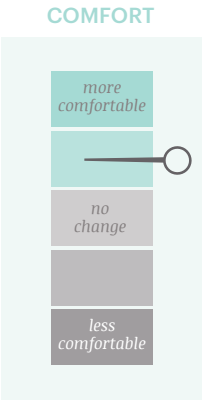
[1] This number includes gas energy converted to kWh. The electrical energy used to run the ducted gas heating system and fans, is listed in T 31 heating line.

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Study Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	18.9	15.1	18.9	9.3	8.4	33.0%
After	17.9	15.6	18.5	8.7	8.6	30.0%
Difference between before and after	-1.0	0.6	-0.3	-0.5	0.3	-3.0%

CASE STUDY 47
Phillip





Occupants	Own or rent	Bedrooms	House type	Heating
	OWNER WITH MORTGAGE		FREESTANDING ONE STOREY	HARDWIRED RESISTIVE + HEAT PUMP

What did we do?

REPRESENTATIVE GROUP

> As long as I don't have any unexpected dramas [I can manage on my low income], as in, if say for instance one of the family members came back or something like that, it might be a bit different. The change would be out of my control, whatever it is.
>
> *(After Interview 24/08/15)*

What was the result?

Despite his house being of standard construction, Phillip's home upgrades and careful energy management allow him to spend high levels of time in the comfort zone and to use his heater very efficiently. Phillip's ill health meant he relied on maintaining comfort "I couldn't have survived without the heating." Phillip shared energy efficient ideas with a couple of close friends who also worked towards energy efficiency. Phillip's reduction of income had been the catalyst for his focus on efficiency.

- ✗ Energy use increased by 0.85kWh/day (4%) from 21.32kWh/day to 22.18kWh/day.
- ✓ Energy costs reduced by ~$842 per year ($1984-$1142).
- ✓ Time spent in the comfort zone increased from 92.4% to 98.2%.
- ✓ Heating efficiency increased from 0.76 to 0.88 (16.4%).
- ✓ Displayed improved confidence that he could find information on comfort and energy efficiency if needed.

Existing physical conditions of the house

Phillip slept in his caravan (with a plug in heater) while his daughter and her partner lived in his home. Despite the age of the house and single glazing, Phillip's deciduous tree, living room position and heat pump all helped to make this house function thermally at a near-to-standard level.

Type	Stand alone, suburban.
Age	30-39 years.
Construction	Brick veneer, timber frame, tiles, concrete slab (vinyl, carpet).
Insulation	Ceiling only (batts).
Windows	Single glazed, aluminium frame.
Window coverings	Venetian blinds and curtains in all rooms.
Access to sun	Morning sun, main living access north east, skylight in living room.
Heating	Heat pump, column heater in main house, column heater in caravan, halogen heat lamps.

Changes to the home

Other changes to the home:

- Phillip's adult daughter and partner moved out of his house.
- Installed wood and glass barriers to windows in living area.
- Placed bookcases against walls for insulation.
- Partitioned heater areas so they were smaller areas to heat.

GET BILL $MART UPGRADES

Not relevant for this participant.

Overview

When we first met Phillip he shared his house with his daughter and her partner. During this time Phillip slept in a caravan parked outside and used a plug in heater in the van. Phillip found that he had much less control of the household energy use while his family stayed with him. He explained that his daughter used a lot more hot water than he did and this is reflected in the nearly 10% reduction in hot water use in the after period. Interestingly total hot water use in the before and after periods is still relatively low.

Phillip was incredibly careful with energy use and the management of thermal comfort in his home. "I couldn't have survived without the heating," Phillip explained. He struggled with depression and as a result needed to keep his house warm at all times. That he did this is evident in the time spent in the comfort zone (98%). His spaces rarely went above the comfort zone. This was due to Phillip carefully thinking through where he had to sit to get the best from his heating and careful about management of heat flow through the house. The living and the bedroom (where we logged temperatures) were the two main areas he heated.

Efficiency remains good despite high levels of heating and this is likely due to Phillip's very careful management of heat in his home. He was constantly thinking of new ways to improve comfort and to be energy efficient. This continual improvement was supported by a couple of friends who he shared energy efficiency ideas with. Phillip was working towards energy efficient changes throughout the house by gradually making small things changes, for example he put plastic in between kitchen and living area and blankets on the top of wardrobes to stop heat flow.

Phillip explained that he became much more aware of energy efficiency when his income had reduced a number of years before. He found that being efficient allowed him to live on his low income fairly well.

Phillip's time in the comfort zone increased and his overall energy use increased as a result. Phillip's careful comfort management of the home and his endeavours to insulate and zone wherever possible is also visible in the improved time spent in the comfort zone.

Average daily energy use and heating efficiency during winter conditions

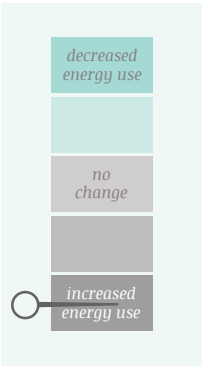
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	3.12	1.18	-1.94	-62.2%
T 41 Heating (hard wired heating)	9.62	12.03	2.41	25.0%
Total Heating	12.74	13.21	0.47	3.7%
Other Light and Power (T31)	4.96	5.69	0.73	14.8%
Hot Water	3.62	3.27	-0.35	-9.7%
Total Household Electricity	21.32	22.18	0.85	4.0%
House Heating Efficiency (degree-hours/kWh/day)	0.76	0.88	0.12	16.4%

Average daily temperatures and time in comfort zone during winter conditions

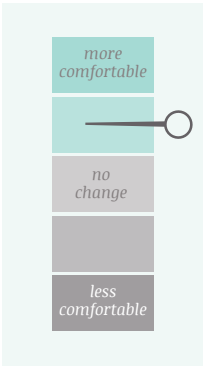
	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	20.3	19.1	10.0	9.6	92.4%
After	21.7	20.2	9.3	11.6	98.2%
Difference between before and after	1.4	1.1	-0.7	2.0	5.8%

CASE STUDY 48
Gina

ENERGY USE



COMFORT



Occupants	Own or rent	Bedrooms	House type	Heating
	OWNER		FREESTANDING TWO STOREYS	WOOD FIRE + HEAT PUMP

What did we do?

REPRESENTATIVE GROUP

> Yeah, I've had that on all the time on the lowest of the heat, it's on 18 all the time, and I have the bedroom doors shut too in the day normally and open them at night and that warms my bedroom. I shut my bathroom doors and it's freezing to go out to the toilet in the middle of the night, but that warms the bedroom. It certainly warms upstairs but there's no one up there. *(After Interview, 31 Aug 2015)*

What was the result?

Gina's energy use decreased dramatically, by nearly 50%. This is likely due to the departure of her granddaughter and because Gina no longer heats the shed outside for craft activities.

While her electricity use has decreased, Gina is actually spending more time above the comfort zone. This is in part because she has a wood heater.

- ✔ Energy use increased by 48.01kWh/day (49.7%), from 96.54kWh/day to 48.53kWh/day.
- ✔ Energy costs reduced by ~$37 per year (from $2667 to $2630).
- ✘ Time spent in the comfort zone decreased from 25.3% to 23.4% (more time spent above 24°C in living from 36% to 55%).
- ~ Given the wood heater, heating efficiency is not accurately measured for this home.
- ✔ Displayed improved confidence that she could find information on energy efficiency if needed.

Existing physical conditions of the house

This house has been well maintained however in recent years this has been more difficult after the death of Gina's husband and her own ill health. Due to old insulation, single glazing and lack of good year-round solar access, the thermal performance of this house was poor.

Type	Stand alone, suburban on very large suburban block.
Age	Approximately 40 years old.
Construction	Timber/brick walls, some timber framed, some triple brick, shingles/corrugated metal, timber suspended floors (300mm), some concrete slab (tiles/carpet).
Insulation	Ceiling insulation (batts – old), wall (batts and sisalation – old).
Windows	Single glazed, timber frame.
Window coverings	Curtains (bedrooms), exterior blinds kitchen/sun room.
Access to sun	Trees to the north east and north west that affected winter sun, living room on south west, open verandas around the living area which would have blocked sun, little direct sun to living room, 2 skylights.
Heating	Heat pump (living), wood fire (living), electric radiant (bathroom, other), fan heater.

Changes to the home

Other changes to the home:

- Granddaughter moved out.
- Changes to heating temperatures and use due to serious illness.
- Moved an outside heater inside – stopped using the shed for craft.

GET BILL $MART UPGRADES

Not relevant for this participant.

Overview

Gina's health was not good and she had felt a lot more vulnerable to cold in recent times due to her illness and ageing. It had also been a particularly cold winter in 2015. She had practical help and support from her family, but most of them lived on the mainland so could provide regular help. The family were not in a position to financially assist either. She has plans to sell her home soon and as a result was using some energy on maintaining a (mostly unused) swimming pool in order to keep it looking respectable. Although she was heavily involved in local community activities, she said she would prefer to ask her family for help first.

Gina uses both a wood heater and a heat pump, although she finds it increasingly difficult to manage the wood heater. She uses bottled gas to cook with.

She said she thought she was using her heater a lot more but that comfort was very important. Her time in the comfort zone actually decreased, but this was mostly because she spent more time above 24° (from 36% to 55%).

Gina's energy use, including heating use, and the moisture levels on her windows reduced dramatically during the study. This is most likely due to a long hospital stay, her granddaughter moving out, no longer spending time doing craft in the shed (which had been heated) and increased use of zoning due to living alone and having limited mobility. However, her use of the wood heater obscures the scale of these changes.

Average daily energy use and heating efficiency during winter conditions

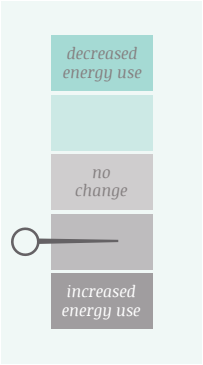
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.00	0.00	0.00	0.0%
T 41 Heating (hard wired heating)	38.67	28.54	–10.13	–26.2%
Total Heating	38.67	28.54	–10.13	–26.2%
Other Light and Power (T31)	39.49	13.10	–26.39	–66.8%
Hot Water	18.37	6.88	–11.49	–62.5%
Total Household Electricity	96.54	48.53	–48.01	–49.7%
House Heating Efficiency (degree-hours/kWh/day)	0.24	0.39	0.15	63.7%

Average daily temperatures and time in comfort zone during winter conditions

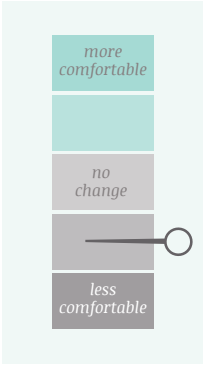
	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	22.3	14.4	9.1	9.2	25.3%
After	23.8	15.5	8.6	11.1	23.4%
Difference between before and after	1.6	1.2	–0.5	1.9	–2.0%

CASE STUDY 49
Anna

ENERGY USE



COMFORT



Occupants	Own or rent	Bedrooms	House type	Heating
	OWNER		FREESTANDING ONE STOREY	GAS HEATER

What did we do?

REPRESENTATIVE GROUP

> I feel more cold and I'm most of the time sick during the winter and I think it's because of the house. I cannot leave the heater 24 hours, it costs a fortune.
> *(After interview, 31 Aug 2015)*

What was the result?

Anna decreased the time she spent in the comfort zone and continued to feel cold in her home. It is likely she reduced her gas heating in order to save money as her energy bills were a huge source of stress. Anna was cold and financially stressed in her home due to its poor thermal performance, thin curtains that were rarely used, and a low income.

- ✗ Electricity use increased by 0.66kWh (13.7%), from 4.80kWh/day to 5.46kWh/day.
- ✗ Electricity costs increased by ~$48 per year (from $369 to $417).
- ✗ Time spent in the comfort zone decreased from 19.7% to 12.7%.
- ~ Given the gas ducted heating, heating efficiency is not accurately measured for this home.
- ✓ Displayed improved confidence that she could find information on thermal comfort and energy efficiency if needed.
- ✗ Draughts remained problematic.
- ✗ Self-reported moisture and mould remained high.

Existing physical conditions of the house

This house was very draughty, with draughts through the floorboards, doors and windows. Some windows did not close properly. High levels of moisture and mould were reported, with humidity peaking at 80-85% in the after period. Temperatures were very close to dew point. The performance of this house was very poor.

Type	Stand alone, suburban.
Age	60+ years.
Construction	Weatherboard, timber frame, corrugated metal rood, suspended timber floor (tiles, polished timber), underfloor enclosed by brick wall.
Insulation	Unknown (suspect none).
Windows	Single glazed, steel frame.
Window coverings	Curtains (living room light, other rooms lace), lightweight blinds.
Access to sun	Northern living room sun access all day, afternoon sun in the kitchen, morning sun in bedrooms.
Heating	Gas ducted heating, plug-in electric.

Changes to the home

Other changes to the home:

- Worked hard not to increase power use due to concern about cost.

GET BILL $MART UPGRADES

Not relevant for this participant.

Overview

Anna was in her 80s. She felt the cold and suffered from various illnesses as a result. Her house was very draughty and had issues with condensation. She did not close the curtains because she liked to be able to look out and thought heavy curtains were ugly; yet, closing curtains would have significantly increased the thermal efficiency of her home. She tried to reduce energy use by turning appliances off at the power point when not in use and only heating the amount of water that she needed. She had also tried to install draught-proofing but found this difficult and the draught-proofing material fell off. She may also have stopped using one plug-in heater and changed it for another.

Anna uses gas for both heating and cooking. She was very stressed about her gas bill and her efforts to reduce it probably account for the reduction in time spent in the comfort zone. Similarly, although Anna's electricity usage increased, it is likely that when her gas usage is taken into account, her overall energy use decreased. (Lack of access to Anna's gas bills means this cannot be confirmed).

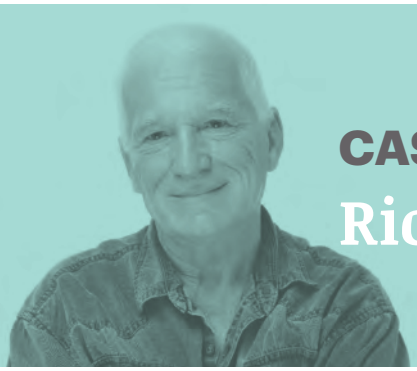
Anna's sense that there were people she could ask about energy efficiency and thermal comfort improved, but she did not think she had a strong community she could call upon when needed. Although she did have children who would look after her, she felt strongly the contrast between life in her original home of France and life in Australia; she thought that in Australia as an older person she was not cared for by the community.

Average daily energy use and heating efficiency during winter conditions

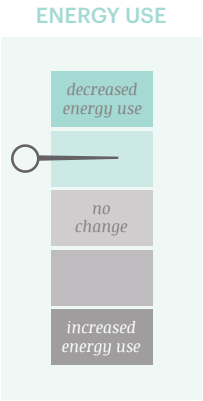
	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	1.50	1.38	–0.12	–8.1%
T 41 Heating (hard wired heating)	0.00	0.00	0.00	0.0%
Total Heating	1.50	1.38	–0.12	–8.1%
Other Light and Power (T31)	3.16	3.84	0.68	21.4%
Hot Water	0.14	0.24	0.10	72.5%
Total Household Electricity	4.80	5.46	0.66	13.7%
House Heating Efficiency (degree-hours/kWh/day)	4.54	4.96	0.42	9.3%

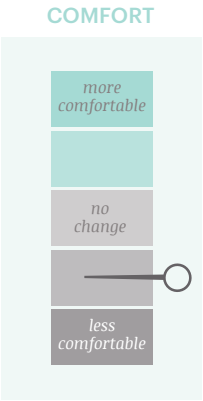
Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	15.1	15.5	8.5	6.8	19.7%
After	14.0	14.6	7.5	6.8	12.7%
Difference between before and after	–1.1	–0.8	–1.0	0.0	–7.1%



CASE STUDY 50
Richard and Deanne





Occupants	Own or rent	Bedrooms	House type	Heating
	OWNER		FREESTANDING ONE STOREY	PLUG-IN ELECTRIC + HARDWIRED RESISTIVE

What did we do?

REPRESENTATIVE GROUP

> But it would be very nice just to be comfortable [financially] so we didn't have to worry so much about if she's not well or of course I don't mind staying home or whatever but I'd like to have things set up so she didn't have to work too hard. Just making sure the comfort level can be met.
>
> *(Before Interview 25/05/2014)*

What was the result?

