ACT Government

Environment and Sustainable Development

Outreach Energy and Water Efficiency Program

Case study report

JUNE 2013

Contents

Further information

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Belconnen Community Service

Communities@Work

Northside Community Service

Society of St Vincent de Paul

YWCA of Canberra.

Assessors and retrofitters from C&J Group and Cool Planet provided energy and water efficiency assessments, education and retrofitting for the Outreach Program. Staff from Housing ACT coordinated the energy efficiency improvements on Housing ACT properties.

Prepared by

Scinergy: the Science of Energy Efficiency

Edited by Biotext Pty Ltd, Canberra

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Summary

Between March and September 2012, Scinergy conducted diagnostic assessments and analysis on a sample of 11 low-income households participating in the ACT Government's Outreach Energy and Water Efficiency Program.

The aims of the project were to collect and analyse data to determine whether the Outreach Program is improving household energy efficiency, and to inform and improve policy and program implementation. The project included:

- analysing the thermal performance of the building envelope for each case study house
- predicting the effectiveness of proposed retrofits for specific houses using thermal performance simulations (theoretical modelling)
- measuring the actual temperature, air leakage and energy use in each house before and after replacing appliances, retrofitting and educating the household
- determining the effectiveness of building envelope retrofits and household appliance replacement
- comparing the predicted results with the actual results.

Overall, the case studies show that the Outreach Energy and Water Efficiency Program is assisting low-income households to improve the energy efficiency of their homes, reduce their energy consumption, reduce their energy bills and contribute to reducing greenhouse gas emissions.

Comparison of winter energy bills from 2011 and 2012 shows that 9 out of 11 case study homes reduced their energy consumption and saved money on their bills as a result of participating in the Outreach Program.

Key results recorded across all case study homes were:

- an average 22% reduction in energy use in the winter quarter compared with the previous year, made up of
  - 33% reduction in electricity consumption in the winter quarter compared with the previous year
  - 5.9% reduction in gas consumption in the winter quarter compared with the previous year
- an average $270.60 net dollar saving per household in the winter quarter
- a total reduction of 18.44 tonnes of carbon dioxide equivalent (CO_2-e) in the winter quarter.

Of the eight case study homes that underwent thermal modelling, all increased their energy star rating after retrofitting.

When considering cost-effectiveness, draught sealing was consistently the most effective retrofit measure. Insulation and heavy drapes with pelmets also significantly reduced energy use and increased comfort in case study homes.

Data from four case study homes showed that replacing old, inefficient refrigerators with new models can halve the energy used for refrigeration.

The project also highlights the importance of behaviour in the context of energy reductions.

Refer to Section 4 'Findings and recommendations' for more information.

1 Background

1.1 The Outreach Energy and Water Efficiency Program

The Outreach Energy and Water Efficiency Program assists low-income households in the ACT to improve the energy and water efficiency of their homes, reduce their energy and water consumption, reduce their energy and water bills, and contribute to reducing greenhouse gas emissions. The program has been developed by the ACT Environment and Sustainable Development Directorate with a budget of $7.8 million over four years to July 2015.

The program provides eligible low-income households with some or all of the following assistance:

- a home energy efficiency assessment and education
- new energy-efficient and water-efficient appliances to replace old, inefficient appliances
- a retrofit to improve the energy efficiency and water efficiency of households.

The Outreach Program is delivered by the following community welfare organisations:

- Belconnen Community Service
- Communities@Work
- Northside Community Service
- Society of St Vincent de Paul
- YWCA of Canberra.

These organisations implement the program through their existing clients and obtain client referrals from networks within the community services sector of the ACT. Each organisation has been provided with funding to deliver the program, including funding for an Energy Efficiency Officer in each organisation. The role of the Energy Efficiency Officer is to identify eligible households that would benefit from energy-efficient and water-efficient appliances, and refer them for a home energy efficiency assessment, retrofit and education session delivered by a panel of service providers funded directly by the ACT Government. Energy Efficiency Officers can also refer clients to Housing ACT for draught sealing and ceiling insulation top-ups.

1.2 Project aims

The aim of the project was to collect and analyse data to determine whether the Outreach Program is improving household energy efficiency, and to inform and improve policy and program implementation. The project included:

- analysing the thermal performance of the building envelope for each case study house
- predicting the effectiveness of proposed retrofits for specific houses using thermal performance simulations (theoretical modelling)
- measuring the actual temperature, air leakage and energy use in each house before and after replacing appliances, retrofitting and educating the client
- determining the effectiveness of building envelope retrofits and household appliance replacement
- comparing the predicted results with the actual results.


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2 Methodology

Between March and September 2012, Scinergy conducted diagnostic assessments and case study analysis on 11 low-income households participating in the Outreach Energy and Water Efficiency Program using an 'assessment–education–retrofit' process.

2.1 Recruitment of case study participants

To be eligible for inclusion in the Outreach Program and the case studies, participants had to be:

- ACT residents
- experiencing financial hardship
- earning less than the maximum income limit as defined in the Outreach Program specifications.