Richard and Deanne lived in a house that was very draughty and very difficult to keep warm and cost them lots in heating energy. On their limited budget, making improvements was very difficult, but they were renovating anyway. Renovations meant that things changed in the house quite regularly creating a dynamic living environment. Richard and Deanne would have benefitted from energy efficiency information to help them in their reworking of the house.

- ✔ Energy use reduced by 4.45kWh/day (7.3%) from 60.76kWh/day to 56.31kWh/day.
- ~ Self-reported energy costs remained the same (no billing data available for this participant).
- ✘ Time spent in the comfort zone decreased from 27.3% to 10.6%.
- ✘ Heating efficiency decreased from 0.14 to 0.12 (17.5%) – very low.
- ✔ Displayed improved confidence that she could find information on energy efficiency and comfort.
- ~ Draughts under doors.

Existing physical conditions of the house

Richard and Deanne live in a standalone suburban house on a standard block. Approximately 50 years old, the house is timber framed with weatherboard cladding, suspended timber floors (with carpet and vinyl), on a brick plinth and a corrugated metal roof. The house also had a skylight in the hallway. The house is on a main road with a train line near, so has reasonable access to sun. The long axis of the house sits northwest to south west. The living room is on the north corner of the house in open plan with the kitchen and dining areas which, sits on the west corner. The living and dining areas had access to sun most of the day. Heating was provided by an old radiant fan wired in heater in the living, a plug in radiant fan heater in the dining/living, wired in radiant strip heaters in the study, spare bedroom and bathroom and electric blankets.

Despite a reasonably well positioned living area, the lack of insulation, single glazing and poor choices for heating and other features lead to this house performing poorly thermally.

Insulation	External walls of dining area only (batts added in 2013).	VERY POOR
Windows	Single glazed, aluminium and timber frames, no pelmets.	POOR
Window coverings	Roller blinds (kitchen and dining) and curtains (heavy weight) varying condition other areas.	POOR
Under floor space	Suspended timber floor (at 1.0m high), underfloor enclosed with brick, no insulation.	POOR
Mould and moisture	Mould in toilet only. Measures show intermittent chance for temp to reach dew point and high humidity peaks in winter at 80 in bedroom before and after and 70% to 80% in after period in living area.	POOR
Other conditions of note	Currently renovating to update and improve condition.	
	Draughts under doors and due to work on going as part of renovation.	POOR

Changes to the home

Other changes to the home:

- Richard and Deanne purchased a new plug in heater and reduced the use of their wired in heater.
- The house was subject to ongoing renovations.

GET BILL SMART UPGRADES

Not relevant for this participant.

Average daily energy use and heating efficiency during winter conditions

	Before	After	Change
	(kWh/day)	(kWh/day)	(%)
T 31 Heating (plug in heating)	35.25	38.62	9.6%
T 41 Heating (hard wired heating)	4.80	3.38	-29.5%
Total Heating	40.04	42.00	4.9%
Other Light and Power (T31)	10.70	3.80	-64.5%
Hot Water	10.02	10.51	4.9%
Total Household Electricity	60.76	56.31	-7.3%
House Heating Efficiency (degree-hours/kWh/day)	0.14	0.12	-17.5%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	17.7	12.6	9.4	5.8	27.3%
After	14.7	12.9	8.8	5.0	10.8%
Difference between before and after	-3.0	0.3	-0.6	-0.8	-16.5%

Total Household Electricity reduced by 4.45 kWh/day from 60.76kWh/day to 56.31kWh/day (-7.3%). Hard wired heater use reduced by 1.42 kWh/day, while plug in heating use increased by 3.7kWh/day (9.6%). Richard and Deanne relied heavily on plug in heaters as the hard wired heater was old, very energy intensive and not very effective.

Heating efficiency went down slightly from 0.14-0.12. This is a poor heating efficiency ratio. Richard and Deanne's wired in and plug in heaters were not heating spaces efficiently. In the living room because their wired in heater was so ineffective they often used plug in heating. The average daily heating energy suggests that they would have used heating for a long period every day. The intensity of heater use can be seen in the before and after examples graphs. While some of this heating was localised and would not have registered fully on the temperature loggers, some effect would be seen.

Living room average winter temps reduced from 17.7 to 14.7°C in the after period. The bedroom stayed more stable going from 12.6 to 12.9°C. These averages are much lower than average and median for the Greater Hobart no upgrade group and also the overall detailed study group.

Aligned with this percentages of time spent in the comfort zone reduced noticeably in the after period from 27.3% to 10.8% (with negligible time spent above the comfort zone at all). This is a small % of time in the comfort zone, especially considering the heating being used.

Energy and comfort

Richard and Deanne were in the middle of home renovations and throughout the project had different areas of the house being fixed and adjusted. This would have contributed to poor heating efficiency, and the reduction in temperatures and time in comfort zone. General poor thermal performance of the building shell would also have undermined efficiency and temperatures.

Electricity used on the Other Light and Power circuit decreased substantially from 10.7kWh/day to 3.8kWh/day, a change of 64.5%. This decrease may have been due to different appliance and equipment use in the home as dictated by the renovations, or possibly due to an unknown heater being used before and not after. Some stages of building renovations are likely to be more energy intensive than others and have required different heating practices.

Richard and Deanne's household was quite dynamic over the period of the project due to their renovations and Deanne stopping her casual work. These changes would have all affected energy use and comfort in the house in different ways.

Moisture in the house did not appear to be a big problem, although mould was noted in the toilet. Measures show intermittent times where temp could reach dew point and some high humidity peaks in winter at 80 in bedroom before and after and 70% (before) to 80% (after) in the kitchen area. As with other houses surface condensation was still likely to occur at intervals due to the poor thermal performance of the building skin.

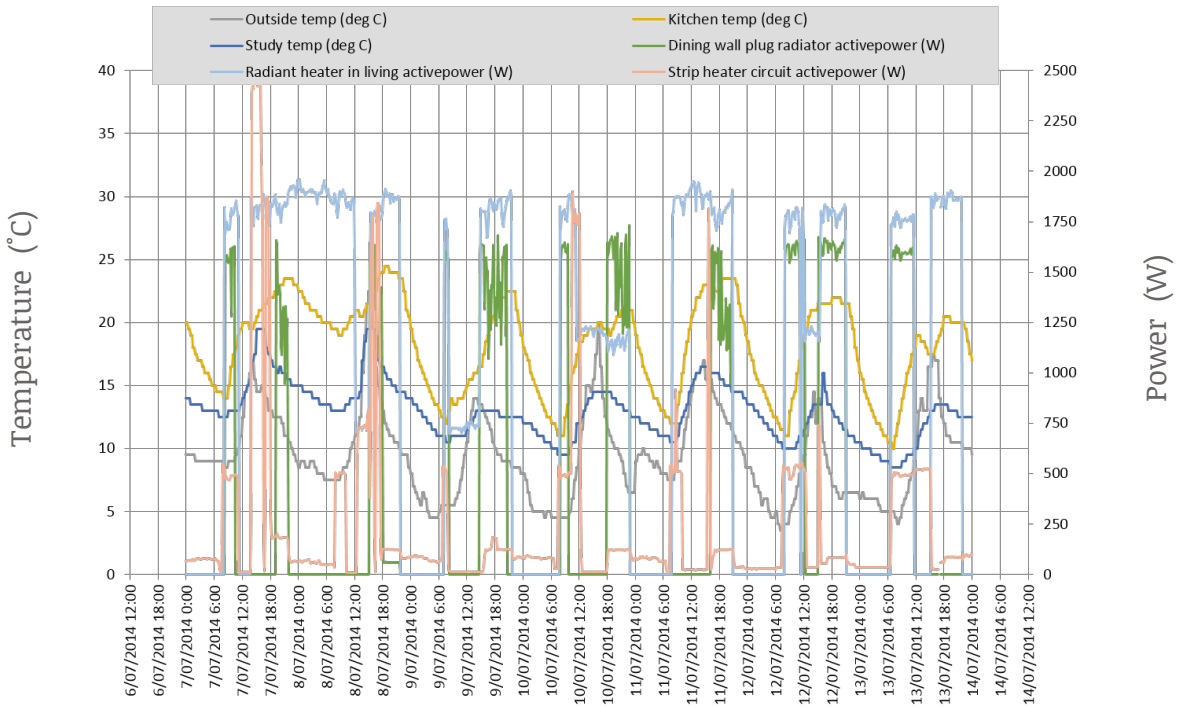
It takes a couple of hours at least [to heat the house up].

(Before Interview 25/05/2014)

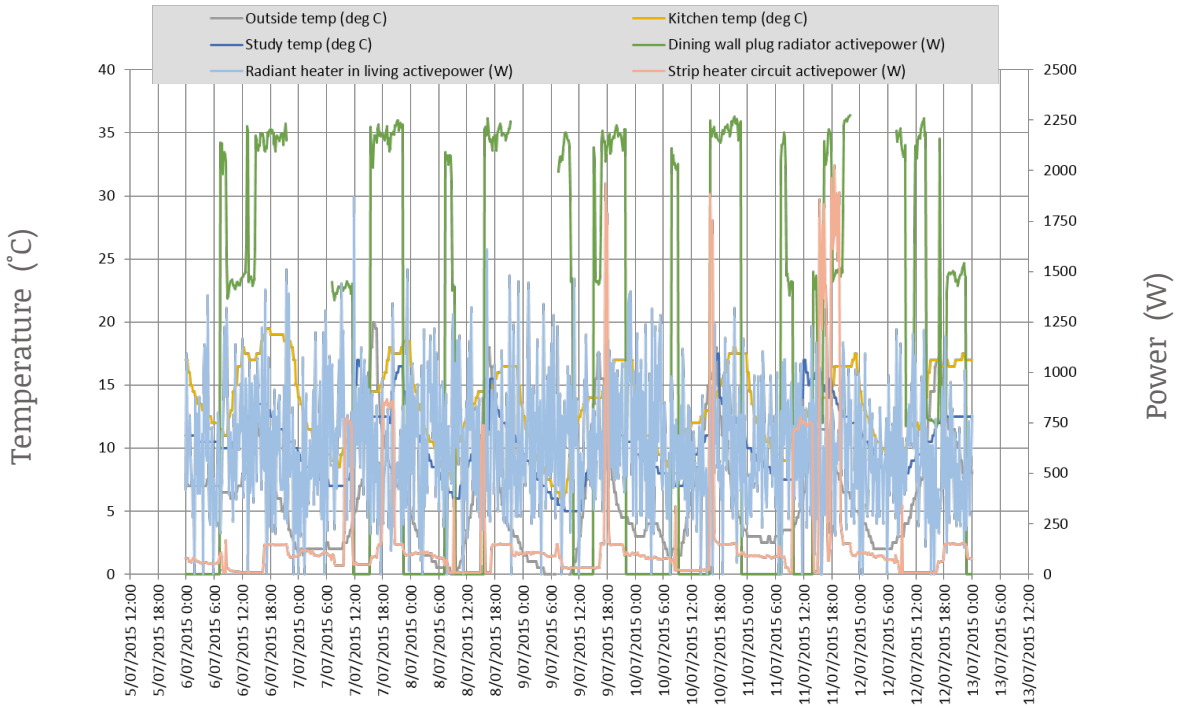
"I'd like to get away as much as I could from depending upon hydroelectric power just to do the heating as well. I'd like to have something a little bit more independent.

(Before Interview 25/05/2014)

Before period: example week in winter showing selected energy use and temperature readings



After period: example week in winter showing selected energy use and temperature readings



Energy affordability

Richard and Deanne used a large amount of electricity. Richard explained that their energy bills showed them their relatively high use:

> When I get my power bill they give you the rating for two people or three people to have or whatever. The last couple of times there's been enough for six people in our house. So it's too much for us two people. *(Before Interview 25/05/2014)*

No energy billing data was available for Richard and Deanne but they were certain that their energy use had not changed at all over the course of the project. The electricity use data discussed above indicates that energy use did decline in the house and that Richard and Deanne are likely to have had slightly lower bills.

A decrease in bills would have been greatly appreciated by Richard and Deanne although they had careful systems in place to keep up payments:

> I have money taken out of the bank to pay for the power each fortnight. So at the moment it's been keeping pace because I don't have bills. I just have deductions the whole time.
>
> *(Before Interview 25/05/2014)*

Personal and community change

Richard and Deanne are a retired couple in their sixties. Deanne retired from a casual job partway through this project. While on a low income, Richard and Deanne are slowly renovating their house as the funds become available.

In doing their renovations Richard and Deanne have been conscious of trying to improve their comfort and energy efficiency. Deanne explained that she would like to replace the large living room windows on the north east of the house with smaller windows. When asked why she wanted to do this she explained that:

> You don't need the big windows, cold and heat, you don't need them big.
>
> *(After Interview 01/09/2015)*

It is likely that Richard and Deanne felt so cold in their house due to draughts and little thermal resistance. Sitting near the large windows in the living room, they were likely to have felt cold due to the cold radiant temperature of the windows. While replacing the windows would reduce heat loss, smaller windows would also limit the amount of sun that could heat the house. Richard and Deanne were conscious of energy efficiency and thermal comfort but perhaps not quite aware of all the potential implications of different changes.

When we visited them in September 2015 the curtains to the living area were closed during the day suggesting they may not have made much use of sunlight.

Personal and community change

Richard and Deanne were clearly frustrated by the house and the way that it performed. While doing their best to improve things on their limited budget, they explained:

> We do use too much [electricity]. Not knowing how to [reduce electricity use] because of the house and everything else. We just need to win lotto and move out.
>
> *(Before Interview 25/05/2014)*

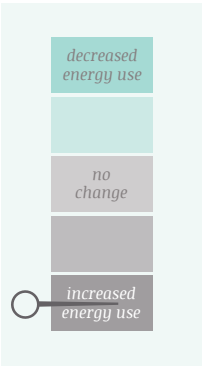
Deanne expressed a clear sense that they lived in a strongly connected community. They had good family connections close by and while they did not really know their neighbours, Deanne felt that she knew where to go to seek advice on energy efficiency and thermal comfort. Both she and Richard said that they would go to the local shops and talk to the gas suppliers or go to the energy supplier directly.

Richard and Deanne also received help from Community Base Support, a free support service for people with mental or physical challenges and their carers. This indicates there may have been some changes to the health situation of the householders and this may have affected energy use.

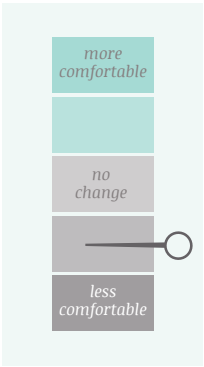
Richard and Deanne lived in a house that was very draughty and very difficult to keep warm. On their limited budget they were slowly making renovations to their home. Mostly these renovations are likely to improve their comfort and energy efficiency but limits to their technical knowledge limited their capacity for this somewhat.

CASE STUDY 51
Irene

ENERGY USE



COMFORT



Occupants	Own or rent	Bedrooms	House type	Heating
	OWNER WITH MORTGAGE		FREESTANDING ONE STOREY	HEAT PUMP

What did we do?

REPRESENTATIVE GROUP

[I don't put the heater on during the day] if I can help it; unless some visitors are coming around. But I didn't have very many visitors. Perhaps once I did put it on at 4pm – I couldn't bear it any longer. But I was using the computer so I was getting a bit cold so I put a water bottle on my lap and a blanket, one of these throw rugs, and kept warm like that and just layered up.

(After Interview 07/09/2015)

What was the result?

Irene continued to live in a very cold house (well below her desired comfort levels) even with an increased use of heating. Her heating was inefficient and her low income made any changes or improvements impossible, despite her desire for a more efficient heater.

✗	Energy use increased by 9.09kWh/day (43%) from 20.81kWh/day to 29.9kWh/day.
✓	Energy costs reduced by ~$87 per year (based on estimated rather than actual data supplied by the energy provider).
✗	Time spent in comfort zone decreased from 7.7% to 7.2%.
✗	Heating efficiency decreased from 0.77 to 0.41 (47.1%).
✗	Displayed decreased confidence that she could find information on thermal comfort if required.
✓	Displayed increased confidence she could find information on energy efficiency if required.
~	Possible surface condensation (but may just avoid) – measures show temp regularly comes close to dew point in living and bedroom, but humidity peak is 75% (which is ok).
✗	Draughts remained a problem

Existing physical conditions of the house

Irene lives in a stand alone house that is approximately 30 years old. The house sits on a steep slope that falls to the north. A split level open plan house; it is constructed with brick veneer, a tile roof, and suspended timber floors (with carpet and vinyl).

The long axis of the house is almost east to west and the living room sits on the north with solar access from the north (but Irene appeared to keep curtains drawn a lot). Bedrooms sat to the south of the house. The living room is on the lower level and is open plan to the kitchen and the corridor spaces, which lead to the higher level bedroom area. As the corridor to the bedrooms is open to the living area, Irene finds that heat easily flows through and up. Heating is provided by the original (now inefficient) heat pump that is as old as the house (likely one of the first heat pumps produced for homes).

With a lack of insulation, single glazing, an old heater and living room heat moving quickly away into corridors and bedrooms (up the split level) this house has a very poor thermal performance.

Insulation	Ceiling (batts) only.	POOR
Windows	Single glazed, aluminium frames, no pelmets.	POOR
Window coverings	Lace and heavy curtains (living and bedrooms), kitchen blind.	NEAR STANDARD
Under floor space	Suspended floor, underfloor enclosed with brick wall, no insulation.	POOR
Mould and moisture	Possible surface condensation – temperature regularly close to dew point, humidity peak 75% (peak slightly worse after period).	POOR
Other conditions of note	Very old built in heater – upgrading this would require filling in a wall and some other major adjustments.	POOR
	Draughts and stack effect from open plan, split level and cracks in bathroom wall.	POOR

Changes to the home

Other changes to the home:

- Irene has tried to stop using her heater during the day.
- Changed work hours mean that Irene is home more often in the evenings.
- Irene replaced her fridge with a smaller second hand one.
- Irene has a new television.

GET BILL SMART UPGRADES

Not relevant for this participant.

Average daily energy use and heating efficiency during winter conditions

	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
T 31 Heating (plug in heating)	0.15	0.35	0.19	125.2%
T 41 Heating (hard wired heating)	4.85	9.75	4.90	100.9%
Total Heating	5.00	10.09	5.09	101.6%
Other Light and Power (T31)	10.99	13.65	2.66	24.2%
Hot Water	4.81	6.16	1.35	28.0%
Total Household Electricity	20.81	29.90	9.09	43.7%
House Heating Efficiency (degree-hours/kWh/day)	0.77	0.41	-0.36	-47.1%

Average daily temperatures and time in comfort zone during winter conditions

	Living Temp (°C)	Bedroom Temp (°C)	Outdoor Temp (°C)	Avg out/in temp diff (°C)	% time in comfort zone (18°C – 24°C)
Before	14.1	10.8	8.6	3.8	7.7%
After	13.9	11.0	8.4	4.1	7.2%
Difference between before and after	-0.1	0.2	-0.2	0.3	-0.6%

Referring to the tables and graphs presented, multiple changes were noted. Total Household Electricity use increased by 9.09 kWh/day from 20.81kWh/day to 29.90kWh/day (43.7%). The increase in overall energy use is likely due Irene's changed employment patterns – she spent more time in her home in the after period.

Total heating increased by 101.6% with the bulk of this due to increased use in the heat pump (from 4.85kWh/day to 9.75kWh/day). Plug in heater (which was electric blankets in this instance) use increased very slightly from a low 0.15kWh/day to (also low) 0.35kWh/day. Heating efficiency greatly reduced in the after period as substantially more heating was used which stretched the capacity of the house to retain the heat. The heater being used was also very old and not very efficient due to its age and its need of maintenance.

People think I'm funny. I went around to my friend's place who had a log fire and I've got this blanket on and they reckon 'Oh it's not cold'. To me, I was... you know, it's just my body temperature, I think. Perhaps when you get older, you feel really cool.

(After Interview 07/09/2015)

Energy and comfort

With the significant increase in heating Irene didn't really have a corresponding increase in heating efficiency or comfort in general. Heating efficiency reduced 0.77 to 0.41 (-0.36, -47.1%). Graphs show that she did not necessarily heat to higher temperatures, but more likely heated more frequently to the same sorts of temperature limits. The lack of an increase in heating efficiency with this sort of increase in energy use is notable and likely indicates something like a window was being left open or a new significant draught had developed. Irene mentioned there was a crack in the bathroom wall and that she kept windows in unused spare bedrooms slightly open. These would both create draughts.

There was around 4°C temperature difference between indoor and outdoor in this house. While better than some houses in this study, this difference is still indicative of very poor thermal resistance. From the charts, we can see that the living area responds to the outside temperature but that there is a buffer (temperature difference). The bedroom temperature also responds somewhat to the outside temperature but doesn't seem to have the same spikes in warmer temperatures. The charts show that once the heat pump is switched off the temperature inside drops quickly.

Time spent in the comfort zone decreased (from 7.7% to 7.2%) despite already being exceedingly low. The average temperature for Irene's living space was 13.9°C, while the average for the bedroom was 11°C. The living area average dropped slightly while the bedroom average rose slightly in the after period. These temperatures are well below the average and median temperatures of other houses in this study.

In the before period Irene was doing overnight care work away from home (caring for others) – she could be away up to 3 nights every fortnight. In the after period she was not doing the overnight care work and was actually looking for more care work. Such a change in household occupancy patterns would explain the increase in electricity consumption.

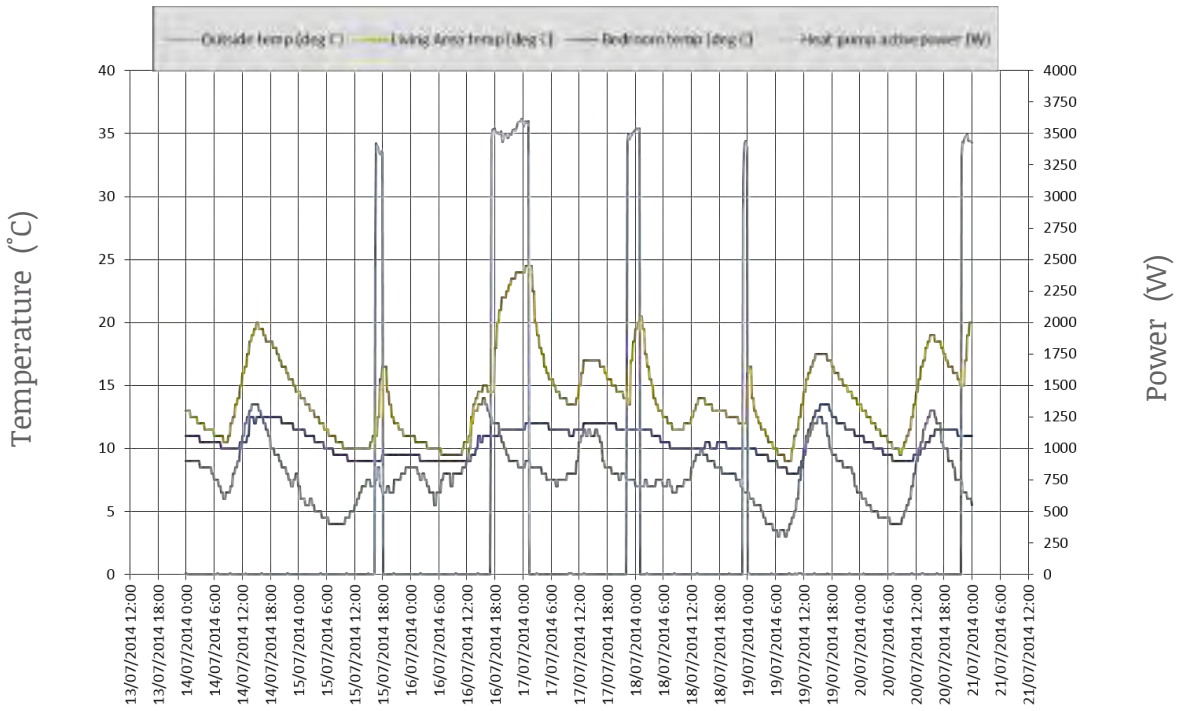
Hot water use increased 4.81 to 6.16kWhr/day (1.35kWhr/day increase, 28.0%). Irene said in her After Interview that she had longer showers when she was not working and had not had as much work in the after period.

Other Light and Power increased by 24.2% (from 10.99kWh/day to 13.65kWh/day). More power was again likely being used with an increased amount of time being spent at home (with more cooking, computer use and television, for example). Irene did purchase a replacement fridge, which was smaller but was second hand. This could have either increased or decreased her use of light and power as well.

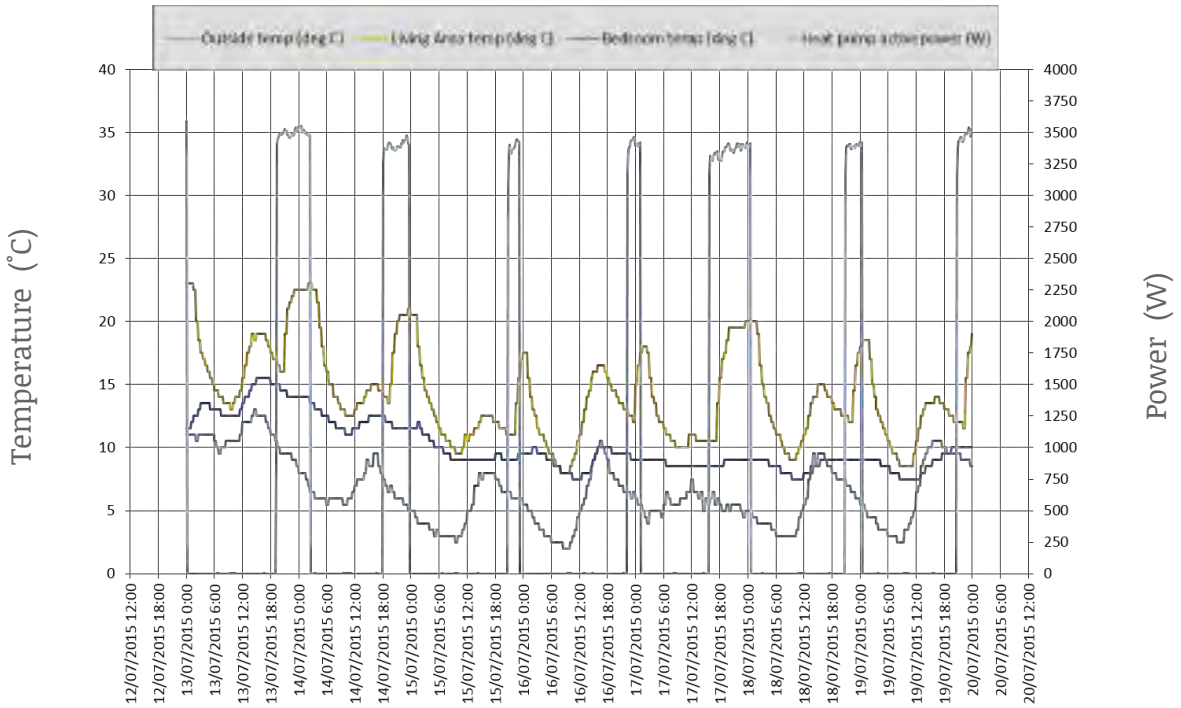
There was possible surface condensation, but Irene said she didn't have much of a problem. Measures show temperatures comes close to dew point in living and bedrooms with humidity reaching a peak of 75%. This humidity level as the peak is not too much of a problem. Ironically draughts probably help reduce any potential moisture problems here. Irene said when her (now adult) children lived with her moisture had been an issue in the bedrooms.

> But the shutters [on the heater] don't turn and it does start off with a cool draught. I feel it's not too bad but my friend's saying it's still cold. But if you go out in the other part of the house you can feel there is heat here. I notice the difference.
>
> *(Before Interview 10/07/2014)*

Before period: example week in winter showing selected energy use and temperature readings



After period: example week in winter showing selected energy use and temperature readings



Energy affordability

Irene had less work than she wanted and this made paying household bills difficult:

> I haven't got a lot of hours in my work, so 23 hours a fortnight, that's not a week. So I'm just managing with my bills and things.
> *(After Interview 07/09/2015)*

When asked what she did when a big electricity bill arrived she said,

> I just spend less on groceries and stuff or juggle the finances. I've done that for a long time because I've been on and off employment and I haven't got as many hours as I used to. *(Before Interview 10/07/2014)*

To save money Irene rarely turned the heater on except when visitors came. While she would have liked to upgrade to a more efficient heat pump, this was beyond her financial capacity.

Irene carefully budgeted to ensure she was able to pay her bills, explaining:

> Everything has gone up, like rates and things, so you have to put spare money on the bills. Like, I want to try and pay the rates off gradually. So if I got the extra money, I'll start paying some more off because there's another $400 due in February and, say, if something else is due in February, it floods. So you have to try and reduce things in advance, that's what I find. That's how I did the Aurora bill last time. I paid $50 off a fortnight or something and then I reduced it down a bit so I didn't have a huge bill when it did come in.
> *(After Interview 07/09/2015)*

The billing data we have for Irene is based partially on estimates by the energy supplier. The supplier estimates that her bills have decreased by approximately $87 per year. Her energy use has increased in the winter periods but she may be using less overall. It is hard to say whether or not her energy bills have decreased.

Personal and community change

Irene is in her 50s and lives alone. Her house is very difficult to heat and the heat pump that she uses is very old. As Irene explained the heater often blows out cold air and that,

> It's out-dated now. I can't replace it. I was told it's nearly past its due date and needs replacing. But it was expensive in those days. $3,000 and they're still about the same price.
>
> *(Before Interview 10/07/2014)*

Not only is a replacement heater expensive, but Irene noted that the heat pump costs a lot to run. She said that,

> If it was that cold in the afternoon and I don't want to put the heater on I have put a water bottle on my lap and a rug over the top trying to save power because it's usually too expensive to have the heater going all the time.
>
> *(Before Interview 10/07/2014)*

Irene knew the heater was old and inefficient and also knew that trying to heat herself in the living area also meant having to heat upstairs near the bedrooms due to that area being higher than the living room. Irene also appeared to keep curtains shut when sun was available and leave windows in spare bedrooms ajar to ensure they stayed fresh. These two actions also undermined comfort.

Irene wanted to make some other minor changes to her home, such as shifting to energy efficient lightbulbs. She explained that this was physically difficult and that costs were prohibitive.

As a shift worker it is difficult for Irene to be involved in regular community activities. She liked to attend local council information evenings at the community centre, but often found the timetabling difficult. Over the course of the year, Irene increased her sense of connection to the local community and displayed improved confidence that there were people in her community who could help with energy efficiency and thermal comfort.

The poor thermal resistance of Irene's house, coupled with the old heater and the stack-effect (heat rising away from the living area) area, created an uncomfortable indoor environment. Despite her frustration, difficulty getting enough work meant Helen did not always have enough money for groceries, let alone making changes in her home.

4. Comparative analysis findings

This section presents tabulated comparative analysis of outcomes as compared with key parameters in order to examine outcomes of the interventions and to identify relationships between outcomes and household characteristics.

Comparisons are conducted using the data collected from the individual case studies, specifically: electricity consumption for heating; total electricity consumption; household heating efficiency; indoor/outdoor temperature differences (ÐT); average living room temperature; % of time in the comfort zone; and plug-in versus hard-wired heater use. Findings from the cases are collated and the average outcomes are compared across: GBS approach groups; for different house construction eras; and for different heater types.

There are five sets of comparative analysis which examine:

1. Whole of detailed study approach groups compared across key indicators (not including heating energy related indicators)
2. Approach groups compared across the energy and comfort indicators
3. Household heater type compared across the energy and comfort indicators
4. Households grouped into quintiles based on the energy and comfort indicators and then compared using energy and comfort indicators, and
5. Analysis by house construction age using 'before' baseline measures of energy and comfort.

Analysis set 1. above, includes all households in the study, but doesn't not undertake comparisons relating to heating energy. Analysis sets 2 to 5 do include analysis of heating energy and associated indicators, but to do this, sets 2 to 5, exclude households with wood heating, gas heating, and households that moved during the study. For wood and gas heating, the reason for the exclusion of these houses is that insufficient data on wood and gas use was available to enable reliable analysis of heating energy. For households that moved, these were excluded because the change of house created potentially very large changes to heating energy that are not attributable to the GBS project.

4.1 Whole of Detailed Study – Approach groups compared across key indicators

This section includes three comparative analyses across the GBS approach groups based on:

- Average daily total electricity consumption per household and per occupant. (kWh/day)
- Proportion (%) time in comfort zone, and
- Average hot water electricity consumption per household and per occupant. (kWh/day)

This section includes all households in the Detailed Study, including those with non-electric heating, and those households that moved house during the study. Outcomes relating to heating energy are not considered in this section.

Table 4 presents some background data on the number of households in each approach group and the average number of occupants per household in the different approach groups during the before and after monitoring periods.