Participation may assist in reducing financial hardship associated with high energy or water consumption costs.

Outreach participants were asked by the community organisations if they would like to take part in the case studies. Participation in the case studies was entirely optional.

The houses and clients selected were new participants in the Outreach Program, had energy usage data available for at least the previous 12 months, and had potential for a variety of different retrofit and education measures.

2.2 Tools

The methodology was based on the well-established theory that an insulated and airtight envelope is the key to an energy-efficient and comfortable building. Using various technologies, data were collected to assess how well each building was performing, prioritise improvements, and measure the effect of changes on energy use and comfort. Tools included:

- household electricity-use monitors
- appliance electricity-use monitors
- temperature data loggers
- fan depressurisation to quantify and locate air leakage (see Box 1)
- thermographic inspection of the building envelope to locate insulation gaps and air leaks
- thermal performance simulation of the building to predict heating and cooling loads. Thermal performance was modelled using BERSPro 4.2 software (which is accredited under the Australian Government's Nationwide House Energy Rating Scheme [NatHERS]) to show the difference between the thermal starting point (initial star rating) and end point (star rating after retrofitting) of the case study houses (see Table 2).

Anecdotal information was also collected at site visits.

2.3 Data collection timeline

Data were collected over approximately eight weeks to measure:

- improved efficiency of replaced appliances
- baseline electricity consumption and temperature profile
- energy consumption and temperature change due to education
- energy consumption and temperature change due to retrofitting
- qualitative feedback and insights into behavioural change from clients.

Box 1 Measuring air leakage

Air leakage is the uncontrolled movement of air into and out of a building (infiltration) that is not for the planned purpose of exhausting stale air or bringing in fresh air (ventilation). It is driven by three main forces:

- wind, which exerts constantly changing pressures on buildings (high on the windward side and low on the leeward side, roughly 150–1500 pascals [Pa] differences)
- the stack effect, where rising warm air causes pressure differences within buildings (lower pressures at the top, higher pressures near the floor, around 5–10 Pa differences)
- mechanical heating and ventilation systems, which create pressure differences within buildings as they heat, cool and move air (5–10 Pa differences).

Air leakage can account for 30% or more of a building's heating and cooling costs,[a] so controlling air leakage is the most effective way to achieve direct energy savings. In Canberra, typical air leakage rates are equal to two complete air changes per hour, which represents a substantial amount of energy and money, especially in winter. Uncontrolled air leakage also compromises the effectiveness of other, more expensive, energy efficiency measures such as new heating systems, window dressing and double glazing.

The best way to measure air leakage is to use a blower door and thermal camera. The blower door includes four components: a calibrated fan, an expandable door-panel system, a sensitive gauge to measure fan flow and building pressure, and tailored computer software. The fan is sealed into an exterior doorway with the door-panel system and then used to draw air out of the building, creating a pressure difference between inside and outside. This pressure difference causes air from outside, at higher pressure, to move into the building through all the gaps in the building envelope. The tighter the building envelope (fewer gaps and cracks), the less fan speed is needed to create a change in building pressure. The pressure gauge and computer are used to regulate and record the air flow and pressure differences.

The thermal camera is used to locate the air leaks: as long as the air being drawn in through the leaks is warmer or cooler than the inside of the house, the area surrounding the leak will change temperature and show up on the thermal image. Even if there is little temperature difference between inside and outside, an infra-red scan can still be effective, because subfloor spaces are generally cooler, and roof spaces generally warmer, than the external air temperature. This technique allows you to find significant, and otherwise undetectable, leaks without having to enter the roof or floor space. A thermal camera can also show where insulation is missing or has been improperly installed.

a US Department of Energy, Office of Building Technology, http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/26446.pdf

Data were collected from the households according to the following timeline provided by the Outreach Program to Energy Efficiency Officers and service providers:

Week 1: Client referral and baseline appliance data

- Energy Efficiency Officer identifies client who would like to participate in the study.
- Energy Efficiency Officer conducts a home energy assessment and installs appliance energy monitor on appliance(s) to be replaced.

Week 2: Appliance replacement and installation of energy and temperature monitors

- Energy Efficiency Officer records previous week's energy use of old appliance and fits energy monitor to new appliance.
- Scinergy installs temperature data loggers (two internal, one external).
- Scinergy/electrician installs household electricity-use monitor.
- Service provider conducts a comprehensive home energy assessment and education session, and prioritises energy efficiency improvements to determine retrofit measures.

After the Week 2 visit: Thermal performance simulation

- Scinergy assesses the potential thermal performance (predicted heating and cooling loads and star rating) using simulation software.

Week 4: Building envelope testing #1 and education

- Scinergy retrieves appliance energy monitor from new appliance and collects data.
- Scinergy conducts air leakage testing via fan depressurisation and thermographic inspection of building envelope.
- Service provider carries out educational component of program, introduces client to household energy monitor and identifies potential energy-saving behavioural changes.