Table 4: background data on detailed households

GBS Approach Group	Number of houses in Detailed Study Sample	Average occupants per household in the before period	Average occupants per household in the after period
CCB	16	3.2	3.1
EDUG + CCB	11	3.5	4.0
REP	12	1.8	1.6
EDUG	12	1.8	1.8

4.1.1 Change in Total Household Electricity use – All households

Change to avg daily total household electricity use				
GBS Approach Group	Before	After	Change	Change
	(kWh/day)	(kWh/day)	(kWh/day)	(%)
CCB	49.93	51.23	1.31	2.6%
EDUG + CCB	32.52	34.21	1.68	5.2%
REP	33.78	31.90	-1.91	-5.6%
EDUG	21.05	22.29	1.24	5.9%

Change to avg daily total household electricity use – compared to the representative group				
GBS Approach Group	Before	After	Change	Change
	(kWh/day)	(kWh/day)	(kWh/day)	(%)
CCB	16.14	19.33	3.28	8.2%
EDUG + CCB	-1.26	2.31	3.59	10.7%
REP	-----	-----	-----	-----
EDUG	-12.73	-9.61	3.14	11.4%

Findings

- Only the representative group showed an average decrease in overall household electricity use across the projects.
- There is a large difference in actual household electricity consumption between the different project groups. This can be largely explained by the fact that the household sizes in the Clarendon Vale /Rokeby area are much larger than the households in the Greater Hobart groups.
- Changes to wood heating usage, not reported in these results is having a significant impact on electricity consumption in some households and is skewing these results.
- Households moving between houses is also having a significant impact on electricity consumption in some households and is skewing these results.

4.1.2 Change in Total Electricity use per occupant – All households

Change to avg daily total household electricity use per occupant				
GBS Approach Group	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
CCB	17.05	17.72	0.67	3.9%
EDUG + CCB	12.36	9.89	-2.46	-19.9%
REP	24.01	22.96	-1.06	-4.4%
EDUG	12.31	12.68	0.37	3.0%

Change to avg daily total household electricity use per occupant – compared to the representative group				
GBS Approach Group	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
CCB	-6.97	-5.24	1.73	8.3%
EDUG + CCB	-9.83	-12.81	-2.99	-15.5%
REP	-----	-----	-----	-----
EDUG	-10.59	-10.28	0.31	7.4%

Findings

- The larger number of persons per household in the Rokeby/Clarendon Vale groups, leads to lower electricity consumption on a per occupant in those households.
- When considered on a per occupant basis, the EDUG + CCB households recorded a 15.5% reduction in energy consumption compared to the representative group. There were a number of households in the study in which people moved to and from the house, altering the participant populations for the after period in all four of the GBS approach groups.

4.1.3 Change to % time in defined comfort zones – All households

The thermal comfort zone was defined for the purposes of the study as the proportion of time over a 24 hour period that the internal temperature of the house was between 18 and 24°C. Here we present the time spent in the comfort zone for each group of houses during the before and after periods, and the change between the periods. All houses in the study are included in this comparison, including houses with wood fires, gas heating and households that moved.

Change to % time in comfort zone				Change to % time in comfort zone – compared to representative group	
	Before (%)	After (%)	Change (%)		Change (%)
CCB	45.6%	50.6%	5.0%	CCB	3.8%
EDUG + CCB	31.5%	35.4%	3.9%	EDUG + CCB	1.7%
REP	36.5%	38.6%	2.2%	REP	------
EDUG	21.6%	21.7%	0.1%	EDUG	-2.1%

Findings

- This comfort zone table compares all of the houses in the study, including houses with wood fires, gas heating and households that moved etc.
- All groups showed an increase in time in the CZ, but it was the CCB group that increased the most.
- Interrogation of individual household data showed that a major factor in this result was the number of households with wood fires, which were skewing the results.
- Once houses with non-electric heating are excluded from the sample more sensible comparisons of comfort between the study approach groups can be seen - (see further analysis in section 4.2.)

4.1.4 Hot Water electricity consumption per household – All households

Hot water consumption is compared across all houses in the study including houses with different heating types as this would not affect hot water heating.

Household hot water electricity consumption (kWh/household/day)				
GBS Approach Group	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
CCB	12.23	13.72	1.49	12.2%
EDUG + CCB	9.37	9.09	-0.28	-2.9%
REP	6.35	5.63	-0.72	-11.3%
EDUG	5.99	6.36	0.38	6.3%

Household hot water electricity consumption – compared to representative group				
GBS Approach Group	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
CCB	5.88	8.09	2.21	23.5%
EDUG + CCB	3.02	3.47	0.44	10.5%
REP	-----	-----	----	-----
EDUG	-0.36	0.73	1.09	17.6%

Findings

- Changes to hot water heating energy were varied across the approach groups with the CCB recording a 12.2% increase in use on a household basis. The Rep group had an 11.3% reduction.
- There is a large difference between the overall hot water use across the 4 groups. This is partly caused by different household sizes, which are larger on average in the CV/R groups.

4.1.5 Hot Water electricity consumption per occupant – All households

Hot water electricity consumption (kWh/person/day)				
GBS Approach Group	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
CCB	4.34	5.00	0.67	15.4%
EDUG + CCB	3.10	2.45	-0.65	-21.1%
REP	4.28	3.72	-0.56	-13.1%
EDUG	3.53	3.62	0.09	2.5%

Hot water electricity consumption per person – compared to representative group				
GBS Approach Group	Before (kWh/day)	After (kWh/day)	Change (kWh/day)	Change (%)
CCB	0.06	1.29	1.23	28.5%
EDUG + CCB	-1.18	-1.27	-0.09	-8.0%
REP	-----	-----	----	-----
EDUG	-0.75	-0.09	0.65	15.7%

Findings

- When hot water consumption is analysed per occupant, the levels of consumption are relatively similar for the four different approach groups.
- Change to household hot water energy consumption per occupant is widely varied across the groups. This is in part because of the change in average occupant numbers across the groups.
- The baseline REP group experienced a 13.1% reduction in hot water consumption per occupant.
- The EDUG+CCB group had the largest reduction of 21.1% on a per occupant basis, 8% greater reduction than the REP group.
- Hot water consumption increased by 15.4% per occupant for the CCB group, or 28.5% more than the representative group.
- Hot water consumption increased by 2.5% per occupant for the EDUG group, or 15.7% more than the representative group.

4.2 Approach groups compared across energy and comfort indicators

In this section the four approach groups are compared across five key indicators of performance relating to household energy and comfort.

For these comparisons, houses with wood fires, or gas heating, and households that moved from one house to another during the study are excluded from the comparison. Unfortunately, not enough data was available to reliably calculate wood or gas heating consumption. The table below presents background data on the sample group sizes for this section of analysis, and the average number of occupants per household in the different approach groups during the before and after monitoring periods.

GBS Approach Group	Number of houses in Detailed Study Sample	Average occupants per household in the before period	Average occupants per household in the after period
CCB	9	3.7	3.4
EDUG + CCB	9	3.3	4.0
REP	8	1.8	1.5
EDUG	9	1.9	1.9

The key indicators are average changes to:

1. Total heating electricity (kWh/day) – the combination of all electric heating types in the house
2. Total household electricity (kWh/day)
3. House Heating Efficiency (HHE) (degree-hours/kWh/day)
4. ΔT – difference between inside and outside temperature (°C)
5. Proportion (%) of time the house is within the defined comfort zone (18–24°C)

All five comparisons are presented below on a 'whole of household' basis. Per occupant comparisons are also undertaken for heating energy and total electricity use.

At the end of this section there is also one further, specific comparison undertaken which analyses the changes to plug-in heating and hard-wired heating across the four approach groups.

4.2.1 Household based comparison of approach groups across five key indicators

Household comparison of approach groups across five key indicators								
Approach Group	Indicator 1		Indicator 2		Indicator 3		Indicator 4	Indicator 5
	Change to Total Heating Energy		Change to Total Household Electricity		Change House Heating Efficiency		Change to ΔT	% Time in CZ
	(kWh/day)	(%)	(kWh/day)	(%)	(deg hrs / kWh/day)	(%)	(°C)	(%)
CCB	1.88	6.2%	3.59	6.3%	0.00	0.5%	1.04	-0.3%
EDUG + CCB	4.00	29.2%	3.79	11.3%	0.21	25.4%	0.51	5.9%
REP	2.44	12.7%	2.78	9.2%	-0.02	-4.5%	0.65	1.9%
EDUG	0.67	7.2%	1.53	6.2%	-0.06	-7.6%	0.25	-0.1%

Household comparison of approach groups across 5 key indicators – compared to representative group								
Approach Group	Indicator 1		Indicator 2		Indicator 3		Indicator 4	Indicator 5
	Change to Total Heating Energy		Change to Total Household Electricity		Change House Heating Efficiency		Change to ΔT	% Time in CZ
	(kWh/day)	(%)	(kWh/day)	(%)	(deg hrs / kWh/day)	(%)	(°C)	(%)
CCB	-0.55	-6.4%	0.81	-2.9%	0.02	5.0%	0.39	-2.1%
EDUG + CCB	1.56	16.6%	1.01	2.1%	0.24	29.9%	-0.14	4.0%
REP	----	----	----	----	----	----	----	----
EDUG	-1.77	-5.5%	-1.25	-2.9%	-0.04	-3.1%	-0.40	-2.0%

4.2.2 Per occupant comparison of approach groups

Per occupant comparison of approach groups for heating and total electricity				
Approach Group	Indicator 1		Indicator 2	
	Change to Total Heating Energy per occupant		Change to Total Electricity per occupant	
	(kWh/day)	(%)	(kWh/day)	(%)
CCB	0.47	4.6%	1.50	7.9%
EDUG + CCB	-1.10	-16.7%	-2.58	-19.0%
REP	3.06	24.2%	4.22	20.8%
EDUG	0.17	3.1%	0.28	2.0%

Per occupant comparison of approach groups for heating and total electricity – compared to the representative group				
Approach Group	Indicator 1		Indicator 2	
	Change to Total Heating Energy per occupant		Change to Total Electricity per occupant	
	(kWh/day)	(%)	(kWh/day)	(%)
CCB	-2.59	-19.6%	-2.72	-12.8%
EDUG + CCB	-4.17	-40.9%	-6.80	-39.8%
REP	----	----	----	----
EDUG	-2.89	-21.1%	-3.94	-18.8%

Findings

Indicator 1 – Change to total heating energy

- All approach groups recorded an increase in total heating energy per household. The largest increase was in the EDUG + CCB group.
- However, when occupant levels are factored in, heating energy use reduced per occupant by 16.7% in the EDUG + CCB group.
- On a per occupant basis all 3 groups with support activities reduced heating energy consumption compared to the representative group.
- A major factor in the increase in household heating was the fact that the 'after' winter was a significantly colder winter, than the 'before' winter. For Hobart, the mean winter temperature for 2015 was 8.5 degrees and for 2014 was 9.9 degrees. (BOM, 2014). Across Tasmania, the after winter (2015) had the coldest winter mean temperature since 1966. Night time mean temperatures were the coldest since 1995 and daytime temps were the coldest since 1992 (BOM, 2015). The mean winter temperature for the before winter (2014) was above average across the state. These differences were reflected in the monitored outdoor temperatures at the detailed households.
- Increases in household heating did lead to an increase in comfort levels for the EDUG + CCB households.
- There was a significant switch to hard wired heating from plug-in heating. (refer to separate analysis later in this section)

Indicator 2 – Change to total electricity use

- Due to the large proportion of household energy being used for heating during the winter period, total electricity consumption is strongly linked to total heating consumption.
- Households in all 4 approach groups increased their total electricity consumption in the after winter. Again, however, when occupant levels are factored in, there is a decrease in electricity consumption by occupant with the EDUG group decreasing by 18.8%, the CCB group decreasing by 12.8% and the EDUG+CCB group decreasing by 39.8% relative to the representative group.
- The previous comparisons of hot water and other household electricity consumption demonstrate that the main contributor to overall increases in household electricity consumption was the additional heating in the after winter.

Indicator 3 – Change to House Heating Efficiency

- The house heating efficiency (HHE) results show a marked difference between the households in the CCB groups and in those in Greater Hobart.
- For the EDUG + CCB group HHE increased by 25.4%, and the CCB group increased by 0.5%
- For the EDUG group, HHE decreased by 7.6% and for the REP group decreased by 4.5%
- These results for the CCB groups are seen as being strongly related to the change in heater use from plug-in to hard-wired heaters (T31 to T41/42), which would have included greater use of heat pumps which deliver greater heating efficiency. One of the messages from the GBS community activities and in-home education sessions was that switching to T41/T42 heating sources would save the householder due to the cheaper tariff.
- While, upgrades as part of the GBS study may have had some minor affect in improving HHE. This is not seen to be a discernible impact. Other factors such as heater use and the differing winter conditions will have contributed the greater influence to changes in HHE across the groups.

Indicator 4 – Change to ΔT (Inside/Outside temperature difference)

- Households in all approach groups managed to increase the ΔT
- This however does not mean that it was warmer inside during the after period, because the after winter was colder.
- The larger ΔT was created by significant increases in heater use across all groups.
- The CCB group were able to create the largest increase in ΔT of 1.04 degrees between the before and after periods

Indicator 5 – Change to proportion (%) of time in Comfort Zone

- Though the ΔT was larger for all groups in the after period, only the EDUG + CCB group were able to record a significant increase in % time spent in the defined comfort zone (CZ).
- Using the representative group as a baseline, the EDUG + CCB group managed to achieve 4.0% more time in the CZ, while the CCB group experienced 2.1% and the EDUG group 2.0% less time respectively in the CZ.
- These drops in time in CZ are seen to be more to do with the colder winter than anything to do with the upgrade process.
- The increase in time in the CZ in the EDUG + CCB group is seen primarily as a result of significantly greater heater use.

4.2.3 Change to plug-in and hard-wired heating across the four approach groups

Change to plug-in and hard-wired heating								
	T 31 Heating (plug-in heating)				T 41/42 Heating (hard-wired heating)			
	Before	After	Change	Change	Before	After	Change	Change
	(kWh/day)	(kWh/day)	(kWh/day)	(%)	(kWh/day)	(kWh/day)	(kWh/day)	(%)
CCB	6.21	5.05	-1.16	-18.7%	23.95	26.99	3.04	12.7%
EDUG + CCB	2.05	0.97	-1.08	-52.6%	11.65	16.73	5.08	43.6%
REP	5.53	5.16	-0.38	-6.8%	13.73	16.55	2.82	20.5%
EDUG	1.78	1.63	-0.14	-8.0%	7.50	8.31	0.81	10.8%

Findings

- There was a reduction in plug-in heating across all four approach groups.
- The greatest reduction was in the CCB groups.
- There was a corresponding increase in hard-wired heating across all groups. This includes both hard-wired resistive and heat pump heaters.

4.3 Household electric heating type compared across key indicators

In this section, households are grouped according to the types of electric heating within the house. The four groups are defined as follows:

Electric Heating Type Group	Number of houses in Detailed Study Sample	Notes on group definition
All Houses with Heat pumps	24	Includes any house that has a heat pump, whether or not there are other electric heating types present in the household
All Houses with Hardwired resistive heaters	16	Includes any house that has a hard-wired resistive heating, whether or not there are other electric heating types present in the household.
Houses with ONLY heat pumps	5	Includes houses that have a heat pump/s as the only heat source in the household
Houses with ONLY resistive heaters	11	Includes houses that have resistive heating as the only heat source in the household

These four groups are not mutually exclusive. Houses with wood fires and gas heating and households that moved are excluded from the analysis in this section.

The heating type groups are compared using the various key measures, for the before and after periods and to compare the change between the periods. The following measures are used:

- Plug-in (T31) heating energy (kWh/day)
- Hard-wired (T41/42) heating energy (kWh/day)
- Total heating energy (kWh/day)
- Total household electricity use (kWh/day)
- House Heating Efficiency (HHE) (degree hours/kWh/day)
- Living Room Temperature (°C)
- ΔT (difference between inside and outside temperature) (°C)
- Proportion of time (%) in the comfort zone.

4.3.1 Plug-in (T31) heating energy

	Daily average plug-in (T31) heating use			
Houses grouped by heating types	Before	After	Change	Change
	(kWh/day)	(kWh/day)	(kWh/day)	(%)
Houses with Heat Pumps	2.82	2.43	-0.40	-14.1%
Houses with Hardwire resistive heaters	5.11	4.56	-0.55	-10.8%
Houses with Only Heat pumps	n/a	n/a	n/a	n/a
Houses with Only Resistive Heaters	7.29	6.11	-1.18	-16.2%

Findings

- Plug-in heating is obviously greatest in houses with only resistive heaters.
- Houses with only heat pumps have no plug-in heating.
- On average, for all houses with plug-in heating there was a reduction in their use associated with the switch to hardwired heating.

4.3.2 Hard-wired (T41/42) heating energy

	Hard-wired (T41/T42) heating energy			
Houses grouped by heating types	Before	After	Change	Change
	(kWh/day)	(kWh/day)	(kWh/day)	(%)
Houses with Heat Pumps	11.70	13.64	1.94	16.6%
Houses with Hardwire resistive heaters	16.96	21.01	4.05	23.9%
Houses with Only Heat pumps	14.55	16.01	1.46	10.1%
Houses with Only Resistive Heaters	16.30	22.60	6.29	38.6%

Findings

- For houses with heat pumps (with or without other heating) there is a lower hard-wired heating energy consumption on average.
- In the after period both households with and without heat pumps had increased their heater use due to the colder winter, but there was a significantly lower increase in heating energy consumption between the before and after periods, in houses with heat pumps (with or without other heating).
- In the before period on average households with heat pumps used 4.6kWh/day less than households with only resistive heating sources.
- in the after period on average households with heat pumps used 9.0kWh/day less than households with only resistive heating sources.

4.3.3 Total Heating Energy

	Total Heating Energy			
Houses grouped by heating types	Before	After	Change	Change
	(kWh/day)	(kWh/day)	(kWh/day)	(%)
Houses with Heat Pumps	14.52	16.07	1.54	10.6%
Houses with Hardwire resistive heaters	22.07	25.57	3.50	15.8%
Houses with Only Heat pumps	14.55	16.01	1.46	10.1%
Houses with Only Resistive Heaters	23.59	28.71	5.12	21.7%

Findings

- The total heating energy reflects the combined trend of T31 and T41/42 heating use.
- In the after period both households with and without heat pumps had increased their heater use due to the colder winter.
- For houses with heat pumps (with or without other heating) there is a lower total heating energy consumption on average.
- There was also a significantly lower increase heating energy consumption in houses with heat pumps (with or without other heating).
- In the before period on average households with heat pumps used 9.0 kWh/day less than households with only resistive heating.
- in the after period on average households with heat pumps used 12.6kWh/day less than households with only resistive heating.

4.3.4 Total Household Electricity

	Total Household Electricity			
Houses grouped by heating types	Before	After	Change	Change
	(kWh/day)	(kWh/day)	(kWh/day)	(%)
Houses with Heat Pumps	34.77	36.72	1.95	5.6%
Houses with Hardwire resistive heaters	40.20	44.05	3.85	9.6%
Houses with Only Heat pumps	36.83	38.52	1.69	4.6%
Houses with Only Resistive Heaters	39.31	44.80	5.49	14.0%

Findings

- Because heating is such a significant proportion of winter electricity consumption, the total household electricity consumption when broken down by heater types is similar to the pattern of total household heating energy consumption.
- For houses with heat pumps (with or without other heating) there is a lower total electricity consumption on average.
- There was also a significantly lower increase electricity consumption in houses with heat pumps (with or without other heating)
- In the before period on average households with heat pumps used 4.5kWh/day less than households with only resistive heating.
- In the after period both households with and without heat pumps had increased their electricity use due to the colder winter.
- In the after period on average households with heat pumps used 8.1 kWh/day less than households with only resistive heating.

4.3.5 House Heating Efficiency (HHE)

	Household Heating Efficiency			
Houses grouped by heating types	Before	After	Change	Change
	(°C-hours/kWh/day)			(%)
Houses with Heat Pumps	0.74	0.80	0.07	9.3%
Houses with Hardwire resistive heaters	0.47	0.42	-0.05	-11.3%
Houses with Only Heat pumps	0.75	0.76	0.01	1.3%
Houses with Only Resistive Heaters	0.35	0.29	-0.06	-16.2%

Findings

- There is a significant difference in HHE ratios for houses with and without heat pumps.
- The average of houses with heat pumps (with or without other heaters) was 0.74 deg hours/kWh/day in the before period.
- This compared to an average of 0.35 deg hours/kWh/day for houses with only resistive heating
- Houses with only heat pumps experienced a small increase in HHE in the after period.
- Houses with heat pumps and other heaters experienced the biggest improvement – a 9.3% increase in HHE. This is seen as being due to the switch from plug-in heaters to heat pumps
- Houses without heat pumps had reduced HHE in the after period. This is seen as being due primarily to the overall increase in energy use, and the colder winter. During colder outside conditions there is a larger temperature difference between inside and out, leading to a stronger heat flow through the poorly resistive building fabric of the typical houses in the study and reduced HHE.
- In the after period, households with heat pumps had more than 2.5 times the HHE of houses with only resistive heaters.

4.3.6 Living Room Temperature

	Living Room Temperature		
Houses grouped by heating types	Before	After	Change
	(°C)	(°C)	(°C)
Houses with Heat Pumps	19.1	19.5	0.3
Houses with Hardwire resistive heaters	17.7	17.8	0.1
Houses with Only Heat pumps	20.6	20.5	-0.2
Houses with Only Resistive Heaters	16.9	16.9	0.1

Findings

- Houses with heat pumps (with or without other heaters), maintained a higher temperature in living rooms during winter, than houses without heat pumps.
- On average the living room temperature in houses with heat pumps in the before period was 19.1 on average.
- For houses with only resistive heating the average temp in living rooms in the before period was 16.9 on average.
- On average there was little change in absolute temperature in the living rooms for houses with any heating type between the before and after period.

4.3.7 Average temperature difference between inside and outside (ΔT)

	ΔT		
Houses grouped by heating types	Before	After	Change
	(°C)	(°C)	(°C)
Houses with Heat Pumps	7.2	8.0	0.8
Houses with Hardwire resistive heaters	6.9	7.4	0.6
Houses with Only Heat pumps	9.1	9.4	0.3
Houses with Only Resistive Heaters	6.5	7.2	0.6

Findings

- houses with heat pumps (with or without other heaters) are able to maintain a greater difference between inside and outside temperature (ΔT).
- The houses with only heat pumps were able to maintain a the largest ΔT of 9.1°C during the before period.
- Houses with only resistive heating were able to maintain a ΔT of only 6.5°C during the before period.
- Houses of all types, on average were able to increase ΔT for the after period – even though this didn't translate into warmer absolute temperatures in living areas as seen above. This was because of the colder ambient temperatures during the after winter.

4.3.8 Proportion (%) of time in comfort zone (18°C – 24°C)

	% time in the comfort zone (CZ)		
Houses grouped by heating types	Before	After	Change
	(%)	(%)	(%)
Houses with Heat Pumps	41.6%	43.2%	1.6%
Houses with Hardwire resistive heaters	31.8%	34.5%	2.6%
Houses with Only Heat pumps	44.4%	42.7%	-1.7%
Houses with Only Resistive Heaters	26.0%	29.6%	3.6%

Findings

- Houses with heat pumps on average were able to achieve temperatures within the comfort zone 41.6"% of the time in the before period.
- This compared to just 26.0% of the time in the comfort zone for houses with only resistive heaters.
- There was a slight improvement to % of time in the CZ for houses with resistive heating, in the after period – primary due to the large increase in heater energy use.
- However, houses with only resistive heating are still spending 13.6% less time in the CZ than houses with heat pumps.

4.3.9 Total Heating vs House Heating Efficiency vs % time in comfort zone.

The following two tables present analysis of the households grouped by heating type as compared against:

- Total heating energy
- House heating efficiency, and
- Proportion (%) of time in the comfort zone, for the before and after periods

Before Period	Total Heating Electricity	House Heating Efficiency	% Time in CZ
Houses grouped by heating types	Before	Before	Before
	(kWh/day)	(°C-hours/ kWh/day)	(%)
Houses with Heat Pumps	14.52	0.74	41.6%
Houses with Hardwire resistive heaters	22.07	0.47	31.8%
Houses with Only Heat pumps	14.55	0.75	44.4%
Houses with Only Resistive Heaters	23.59	0.35	26.0%

After Period	Total Heating Electricity	House Heating Efficiency	% Time in CZ
Houses grouped by heating types	After	After	After
	(kWh/day)	(°C-hours/ kWh/day)	(%)
Houses with Heat Pumps	16.07	0.80	43.2%
Houses with Hardwire resistive heaters	25.57	0.42	34.5%
Houses with Only Heat pumps	16.01	0.76	42.7%
Houses with Only Resistive Heaters	28.71	0.29	29.6%

Findings

- The comparison of heating types against the key indicators of change in heating energy and comfort, demonstrates the benefits of heat pumps in terms of electricity consumption (and hence cost), heating efficiency, and household comfort.
- Households that relied solely on heat pumps used 9.0kWh/day less on average, than households with only resistive heating, during the before period. At the same time households with heat pumps achieved 15.6% more of the time in the CZ compared to houses without heat pumps.
- Houses with heat pumps had a HHE more than double that of houses with only resistive heating, during the before period.
- The benefits of heat pumps increased during the colder winter 'after' winter of 2015.
- Houses that relied solely on heat pumps used 12.7kWh/day less heating energy on average than houses with only resistive heating, while at the same time achieved 13.1% more of the time in the CZ compared to houses without heat pumps.
- Houses with heat pumps displayed a HHE more than 2.5 times greater than houses with only resistive heating during the after period.

4.4 Quintile Based Analysis

In this section, analysis is conducted by dividing households into quintiles based on the various measured parameters in the GBS project. The households in this quintile analysis are the same 35 households used in Section 4.2 (which excludes households with non-electric heating and who moved).

Quintile baseline performance analysis involves a series of comparisons based on 'before' performance of the households as measured by:

- Living room Temperature (°C)
- Average total heating energy (kWh/day)
- Average total household electricity consumption (kWh/day)
- Proportion of time (%) time in the comfort zone.

In each case the quintiles are colour coded from green through to orange, with the best performing households in the top quintile, Q1, at the top of the table in green, for each parameter.

Q1
Q2
Q3
Q4
Q5

Baseline performance of the households, as measured by these indicators, is used to establish quintile groups, which are then compared against key change indicators for the project:

- Change to total heating energy
- Change in living room temperature
- Change in time within the comfort zone

4.4.1 'Before' Living Room Temp – Quintile based analysis

Before Living Temp vs Before Heating Electricity vs Before Total Electricity vs % time in CZ				
	Before Living Temp	Before Heating Electricity	Before Total Electricity	Before % time in CZ
Living Temp Quintile	(°C)	(kWh/day)	(kWh/day)	(%)
Q1	23.00	33.50	59.76	65.6%
Q2	20.01	19.57	33.18	58.3%
Q3	18.17	13.37	28.63	29.4%
Q4	17.16	12.13	34.69	21.5%
Q5	14.62	11.76	26.29	11.1%

Findings – Before living temp vs heating electricity, total electricity & % time in CZ.

- There is a very clear correlation between living room temperatures measured and heating electricity used. Essentially to achieve warmer temperatures, more heating energy is used.
- This also translates to a clear correlation between heating energy and % time in the CZ.
- Essentially the more energy put into heating the more comfort the householder achieves.

Before Living Temp vs Change in Total Heating Energy			
	Before Living Temp	Total Heating Energy Change	
Living Temp Quintile	(°C)	(kWh/day)	(%)
Q1	23.00	2.64	13%
Q2	20.01	0.92	6%
Q3	18.17	0.56	5%
Q4	17.16	2.15	5%
Q5	14.62	4.95	51%

Findings – Before living temp vs change in total heating energy

- There is not a clear correlation between living room temperatures and the change to heating energy that occurred over the course of the GBS project.
- Not surprisingly the lowest temperature households had the highest increase in heating energy as they attempted to improve or maintain their living room temperatures during the colder after winter.
- However, the households with the highest internal temperatures also had an increase suggesting that householders will attempt to maintain the temp that they are used to and will use the extra energy to achieve that temp when it is colder outside.

Before Living Temp vs Change in living Temp		
	Before Living Temp	Change in Living Temp
Living Temp Quintile	(°C)	(°C)
Q1	23.00	0.81
Q2	20.01	0.22
Q3	18.17	0.23
Q4	17.16	-0.86
Q5	14.62	0.26

Findings – Before living temp vs change in living temp

- For the households in the lowest temperature quintile, even with the highest increase in energy consumption, the households were only able to achieve on average a 0.26 deg increase in living room temperature in the after period.
- Households in the top quintile managed to achieve a 0.81 degree increase on average with a heating energy increase that was significantly less than that bottom quintile group.
- Further analysis would be required to determine the reasoning behind these variations. It may be the relationship between households and heater types.

Before Living Temp vs Change in % time in CZ		
Living Temp Quintile	Before Living Temp (°C)	Change in time in CZ (%)
Q1	23.00	-2.1%
Q2	20.01	4.8%
Q3	18.17	0.4%
Q4	17.16	-1.5%
Q5	14.62	7.6%

Findings – Before living temp vs change in % time in the CZ

- The bottom quintile of households ranked by living room temp had the greatest increase in % of time in the comfort zone, but they were starting out from a very low position.
- The decrease in time in the comfort zone for households in the top quintile may in fact be because of extra time spent above the 24°C limit. This raises an issue of energy 'wastage' through unnecessary heating above the standard comfort levels.

4.4.2 'Before' total heating electricity – quintile based analysis

Before Heating Electricity vs Before Living Temp vs Before Total Electricity vs % time in CZ				
Total heating electricity quintile	Before Heating Electricity (kWh/day)	Before Total Electricity (kWh/day)	Before Living Temp (°C)	Before % time in CZ (%)
Q1	5.24	24.39	17.06	20.1%
Q2	10.05	28.56	17.49	33.5%
Q3	13.77	28.43	18.17	37.9%
Q4	20.27	35.01	19.69	38.4%
Q5	40.99	66.16	20.53	55.9%

Findings – Before heating electricity vs living temp, total electricity & % time in CZ

- As may be expected from the analysis based on before living room temperatures, there is a strong correlation between heating energy use and living room temperature and time in the comfort zone.

Before Heating Electricity vs Change in Total Heating Energy			
Total heating electricity quintile	Before Heating Electricity	Total Heating Energy Change	
	(kWh/day)	(kWh/day)	(%)
Q1	5.24	0.63	14%
Q2	10.05	4.07	38%
Q3	13.77	0.05	-1%
Q4	20.27	4.07	23%
Q5	40.99	2.40	6%

Findings – Before heating electricity vs change in total heating energy

- No clear relationship is found between initial household heating energy consumption and the change in heating energy consumption over the course of the GBS project. Analysis of individual households through the case studies may reveal why certain households used more and some less.

Before Heating Electricity vs Change in Living Temp		
	Before Heating Electricity	Change in Living Temp
Total heating electricity quintile	(kWh/day)	(°C)
Q1	5.24	-0.15
Q2	10.05	-0.01
Q3	13.77	0.23
Q4	20.27	0.63
Q5	40.99	-0.04

Findings – Before heating electricity vs change in living temp

- There seems to be no clear relationship between heating electricity consumption levels before the study, and changes to temperature occurring as a result of the study
- Households in Q3 and Q4 experienced an increase in living room temp on average, while households in Q1,2 and 5 experienced a slight decrease on average

Before Heating Electricity vs Change in % time in CZ		
	Before Heating Electricity	Change in Time in CZ
Total heating electricity quintile	(kWh/day)	(°C)
Q1	5.24	1.4%
Q2	10.05	5.2%
Q3	13.77	0.9%
Q4	20.27	5.0%
Q5	40.99	-3.4%

Findings – Before heating electricity vs change in time in CZ

- No clear relationship is found between initial household heating energy consumption and the change in time in the comfort zone over the course of the GSB project
- Quintiles 1 to 4 experienced increases in % time in the comfort zone, though to varying degrees. Those households in the highest energy using quintile experienced a slight drop in time in CZ, however they were starting out with the highest percentage in the before period.

4.4.3 'Before' % time in comfort zone – quintile based analysis

Before % time in CZ vs Before Heating Electricity vs Living Temp vs Total Electricity				
% Time in CZ quintile	Before % time in CZ	Before Heating Electricity	Before Living Temp	Before Total Electricity
	(%)	(kWh/day)	(°C)	(kWh/day)
Q1	78.5%	31.48	21.18	56.13
Q2	46.6%	21.66	21.47	38.23
Q3	31.5%	15.37	18.39	27.46
Q4	20.1%	9.68	16.69	30.96
Q5	9.2%	12.13	15.22	29.77

Findings – Before % time in CZ vs before heating electricity, living temp & total electricity

- There is a relatively strong correlation between the time spent in comfort zones and heating energy consumption.
- This also translates into a reasonably strong correlation between % time in comfort zone and overall house electricity consumption

Before Time in CZ vs Change in Total Heating Energy			
	Before % time in CZ	Total Heating Energy Change	
% Time in CZ quintile	(%)	(kWh/day)	(%)
Q1	78.5%	1.58	8%
Q2	46.6%	2.86	15%
Q3	31.5%	0.33	2%
Q4	20.1%	3.20	29%
Q5	9.2%	3.24	26%

Findings – Before % time in CZ vs change in total heating energy

- There does seem to be some relationship between the initial % of time in comfort zone and the change in household heating energy consumption.
- Households in the lowest 2 quintiles increased their heating energy consumption the most both in terms of absolute kWh and % of household heating energy consumption, presumably in an attempt to either maintain or improve their very low comfort levels.

Before Time in CZ vs Change in Living Temp		
	Before % time in CZ	Change in Living Temp
% Time in CZ quintile	(%)	(°C)
Q1	78.5%	0.45
Q2	46.6%	0.65
Q3	31.5%	0.06
Q4	20.1%	-0.18
Q5	9.2%	-0.31

Findings – Before % time in CZ vs change in living temp

- Unfortunately for those households in the bottom 2 quintiles, the extra heating energy consumption did not translate into increased living room temperatures. The extra heating was eaten up trying to maintain existing temperatures over the colder 'after' winter period
- Households in the top 2 quintiles for % time in CZ managed to increase their living room temperatures over the 'after' period

Before Time in CZ vs Change in % time in CZ		
	Before % time in CZ	Change in Time in CZ
% Time in CZ quintile	(%)	(%)
Q1	78.5%	0.7%
Q2	46.6%	1.8%
Q3	31.5%	1.1%
Q4	20.1%	3.1%
Q5	9.2%	2.4%

- There was a generally small increase to comfort levels for households in all 5 quintiles based on initial comfort levels, though slightly more increase in the bottom 2 quintiles.

4.4.4 Quintile based analysis of change indicators

This analysis is comprised of a series of comparisons of the households divided into quintiles as measured by the following key change indicators:

- Change in total heating electricity
- Change in House Heating Efficiency (HHE)
- Change to ΔT
- Change to % time in comfort zone

Performance of the households, as measured by these change indicators, is used to establish quintile groups which are then compared against the key change indicators for the project to help identify relationships between the indicators.

Change in Total Heating Electricity Vs other change parameters				
Quintile	Change in total heating electricity	Change in Heating efficiency	Change in ΔT	Change in % time in CZ
	(kWh/day)	(%)	(°C)	(%)
Q1	-3.72	31.9%	-0.45	-6.7%
Q2	-0.12	10.4%	0.64	4.3%
Q3	1.15	-3.7%	0.58	2.3%
Q4	3.18	-13.5%	0.76	-3.4%
Q5	10.73	-17.7%	1.53	12.8%

Findings – Change in total heating electricity vs other change parameters

- Change in heating energy has an inverse correlation to change in heating efficiency. The more heating used in a house, the less efficient that heating is in terms of the temperature difference created for the household.
- There is also a close relationship between change in heating electricity and change in ΔT. Less heating means less difference between inside and outside temperature.
- Some relationship to change in time in CZ with the biggest increase in heater energy use providing the biggest increase in time in CZ on average, however the other quintile's averages varied up and down.

Change in Heating Efficiency vs other change parameters				
Quintile	Change in Heating Efficiency	Total Heating Energy Change	Change in ΔT	Change in Time in CZ
	(%)	(kWh/day)	(°C)	(%)
Q1	41.1%	-3.21	0.10	-1.7%
Q2	10.0%	0.98	1.16	-2.2%
Q3	-3.3%	3.04	0.68	5.3%
Q4	-14.6%	4.81	0.53	1.5%
Q5	-25.8%	5.60	0.61	6.3%

Findings – Change in Heating Efficiency vs other change parameters

- The inverse relationship between heating efficiency and heater use is again demonstrated.
- Reduction in time within the comfort zone for those quintiles with improved heating efficiency, also demonstrates the same corresponding relationship as seen in the previous tables
- Change in ΔT however, does not seem to display the same relationship. This could demonstrate some interesting findings requiring closer investigation as it may demonstrate that an increase in heating efficiency is possible at the same time as an increase in ΔT, and potentially an increase in % time in CZ.

Change to ΔT vs other change parameters				
Quintile	Change in ΔT	Change in Heating efficiency	Total Heating Energy Change	Change in Time in CZ
	(°C)	(%)	(kWh/day)	(%)
Q1	2.29	0.6%	8.25	13.9%
Q2	1.04	-4.3%	2.45	0.7%
Q3	0.46	9.2%	1.41	1.6%
Q4	0.19	-8.6%	1.44	1.4%
Q5	-0.91	10.5%	-2.34	-8.5%

Findings – Change to ΔT vs other change parameters

- There is a close relationship between change in ΔT and change in % time in CZ as would be expected.
- There is also a closer relationship between change in ΔT and heating energy consumption
- There is seemingly no relationship between change in ΔT and household heating efficiency. Again this is cause for further investigation to discover how houses achieving an increase in ΔT do so, while also increasing the efficiency of household heating.

Change to % time in CZ vs other change parameters				
Quintile	Change to% time in CZ	Change in Heating efficiency	Total Heating Energy Change	Change in ΔT
	(%)	(%)	(kWh/day)	(°C)
Q1	18.5%	-4.3%	7.54	1.76
Q2	3.9%	-8.4%	3.19	0.55
Q3	0.6%	-11.0%	1.74	0.36
Q4	-2.9%	17.7%	-0.66	0.74
Q5	-10.8%	13.4%	-0.60	-0.34

Findings – Change to % time in CZ vs other change parameters

- There is a close relationship between change in time in CZ and change inΔT.
- There also appears to be some level of correlation between change in time in CZ and change to household energy consumption – with those households experiencing more time in CZ doing so at the expense of extra heating.
- There also appears to be an inverse relationship to HHE. Higher levels of comfort are achieved while HHE decreases due to extra heating energy consumption.

4.4.5 Households ranked by success of outcomes over the GBS project period

The following table presents all 35 households (with wood fire, gas heating and moved households excluded) in terms of overall success measured by the five key thermal and energy indicators.

The rankings are worked out by applying 5 points for each Q1 quintile ranking, down to 1 point for each Q1 quintile ranking, on the 5 key indicators.

House	Group	Total Heating Electricity Change	Total Household Electricity Change	Household Heating Efficiency Change	ΔT Change	% Time in CZ Change	Total rating
		(kWh/day)	(kWh/day)	(°C -hours /kWh/day)	(°C)	(%)	
GBS168	EDUG + CCB	-0.19	-0.22	1.73	2.03	20.1%	23
GBS156	REP	0.47	0.85	0.12	1.99	5.8%	23
GBS026	REP	-1.98	-1.85	0.16	0.21	-1.9%	19
GBS040	CCB	-3.83	-1.74	0.12	0.44	-0.7%	19
GBS724	CCB	-0.58	-5.34	0.03	0.55	2.0%	19
GBS023	REP	-0.28	1.51	0.02	0.37	4.6%	18
GBS045	EDUG + CCB	-0.32	0.89	0.03	0.26	0.0%	17
GBS046	EDUG + CCB	-2.25	-10.65	0.22	-0.33	-9.4%	17
GBS052	CCB	-1.81	4.21	0.04	1.11	-4.3%	17
GBS725	EDUG + CCB	-10.82	-9.88	0.19	-2.86	-16.8%	17
GBS726	EDUG + CCB	-3.84	-5.17	0.39	-0.77	-8.7%	17
GBS019	EDUG	1.47	-0.19	-0.24	0.93	3.0%	16
GBS094	CCB	3.57	2.82	-0.06	1.38	5.2%	16
GBS140	EDUG	-0.28	-1.32	-0.02	-0.36	3.5%	16
GBS022	EDUG	1.72	1.45	-0.07	0.72	4.1%	15
GBS041	CCB	0.58	5.07	0.00	0.19	9.2%	15
GBS097	CCB	2.07	5.01	0.12	3.46	-6.0%	15
GBS144	REP	8.37	7.51	-0.01	2.05	29.3%	15
GBS014	EDUG	-1.53	-1.60	-0.07	-0.92	-5.1%	14
GBS016	EDUG	1.27	9.80	0.00	1.09	-0.7%	14
GBS028	EDUG	0.77	7.20	0.02	0.57	-0.7%	14
GBS131	EDUG + CCB	15.67	20.22	-0.06	2.16	16.4%	14
GBS157	EDUG	1.67	1.61	-0.01	0.29	-1.3%	14
GBS029	EDUG	0.53	1.02	-0.05	0.28	2.6%	13
GBS047	EDUG + CCB	24.33	24.27	-0.47	2.55	43.3%	13
GBS090	EDUG + CCB	5.88	1.94	-0.07	0.44	3.3%	13
GBS098	CCB	7.02	7.41	0.00	1.79	-11.2%	13
GBS018	EDUG	0.37	-4.21	-0.07	-0.33	-6.1%	12
GBS037	REP	3.38	6.51	-0.01	0.89	-6.9%	12
GBS088	CCB	6.26	11.57	-0.01	0.59	4.0%	12
GBS099	EDUG + CCB	7.58	12.71	-0.04	1.15	4.5%	12
GBS036	REP	2.52	3.05	-0.07	0.23	1.1%	11
GBS166	REP	1.95	-4.45	-0.03	-0.78	-16.5%	11
GBS093	CCB	3.68	3.28	-0.22	-0.10	-0.4%	10
GBS268	REP	5.09	9.09	-0.36	0.26	-0.6%	9

Findings

- There is a distinct trade-off between increased comfort and increased energy consumption. See for examples GBS047, GBS131, which both achieved significant changes to time in the comfort zone, but at the expense of considerable extra energy consumption.
- The opposite trade-off is also seen where there is a decrease in energy consumption, but this is associated with decreased comfort. See for example houses GBS046, GBS725 and GBS726,
- Out of the 5 indicators, the HHE is the clearest indicator of overall success. All of the top quintile in HHE are in the top 11 of houses based on overall success ranking
- Such an analysis allows us to identify those houses that are being successful at reducing energy consumption at the same time as increasing comfort levels and then in term investigate more deeply into those cases to identify the underlying reasons for success.
- Likewise, for the opposite cases, where energy consumption has increased and comfort has decreased, we can investigate more deeply to discover what the barriers in those cases that are preventing successful energy and comfort outcomes.

4.5 Analysis by house construction age

Houses are analysed in this section, based on their age. Houses built after 2003 were required to meet energy efficiency standards that meant inclusion of features such as ceiling, wall and floor insulation, high quality, sealing windows, and potentially double glazing. This analysis also uses the 35 houses as described in section 4.2.

The numbers of households in the overall detailed study by house age are as follows:

- Post 2003–5
- 1980–2003–8
- Pre 1980–38

This analysis excludes houses with gas and wood fire heating, as well as households that have moved during the study.

Numbers of households in the sample groups are:

- Post 2003–5
- 1980–2003–6
- Pre 1980–24

Many of the older houses in the study had wood fires.

In some cases, the exact house age was not able to be identified so estimates have been made, based on an expert assessment of construction type, and location of the house.

Here baseline performance of the houses is compared using the data collected in the before period.

House age	Total Heating Electricity	Total Household Electricity	House Heating Efficiency	Living Temp	ΔT	% time in CZ
	Before	Before	Before	Before	Before	Before
	(kWh/day)	(kWh/day)	(degree-hours/kWh/day)	(°C)	(°C)	(%)
Post 2003	11.23	24.95	0.85	17.87	7.76	31.6%
1980-2003	17.90	30.59	0.46	17.10	6.01	37.6%
Pre 1980	19.53	40.40	0.61	19.11	7.33	38.2%

Findings

- Post 2003 houses use significantly less heating energy to achieve similar temperatures and ΔT to the older houses.
- This translates strongly into overall household heating use.
- On average, HHE is greatest in the post 2003 houses. This is not just explained by efficient heating types. Two out of five post 2003 households had heat pumps, the other three relied on resistive heating. 24 out of the 35 households in the sample have a heat pump in the house.
- The older houses are achieving a slightly higher % of time within the comfort zone, but at a significantly higher energy use.

5. Synthesis and discussion

In this section we bring together findings from the detailed analysis of individual cases and findings from the comparative analysis across all of the cases.

Section 5.1 brings together the changes to energy use and thermal comfort that have occurred during the GBS project, drawing on findings from the in-depth analysis of individual households through the case study process and findings from the comparative analysis process.

In Section 5.2 we then explore the factors influencing the changes that occurred, whether these changes were negative or positive. It is as important to understand what when right, to cause positive change, so that those factors may be replicated and improved upon. But it is also important to understand what goes wrong to cause negative change, or no change, so that those process may be avoided or improved upon.

Often it was found in the GBS project that householders were making trade-offs between energy efficiency, comfort and cost. Affecting positive change in one regard, while accepting negative change in the other. These trade-offs and several others related to comfort and energy efficiency are discussed in some detail in section 5.3.

We also provide a review of the methods of monitoring and evaluation as a final summary. Because the GBS project is part of a 'Pilot' scheme to test out the most effective programmes for improving energy efficiency and thermal comfort, a review of the methods of this Detailed Study component of GBS provides some valuable insight into the design of future programs.

5.1 Changes to household energy use and thermal comfort

When considering all houses in the detailed study, we saw both positive and negative changes to energy efficiency and thermal comfort in all approach groups. Across the energy based measures, the EDUG +CCB group displayed the most improvements when considered on a per occupant basis. It is found that the higher occupancy levels in those houses partly contributes to this efficiency. However, it must be said that there was a very wide variation in outcomes for individual households within each of the approach groups. For comfort measures, excluding those households with non-electric heating and those houses that moved, the EDUG+CCB group also displayed the greatest improvement in thermal comfort.

There was an increase in the bottom line, average household energy consumption figure, including all households in the study. More energy was used in the second winter than in the first. However, this increase is clearly explained by the increase in heating demand due to the colder winter in the second year of the study. A secondary influence may have also been the reduction in energy tariffs between the first and second winters that allowed households to feel a little more relaxed about energy costs.

It is difficult to identify any statistical trends out of the comparative analysis of the four approach groups. What is illuminating however are the dynamics and variation of outcomes across the range of individual cases in the Detailed Study. The differing outcomes, both positive and negative, that resulted from ostensibly the same GBS support activities lead the research team to investigate individual cases to search for the underlying factors that precipitated these varied outcomes.

Also informative is the identification of patterns or typologies of household energy use and thermal comfort habits. Such patterns can help to identify needs and or barriers in other households in the future.

5.1.1 Change in energy use during peak winter conditions:

When considering all households in the Detailed Study, it was only the REP group that showed a reduction in overall household electricity usage during the second winter period. When considered on a per occupant basis, these result change significantly, as there was a significant increase in the average occupancy of the EDG+CCB group households in the second winter. On a per occupant basis, the EDUG+CCB group recorded the most significant reduction in electricity usage of 19.9%.

Overall across the four approach groups we found:

	Major decrease	Minor decrease	Little or no change	Minor increase	Major increase
EDUG + CCB	3	3	2	0	3
CCB	2	3	1	6	3
EDUG	1	3	3	4	1
REP	0	2	2	4	4

The key factors in causing these changes are discussed in section 5.2.

5.1.2 Change in comfort during peak winter conditions:

When looking at all households including those with non-electric heating, all groups improved their thermal comfort in the second winter. It was the CCB group that improved the most at 5.0% more time within the comfort zone. The EDUG+CCB group improved by 3.9%, the REP group 2.2% and the EDUG group only marginally improved at 0.1% more time in the comfort zone.

When all houses with wood and gas heating as their main heating are taken out of the analysis, it is the EDUG+CCB group that show the greatest improvement at 5.9% more time in the comfort zone. The other groups had either a marginal increase or decrease in time in the comfort zone.

Overall across the four approach groups we found:

	Major decrease	Minor decrease	Little or no change	Minor increase	Major increase
EDUG + CCB	0	4	1	4	2
CCB	0	4	4	5	2
EDUG	0	1	5	6	0
REP	0	6	2	3	1

The key factors in causing these changes are discussed in section 5.2.

Comfort levels were measured as being between 18-24°C over a 24-hour period. It is understood that it is probably not necessary to have 100% of a 24-hour period within the 18-24°C range. A min of 60-70% is seen to be a good level when measured on this basis. Other more detailed definitions of comfort zones that factor in the time of day, and the different rooms of the household, could potentially be used if more time for data analysis had been available.

The interview and survey data tended to describe and greater increase in comfort as reported by householders, than was being measured by the temperature monitoring. A key factor in this discrepancy seems to be draught reduction, one of the tasks performed during home upgrade visits. Households reporting of reduced draughts and hence increased comfort was frequently not backed up by the temperature measurements. This does not mean that householders were imagining improved comfort. The temperature monitoring was only sensing air temperature. Air movement causes physiological cooling of people as air passes over them, even if the air temperature of the moving air is not cooler. Hence reduction in air movement will cause an increase in comfort in a cold climate, which will not be reflected in simple air temperature measurements.

5.1.3 Change in household heating efficiencies (HHE):

Excluding wood fire and gas heating (using the group of 35 analysed in 4.2 to 4.5), the EDUG+CCB group had the most significant increase in HHE (25%). The EDUG group's efficiency increased by 7.6%, CCB by 0.5% and the REP group decreased in efficiency. This effect is most likely due to a change in household use of heater. In the after period, there was more use of T41/42 wired-in heaters, particularly heat pumps and less use of plug-in heaters.

Generally, heat efficiency ratios, that is, the degree hours of heating achieved per kWh of energy input, per day, were fairly low, which indicated poor performance. Frequently ratios were found to be less than 0.4°C-hours/kWh/day. Across the sample of households this was highlighted by the fact that a few houses did have significantly higher HHE. These were the newer, post 2003 constructed houses and houses with heat pumps as the main source of heating in the house. Houses constructed post 2003 had an average HHE of 0.85°C-hours/kWh/day. Houses with only heat pumps for heating had an average HHE of 0.75°C-hours/kWh/day.

It was found that there are diminishing returns from extra heating energy put into houses. As increased energy is pumped in, less is translated into improvements to temperatures. This diminishing rate of return is found to be fastest in the worst performing, leaky, houses, which were generally older houses.

It must be understood that HHE is a result of a few key factors namely: the thermal resistance of the building shell; the type of heater/s being used; heating practices; window coverings and practices concerning these; door practices; and ventilation practices generally. Hence it is difficult to pin exact reasons on the variation of HHE for each individual household. In one house, the heating type may be the dominant factor, in the next house, the operation of windows, doors and ventilation strategies may be the dominant factor.

5.1.4 Change in heating energy use:

Overall heating energy was up in all approach groups (refer to tables in 4.2.1 for this heating discussion). These increases are seen as mostly being related to the colder winter. Interview responses noted that the cold winter led to more heater use. EDUG +CCB were the only group with heating increase over that of the REP group on a household basis. However, EDUG +CCB's increase clearly correlated with an outcome in terms of time spent in the comfort zone compared to other groups (refer to 4.2.1 change to temperature figures). EDUG had the greatest reduction in heater energy but had a correlating reduction in time in the comfort zone. When assessed on a per occupant basis all groups actually had a reduction in heating energy compared with the REP group. EDUG+CCB group had the biggest reduction on a per occupant basis. Notably, there was a significant increase in average household occupancy in the EDUG+CCB group over the study period (see Table 4 in section 4.1).

Home Energy Helpers, in many homes, encouraged use of more efficient heaters and advised about cheaper T41/42 tariffs. It seems clear that where householders took this advice there was a clear increase use in T41/42 hard-wired heating and corresponding decrease in T31/plug-in heating (refer to 4.2.3). This switch from plug-in heaters to hard-wired was largely beneficial for reducing cost, not necessarily for reducing energy consumption. In some cases, however, the switch lead to more effective heating of a space and therefore less energy use as well. For an example of this effect refer to Case 42 (Teri).

When households were compared across heater types, the results showed that energy use was increased across all heater types (refer to section 4.3). However, houses with heat pumps increased significantly less than houses with resistive heaters, irrespective of the approach group. This indicates heat pumps energy use are more efficient and/or used in more efficient ways. Heat pumps have a higher co-efficient of performance, and they have more effective thermostats and timers. Houses with heat pumps used less energy to begin with and then used even less energy afterwards relative to houses with resistive heaters.

There are however qualitative comments recorded in interviews and surveys that heat pumps do not necessarily provide the most comfortable form of heat. This is backed up by general understanding of comfort that says that radiant heat sources are more pleasant that convective or air borne sources of heat. Heat pumps rely on convective heat.

5.1.5 Change in hot water use:

Change to hot water energy use was varied across the approach groups. Compared to the representative group hot water increased most notably in the CCB group. However all groups increased relative to the representative group. On a per occupant the results were significantly different. Compared to the REP group the EDUG + CCB was the only group that reduced its use on a per occupant basis. CCB had a 28.5% increase in use and EDUG a 15.7% increase when compared to the REP group on a per occupant basis.

Home Energy Helpers, as part of upgrade visits, had retrofitted water efficient shower heads, hot water tank insulation and hot water pipe insulation to various of the houses in the upgrades groups, which did have a notable effect in some individuals houses as seen in the case studies.

5.1.6 Change in moisture levels:

Moisture levels in households was not a key indicator compared across all houses and approach groups. Rather it was assessed on a case by case basis where moisture problems were either noted by the householder or by the research team (refer to case studies for moisture discussions).

Most of the older and poorly insulated houses in the study were seen to be at risk of condensation occurring internally, and often problems of moisture and mould were only avoided through what appeared to be careful management by householders. Internal temperatures in the newer houses were typically well above dew point leading to less surface condensation.

Generally, where moisture was an issue, a reduction was seen over the course of the GBS project, either measured through air temperature and humidity monitoring, or as reported by householders. There were two notable cases where moisture got worse over course of the project. One of these was a newer house that received a home visit upgrade (Case 2, Nonie). This house had existing moisture problems and water leakage into the house due to construction problems. It is believed that there may have been vapour barriers incorrectly installed in relation to the wall and or ceiling insulation adding to the moisture problems in this house. The other house was from the representative group (Case 40 Naomi) where the household used their wood fire much less during the after period and consequently reduced their temperatures and lost radiant heat that previously dried out the house.

5.2 Key factors influencing change to energy use, comfort and energy affordability

Limited household income, the key characteristic of households that are the focus of the LIEEP, was certainly found to be the key barrier to householder making change. Limited incomes meant less capability to improve homes. It was the key barrier to physical upgrades mentioned by householders.

Many other factors also affected household energy use, energy affordability, comfort and the potential for improvement to energy efficiency and comfort. Key influences as gleaned from cases were:

- Income level
- Tenure
- Health and physical capacity of occupants
- Whether there was time available to understand and act
- How much contact (exposure) householders had with home energy helpers and energy champions
- Trust between organisation and householders
- Housing quality (especially thermal performance)
- Occupant numbers and occupant dynamics in the home
- Occupant house use patterns (eg home during day or not)

- Daily energy use practices, eg heater use practices
- Appliance (especially heater and hot water) performance, appropriateness, quality and efficiency
- Availability of affordable high quality fuels for heating, electricity, gas and wood
- Personal and household capacity
- Access to connected community that knew about energy and comfort management
- Payment methods for bills and related feedback on electricity consumption
- Persistence and of daily habits after support activities
- Complexity of everyday lives of occupants.

Below we explore a selection of issues critically influencing household capacity to engage in change for energy efficiency and comfort.

5.2.1 Household Tenure

Renters clearly had less capacity to make any significant changes, particularly structural ones. Troy (case 12) had mentioned that he would have liked to make some small changes, like hanging a curtain over the open doorway to hold in heat, but then said 'it's not my house to do it' and 'I guess I don't want to ruin their house' (before interview 25/6/14). While rental tenure difficulties are well understood (Gabrielle et al 2010), the regularity with which tenure issues were raised points to it being an unresolved issue for a number of GBS participants. The influence of tenure is a structural housing issue that needs resolution through policy.

There were some households that had a good relationship with their landlords, and had managed to effect changes through negotiations with the landlords, for example, Danielle in case 35 had a landlord who was open to her making useful changes to the house.

5.2.2 Physical conditions

The majority of houses in the GBS project are poor building stock that creates uncomfortable indoor environments for householders. This is reflective of low income housing generally. Most thermal performance measures of housing we observed sat within the very poor to under standard categories, (which is why the categories used had more poor performance levels than good). The combination of poor performing building fabric and an inefficient heating system creates a very low comfort environment, higher energy use, and consequently high energy costs. Poor physical conditions are often very difficult to improve without major intervention, and creates significant added stress for the low income householders.

A bright spot in improving house fabric performance as noted in the case studies was draught proofing. This was the most commonly noted upgrade that householders perceived had made a positive difference. Insulation in ceilings and curtains hung by Home Energy Helpers in a small number of houses also raised the thermal performance of elements of the physical house. The effect of these changes often had noticeable effects for households in terms of comfort but were still difficult to discern in temperature or energy monitoring. Stacey's case (22) provides an example of the positive effects that hanging good quality curtains can have.

Discrepancies between reported and measured comfort occurred for various cases. Reporting discrepancies are partly because overall detailed study houses performed poorly and minor improvements would be noticed by householders. Discrepancies also arose because there are so many overriding factors affecting day to day comfort levels, such as weather and occupancy patterns. Despite small upgrades noticeably helping householders with comfort and energy efficiency, such poor baseline standards of performance are hard to overcome with minor home upgrades.

Most houses in the study were standalone dwellings on suburban blocks and had potentially good solar access, but the siting and layout of houses rarely took advantage of this solar access. Living rooms and windows often had east, west or southern aspects. Houses also most commonly had single glazing with aluminium or timber frames with gaps around the frames. Almost without exception walls and floors were uninsulated. Houses constructed post 2003 did have insulation in walls and there were a couple of households where insulation had been retrofitted to floors. Ceilings were sometimes insulated, but typically to a low level or with aged insulation. Alone this ceiling insulation is nowhere near enough to support energy efficient heating.

Poor insulation levels were observed in houses that were built before energy efficiency standards were introduced in 2003. Age of construction therefore has a significant effect on thermal performance of the houses. Interestingly of the three age groups defined, post 2003 was the best performing, but 2003 to 1980 houses performed worse on average than pre 1980 houses. The poor insulation in all older houses is clearly demonstrated by the difference between indoor and outdoor temperatures and the poorer HHE in the older houses.

Only five houses that we observed in the detailed group were built since energy efficiency standards were introduced to the Building Code of Australia. Post 2003 houses in the study show very different outcomes compared to the older houses in terms of thermal resistance of the building shell. Examples such as the houses Olivia (case 41) and Alice (case 37) lived in demonstrate how the new construction facilitates better retention of heat internally. This can even be seen in Emily's house (case3) house, despite the moisture problems that were occurring in this house. This case also demonstrates that it is important when using increased insulation levels and sealing up houses for thermal resistance (as is now the practice) that moisture issues are considered. It is still possible that moisture issues can occur if condensation risk minimisation guidelines are not followed.

Window coverings also often did not provide much thermal resistance. Some medium and heavy curtains did provide reasonable resistance but windows often only had vertical blinds and aluminium horizontal blinds that, while they could help to angle sunlight, did not provide thermal resistance.

In some very poor thermal conditions householders moved house and managed to make significant improvement to indoor comfort and reduce energy use. Case 27 (Pam) and case 725 (Susie) are examples of this.

Some households conducted their own home upgrades – some over many years, for example Dale and Joanne (Case 9) and some during the GBS study period, for example Frank (Case 21). These households are discussed in more detail under the section on personal and household capacity.

5.2.3 Community networks with households

Several of the case studies reveal that help from locals in community is both influential and valuable. See Caitlin's case 6, Danielle's case 35 and Naomi's case 40 (also refer to cases in Watson's 2013 study).

GBS Community capacity building (CCB) activities and Energy Champion interaction with the Clarendon Vale and Rokeby community brought awareness of the GBS project, and energy efficiency generally, to the community and brought validity to the 'one on one' EDUG process rolled out within this local community. Energy champion training and activity embedded knowledge in the local community by upskilling people within the community rather than just relying on outside experts to come in and impart knowledge.

There was a distinct lack of engagement in formal community activities such as workshops and BBQs organised as part of the GBS project. Despite this, engagement by the Energy Champions (self-titled 'Power Rangers') was memorable to the householders (as evidenced through interviews and surveys). Qualitative data and cases point to regular word of mouth interactions between householders and Power Rangers and between householders and others in the community and discussion of energy efficiency in those interactions.

There is evidence of community influence outside of the Get Bill Smart activities encouraging thought and action related to energy efficiency, such as in Danielle's case (35) and Phillip's case (47). Some householders were triggered to act because of involvement in the GBS project. Even some participants without home visits in the representative group did record notable improvements thanks to discussions with their family relations or friends (though generally they didn't record large changes) (see cases 42 – Nonie). GBS CCB activities provided a catalyst to encourage this sort of interaction more often and in more of the community.

Participants saw community networks as requiring some give and take. 'Community' was seen as something that is there when they needed help. Often help would be received through the community neighbourhood centres, but this was also the mechanism through which help could be given to others (for example case 21, Frank). A number of householders were actually the 'wise advisors' in their community without being an official 'Power Ranger' as part of the GBS project. Others would give to the neighbourhood centre if they had extra because they recalled the help that had previously been given to them.

The use of CCB activities as part of energy efficiency programmes can learn from Australian and overseas examples. For example, Hawe et al (2000) describe community health promotion programs that have successfully used CCB. Critiques suggest that for CCB to work effectively there must be a real devolution of power to local community champions so decision-making is not centrally determined. There also needs to be local ownership of the programme and distance kept from commercial interest (Burchell et al 2014). These concepts are supported by the GBS findings.

Evidence in the Detailed Study shows that CCB is most beneficial when used in conjunction with the home visits and home upgrades (EDUG).

5.2.4 Personal connection versus community forums

In the CCB approach there was a lack of engagement by the community in the formal activities organised by the GBS project team. Engagement by Energy Champions (Power Rangers) with householders one on one or in small groups, however, was more effective and was also more memorable for householders interviewed. Hearing about problems and potential solutions from Energy Champions, people that are in similar situations to themselves, created an openness to change in householders.

Overall it is found that the one-on-one Power Ranger's influence and upgrade visit from the Home Energy Helpers was more helpful for direct change than the community forums alone.

People who had a personal relationship with one of the local Energy Champions often thought about change more or made more changes to their house. Caitlin (case 6) and Monique (case 23) provide examples of this. However, even with close family or friend connections in the community, involved as Energy Champions, some households did not record changes (for example, case 15 Gayle and Dennis and case 24 Joe and Beth). In these cases, there seem to be overriding issues such as health, new babies and/or other significant life stresses that take over and prevent engagement with energy efficiency issues.

5.2.5 Personal and individual household capacity for making change

Some householders exhibited personal interest in technology and or skills in the technology or energy area and were inherently more open to engagement and interested in the GBS project, whether or not they had connections to a power ranger in the community (for example, case 9 Dale and Joanne). These people were already more aware of the potential benefits of being energy efficient and had acted to make changes to their home. Often these households were older, retired or semi-retired with a bit more time available to consider change and put plans into action.

There were a small number of households with enough financial and physical capacity to gradually make energy and comfort changes to their houses on their own. One example is Frank (case 21) who had already made change before the GBS study. Frank made further improvements during the study by replacing an old window with double glazing. Another example is the previously mentioned Dale and Joanne who had renovated to include insulation, heat pumps and a heat transfer kit to transfer hot air from the ceiling space into rooms of the house. Both of these households performed well in measured comparison to most of the households in the study.

The majority of households demonstrated an improved capacity to seek information on how to reduce energy use/household comfort. There was also clear evidence that there was household capacity to make small changes to their abodes and lifestyle to improve household energy efficiency and comfort.

5.2.6 Persistence of practices

With some exceptions the study found that there were only a few households who changed markedly on either energy use or thermal comfort indicators, suggesting that household practices and expectations of thermal comfort and energy cost are fairly well fixed. Higher energy use before = higher energy user after and low energy use before = low energy use after. This was also the same for the average temperatures that householders maintained in their houses. If people were living with high temperatures before still lived with fairly high temperatures after.

The concept of acceptable temperature thresholds is reinforced by the findings. The 2015 after winter was colder than the 2014 before winter, but almost all households increased their heater use in order to maintain the same temperature and comfort levels. This applied to equally to households that maintained relatively low temperatures and to households that maintained relatively high internal temperatures.

5.2.7 Heater practices

Heater use practices are important enough to be considered separately. Patterns of heater use do not increase in a linear fashion as temperature decreases. In milder conditions, heaters are not used. As temperature drops, there comes a point where a threshold is reached and the householder turns on the heater. This threshold will be different for each household, explaining the higher or lower temperatures and higher or lower energy use across different households. Making change to energy use will be difficult without changing these thresholds.

Adding complexity to the issue of heating thresholds is the characteristics of the heating device being used. Most resistive heaters have just one or two settings, with no, or poorly functioning thermostats. Hence it is difficult to control the amount of heat being provided by the device. Wood fires are

worse in terms of the ability to control heat output. Numerous houses in the study with wood fires were seen to be heating the house to well above the typical comfort levels, but then quickly diving back well below those comfort levels once the fire is out.

Heat pumps tend to be slightly better at providing control, being newer technology, typically they have better functioning thermostats, and are fitted with timers allowing better control of heat delivery.

5.2.8 Occupant living patterns

Work practice and household occupancy practices greatly affected energy use. In several cases changes in occupancy or work patterns overwhelmed potential energy savings. Examples are: Danielle (case 35), who moved her work to home, Emily (case 4) who had a new baby and Erica (case 7) where another adult moved in with consequent changes to bedroom arrangements and heating practices.

Some participants were mismatched to the size of their houses. There were bigger (eg 3 bedroom houses) with one occupant, such as in Maureen's house (case 1). It can be hard to control comfort in big houses with one person, but there is the benefit that the individual doesn't need to negotiate with others regarding energy use and comfort levels. At the other end of the scale is Nonie's household (case 2) which had 10-12 people in a small 3 bedroom house. This mismatch is, in part, a structural problem with housing availability around Tasmania generally, with such a large proportion of dwellings being detached single houses.

It must be noted, and it was clear from the data gathered in the GBS project, that when considered on a per occupant basis households with more occupants are more energy efficient per person.

5.2.9 Ways of paying for energy

The use of payment plans for paying quarterly electricity bills eased the stress of big bills but also appeared to make people less aware of their energy use overall. It seemed that householders were left with a watered down impression of their energy use patterns. Many also paid for energy in the payments without even seeing the money as it went straight from their pensions or Centrelink payments. This meant there was very little feedback about energy use and people did get confused. There were several instances where householders thought they were using less power but had in fact increased their energy use (or vice versa) according to billing or electricity monitoring data.

The 'Pay as you go' (PAYG) electricity provision system was generally liked by householders in the study because of the control it provided, the awareness of energy use it allowed and the avoidance of big 'bill shock'. HEHs advised on tariffs in general and PAYG tariff explanations were very much appreciated.

For some householders that are good at budgeting, the PAYG system allows them to have a high degree of control and monitoring of their personal energy use. For others it was simply a case of putting money in the meter as required. At least these householders who were less thoughtful about their energy use did have an idea of how much money was being used and how frequently this was being used. The householders got feedback when money was required more frequently through the winter periods.

5.2.10 Heating for comfort and health

A major influence on comfort requirements and energy use is householder health and wellbeing. This is discussed further in the section 5.3, but it is important to mention as a factor influencing change. Poor health and incapacity because of health issues was seen found to be a major barrier to positive change in several GBS households. Health problems, leading householders to need to be in the house more and to being less active, meant that higher levels of comfort were required. Where that need coincides with poor performing housing fabric, and or poor heater efficiency or effectiveness, this invariably lead to high energy use and an incapacity to change or reduce that use (for example, case 15 – Gayle and Dennis).

5.2.11 The complexity and dynamic nature of people's lives

From personal experience we know, and through the case studies it can be seen that, lives are complicated and therefore so too is home management. Many households visited were living in dynamic and changing circumstances in terms of, health issues, occupant numbers, income, work hours, or renovations they were undertaking (as just some of many examples). In interviews we heard not only about busy lives but also about partners moving in or out, kids/grandkids moving in and out and people becoming seriously ill. Added to general complexity in life, in low income and rental households' lives can be even more dynamic. Renters, for example, tend to move house more frequently than other householders.

General comparative analysis does not convey these complexities yet complexities are important

to consider because a) they may be hiding energy efficiencies or other gains that are being achieved, and b) they reduce the control people have over their lives and hence their ability to plan for change. If you are moving house, have new people in, or are changing jobs, you're not less likely to have the space and time to think and act to make improvements for comfort or energy efficiency

Households in the GBS study could be roughly divided into two categories based on demographics. One category is young families, the other is older couples or single person households. A pattern seen in the project was that the older, more established households were leading more stable lives, and had more stable household environments and were abler to plan for and facilitate change. The younger family households tended to have more complex and less stable household situations, and were therefore in a less favourable position to plan for and facilitate positive change.

5.2.12 Wood fuel and wood fires

There seemed to be a number of households relying on wood fired heating to reduce energy bills and improve comfort. While this may be a reasonable heating option, wood fired heating still comes at a cost if the appropriate wood for the fire is to be purchased, and wood fired heating may create indoor air quality concerns. For example, smoke may release into the house if the fire/stove is not properly flued or on the starting up of fires. Several households reported that sourcing properly seasoned dry wood could be difficult and Patricia (case 29) could not use her wood fire because of it smoking indoors.

In favour of wood fires is that fact that they produce radiant heat that is generally accepted as being more comforting than convective heating provided by heat pumps and fan heaters. However as discussed previously the heat output from wood fires is difficult to control leading to overheating and inefficient distribution of heat around the house. In addition, in suburban areas wood fires tend to cause problems for others in the community.

5.3 Critical Trade offs

Often it was found in the GBS project that householders were making trade-offs between energy efficiency, comfort and cost, that is, affecting positive change in one regard, while accepting negative change in the other.

There are many other priorities that householders are dealing with on a daily basis that compete for attention with energy and comfort goals. For example, changes to the time spent in the home due to changes in employment circumstances, or health and wellbeing issue such as householders who stayed at home to care for ill family members or young children. These priorities cannot be ignored and have consequences for comfort and energy consumption.

5.3.1 Energy use versus cost, comfort and health

There was a critical tussle that went on between energy use, cost, comfort and health parameters in most households in the GBS study. Trade-offs between reducing energy costs and maintaining basic levels of comfort came up again and again. Trade-offs becomes particularly apparent where households had to incorporate the comfort of household members suffering illness or chronic health conditions, for example Olivia (case 41) and Cassie (case 34). Another example is when parents were considering the vulnerability of young children to cold and damp conditions. There were many examples of mothers and grandmothers saying they were heating to keep the children healthy (Caitlin case 6, Sarah case 17, Queenie case 20, Pam case 14, Nancy case 113, Beth case 24, Martin and Fiona case 44, and Anna case 49).

The research found that typically, when a household wasn't gaining their desired comfort level (ie a comfort level where they felt warm enough to get on without feeling miserable) and an opportunity to use a little more energy occurred, the household would use it. Most often this was for health reasons. Basic comfort requirements were not being met in many of houses and any opportunity they had to better meet those needs, the households took.

We know that poor public health indicators are linked to low socio-economic status (SES) (Rasanathan et al 2011). Low SES often equates with poor housing stock which in turn can impact on health – including for those vulnerable to respiratory conditions or allergies that might be affected by cold and /or damp or poor indoor air quality (Thompson et al 2009, Howden Chapman et al 2011). So SES presents both direct and indirect impact, direct because a

household has less financial capacity to improve their circumstances and indirect because their economic circumstances constrains their housing choice.

Many households in the study are already very low energy users and cannot possibly be more efficient with their energy use (for example Ingrid, case 33). However, for this frugality, the trade off is very low comfort levels, to the point where life style and physical and mental health are negatively affected.

For most households the thought of saving money through reduced energy use was attractive. However, the study found that when there was evidence of savings being made through energy use reduction or efficiency gains, that money was often put straight back into achieving better comfort through more energy use. For example, if savings were made through the lowering of electricity tariffs, or through changes in usage to the cheaper T41/T42 tariffs, these savings were typically offset by more energy consumption to increase comfort. This is supported by New Zealand research into trade-offs (Howden-Chapman 2009).

5.3.2 Surface condensation/mould vs draughts

There is a delicate balancing act going on in many of the homes in the GBS study. Often the draughts that make people cold can help to dry out surface condensation in a poor performing house. Just a small reduction in humidity levels can be the difference between persistent condensation that causes mould, and intermittent condensation that dries out each day. The frequent occurrence of surface condensation is primarily a result of low indoor temperatures and low thermal resistance of the building fabric. Even in some cases where the air temperature measures recorded did not suggest condensation was likely, householders reported condensation occurring on windows and the insides of external walls. This is because of the significantly colder surface temperature on these surfaces as compared to the air temperature being measured. The drop in temperature at the surface precipitates the moisture out of the air as condensation.

There were a few cases where surface condensation issues appeared kept at bay because of draughts (Irene, case 51, Deanne and Richard case 50, Dale and Joanne case 9). People in Tasmania have before commented that they understand they need to air out/dry out their houses in winter to avoid damp indoors (Watson 2013).

5.3.3 Other trade-offs

There are many other tradeoffs occurring due to the multiple, potentially conflicting, demands on householders. Here we briefly discuss a few of the more pertinent types that were encountered.

Occupant micro-politics at the household scale – This could include differences in priorities of the different householders, negotiations with landlords, caring for animals in the house. These issues can pull householders in differing directions. We observed, for example, that when only one householder was keen to save energy or make changes or one occupant was primarily responsible for paying energy bills, then energy saving actions were often overridden by other occupants (for example teenage hot water use, partners using more energy). New occupants to a home were observed to create a jump in energy use and a loss of control over energy efficiency practices. Tenants would put aside ideas of energy upgrades if landlords didn't support them or if tenants thought landlords would disapprove. Householders would also prioritise animals and their movements through the house over energy efficiency practices.

Lifestyle expectations – Expectations differed about how householders thought they should be able to live. At one extreme frugal householders would not spend any money on heating and their lifestyles suffered as a consequence. At the other extreme, householders expected to be able to do what they wanted when they wanted and to be comfortable no matter what, and hence paid for the privilege to do so.

Heat pumps vs radiant heaters – Heat pumps are significantly more efficient to run and deliver other benefits relating to control of heating, however there is a distinct dislike of convective, fan forced heating systems. Some householders preferred to use radiant heat sources, even if they were less efficient and cost more to run because of the negative perceptions around heat pumps.

Heater flexibility – Plug-in heating is less efficient and costs per kWh being on the T31 tariff, however plug-in heaters can often be more effective at delivering heat to where it is required in the household. Fixed, hard-wired heating may be more efficient, as in a heat pump, but may not be well positioned in the home, leading to more energy use to achieve the same comfort levels.

Moving House vs Staying Put – moving house places a big stress on the householders, but for some the extremely poor performance of their houses and the cost of keeping up comfort levels means that moving house for the sake of comfort is worthwhile. If the move can create a significant increase in comfort levels and or a significant decrease in energy bills, then additional benefits may be gained through making the move. There may be less of the other trade-offs required in the new house.

5.4 Review of methods for monitoring and evaluation

Because the GBS project is part of a broader scheme investigating the best ways to improve household energy efficiency and thermal comfort, it is important to review the success or otherwise of the methods used in monitoring and evaluating the project in order to inform future similar programmes. What other information/data could have been gathered that would have added to the knowledge? What would we have done differently/better?

- The use of integrated qualitative and quantitative research methods proved critical to achieving the desired outcome of gaining detailed understanding. Neither of the qualitative or quantitative data sets collected, on their own would have provided the same insight. This is seen as a success in terms of data collection and triangulation of evidence to reinforce credibility and viability of the results.
- The research approach was a complex and therefore time consuming and costly exercise. Doing the same level of research on future projects, if similar in scope and aims to the GBS project, would seem to be unnecessary.
- Specifying data logging devices and systems for constant logging and for remote data feeding was problematic. Data logging specification and engagement with suppliers was long winded taking several months to resolve. Purchasing electrical logging equipment continued to be challenging into initial field work with the Champions. Commercial problems with supply of 3G modems from Telstra and low supplies of routers in Tasmania meant that the initial electrical monitoring was challenging, was very time consuming and therefore became complicated and held up work on other aspects of the project.
- We settled on relatively new technology for the electricity monitoring, that was not tested in the context for which we were putting it to use. This technology was chosen from existing, off the shelf technologies. We were therefore we pushing the technology and the services behind the technology to achieve beyond its intended usage. The monitoring was a success overall, but there were struggles along the way, getting the technology to work as we required it to.
- Recording and sending information to a remote cloud storage facility proved to be problematic at times within the CVR community because of poor 3G internet coverage in the area. Several householders reported that they had this problem with their own phones.
- Having electricity and temperature sensors left within participant households for over 15 months was potentially fraught with difficulty. In generally however, participants did a great job in looking after the equipment. There certainly were many occasions when equipment was accidentally un-plugged or turned off. Remote monitoring of the electricity monitoring equipment meant that these disruptions could be detected and the householder contacted to quickly rectify the problem. There was only one household in the study, for which the equipment was removed and the monitoring terminated because the household was not able to keep the equipment plugged in.
- The temperature logging equipment worked extremely well. They loggers were extremely reliable and simple to use and simple to access data form. There was less than 1% failure rate in temperature data gathering over the life of the project.
- Data extracting from the cloud storage proved very problematic and time consuming. This was partly due to the large amount of data to be extracted, but also partly due to the inexperience of the provider in working on this sort of project and at such a large scale
- Many of these problems with technology could be avoided the next time around if a similar project were to be undertaken.
- The evolution of the two approaches are not the same level. In-home upgrades are a relatively long-established form of energy efficiency improvement activity. The GBS team had been involved in delivering such services for many years and hence had refined the process. The CCB approach was new to all in the GBS team. Further refinements of the approach over time may yield improved results in terms of participation and or outcomes for households.
- The numbers of households in the different approach groups not the same, possibly leading

to some distortion in the results. The numbers are also relatively small. Though given the time and expense in undertaking such detailed research in to 51 houses, it is difficult to see justification for expanding the numbers at such a detailed level of research.

- Reliance on recall of participants is a problem so measuring certain types of change is difficult
- Data on wood usage is one specific piece of data, that while difficult to accurately collect, would have been very beneficial to have more completely collected. The data that was collected was insufficient to make reliable calculations of wood heater energy use.
- Electricity billing data collected was not easy to compare to the detailed monitoring data, because different timeframes were involved, and different methods had to be used to work through the bill data. The detailed data was specifically focused on the peak winter period, whereas the billing data was limited to the billing cycle.

It was a lot of effort to gather such a broad range of data and to such depth at the same time, however this is a very valuable data set that could be used for many other purposes into the future.

6. Conclusion

The Detailed Study aimed to gain further insight into energy efficiency and thermal comfort behaviours through more nuanced understanding of the conditions that householders experience, the changes (outcomes) that occur over the GBS study period, key influences affecting those changes, and trade-offs made between energy use and comfort.

Through analysis of the case studies we were able to identify the performance of individual households and the rich and varying ways they responded to energy use, energy costs and comfort needs. The use of mixed qualitative and quantitative data sets provided a useful picture of household experiences and allowed researchers to detect important changes and improvements. Comparisons across households provided insight into key performance indicators and patterns of energy and comfort change. Through these explorations we identified some key findings, namely:

- Changes measured after GBS activities were undertaken suggest the EDUG +CCB group showed most signs of improvement of all of the groups. While the CCB component needs further refinement, it shows signs of being beneficial when undertaken in conjunction with in-home education and upgrades.
- A wide range of factors influenced household energy use, energy costs, and comfort. These factors are important to consider when designing programs as they will affect potential outcomes.
- The effects of various factors on energy and comfort outcomes becomes clearer when trade-offs are examined. The occurrence of trade-offs indicates conflicting priorities for the householder. Critically, energy savings were regularly traded to improve comfort and health.
- Differing priorities across households indicate that any one single measure cannot be relied on in an energy efficiency program. Further, energy use reduction, thermal comfort improvement and householder cost savings are three separate goals that may not be achievable simultaneously for a household. Programmes therefore need to be designed to accommodate these goals in order to be effective.
- In general, energy and comfort performance of the physical housing stock and heating systems was poor. Houses that were built before 2003 had very poor levels of thermal performance; homes built since 2003 performed significantly better. This is a significant structural problem for energy efficiency programs to overcome.
- There were significant differences in household heating efficiencies which were caused by widely varying heater performance combined with widely varying thermal performance of housing fabric.
- The persistence of householder practices and expectations around comfort and energy use was notable. Householders tended to increase their heater use in order to maintain the same temperature and comfort levels that they were accustomed to in the colder after (2015) winter.

A key theme of all these conclusions is that there is a complexity, variation and dynamism across low income households which suggests the need for a tailored approach to future energy programmes. The depth of understanding developed through this Detailed Study can be used to guide, not only the tailoring of, but also the overall structural development of, energy efficiency programmes for cool temperate climates such as Tasmania.

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(Footnotes)

1 This number includes gas energy converted to kWh. The electrical energy used to run the ducted gas heating system and fans, is listed in T 31 heating line.