Week 6: Retrofit

- Service provider oversees retrofit and installation of curtains (if required).
- Service provider carries out draught-proofing.

Week 8: Building envelope testing #2 and data collection

- Scinergy retrieves temperature data loggers and collects results.
- Scinergy downloads data from household energy monitor (monitor left with client).
- Scinergy conducts air leakage test to measure improvements achieved through retrofit.

After Week 8: Education and quality assurance

- Service provider conducts final education session, and checks the quality of retrofit and customer satisfaction.


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3 Results

This section summarises the results of the project. Full details for individual case studies are presented in Appendix A.

3.1 Characteristics of case study participants

The characteristics of the participating households varied greatly in:

- the size, age, type of construction, design and orientation of buildings
- the number, age and education level of residents, and their interest in and behaviour relating to energy and water efficiency.

Six of the 11 households were Housing ACT residents, and five were home-owner–occupiers. In the Outreach Program as a whole, approximately 75% of participants live in Housing ACT properties.

All case study households had between one and three residents, although the number of people in the house could vary considerably at any point in time. These variations included new residents moving in during the case study, support staff present (in one household) and household members being away on holidays.

Many of the case study participants spent considerable time at home because of their financial circumstances. Many were retired, unemployed or on disability support pensions. At least two of the households had members with respiratory conditions related to cold temperatures, although health concerns were self-reported, and monitoring improvements in health was outside the scope of this project.

A summary of the household characteristics is provided in Table 1.

Table 1 Characteristics of case study participants

Case study number	Number of occupants	Type of residence	Financial circumstances	Description
1	3	Owner–occupier	Unemployed full-time student	Mother with teenage children. Two large living areas with reverse-cycle air-conditioning; central gas heating. Electricity and gas.
2	1	Housing ACT	Disability support pension	Chronic cardiac and respiratory health conditions. Gaps around doors and windows. Participant uses portable electric resistance heater instead of the electric resistance wall heater because of its location. Electricity only.
3	1	Owner–occupier	Retired, old-age pension	Participant has large winter heating bills. In 2011, participant had health concerns, and a second person was living in the home. House has electric heating in slab. Electricity only.
4	3	Housing ACT	Single-parent pension	Mother of young children with respiratory health concerns. A second adult moved in during the case study monitoring. Extremely cold house, with limited solar heat gain because of house orientation, and very draughty. Electric resistance heating. Electricity only.
5	3	Owner–occupier	Disability support pension	Insulation was thin and patchy, and the house had permanent vents in every room. Gas heating in living areas. Electric reverse-cycle systems in bedrooms. Electricity and gas.

Case study number	Number of occupants	Type of residence	Financial circumstances	Description
6	2	Housing ACT	Single mother with part-time work	House very cold in winter and very hot in summer. Electric resistance wall-mounted heater. Electricity only.
7	3	Owner–occupier	Not listed	House cold in winter, hot in summer. House had a number of significant air leakage points, including a skylight. Northerly aspect. Wall-mounted electric panel heater. Electricity and gas.
8	3	Housing ACT	Not listed	House cold in winter and hot in summer. Electric heating. Electricity only.
9	1	Housing ACT	Centrelink pension	Three-storey apartment built approximately 50 years ago. Inefficient electric resistance heating. Electricity only.
10	3	Housing ACT	Disability support pension	Three tenants with disabilities; 1-2 staff onsite 24 hours per day with up to 7 people present at any one time. Tenants do not have direct control of energy use and rely on staff members for assistance. Gas heating. Electricity and gas.
11	2	Owner–occupier	Disability support pension	Householders get very cold in winter. Draughty house with many points of air leakage. Gas heating. Electricity and gas.

3.2 Thermal performance simulation

Thermal performance of the buildings was modelled to show the difference between the thermal starting point (initial star rating) and end point (star rating after retrofitting) of the case study houses (Table 2). Of the eight case studies that underwent thermal modelling, every house increased its energy star rating after retrofitting.

In Canberra's climate, a 3-star home is predicted to require 387 megajoules per square metre (MJ/m^2) for heating and cooling, which is 2.3 times more energy per square metre than a 6-star home (165 MJ/m^2).[1]

The differences in modelled thermal performance among houses are mainly due to differences in windows (orientation, window dressings and size relative to room floor area), insulation levels and air tightness. Case study 3, for example, was well sealed (with few ceiling penetrations or other air leaks), and had north-facing windows to the main living areas (allowing passive solar heat gain over winter), heavy drapes to most windows, and both ceiling and wall insulation. In contrast, case studies 4 and 5 were extremely leaky (with permanent ceiling vents in every room), and had little opportunity for passive solar heat gain to living areas, poor-quality window dressings, thin ceiling insulation and no wall insulation.

The importance of draught sealing is often underestimated in Canberra's climate. Thermal performance modelling suggests that energy savings of approximately 10–20% can be achieved in some of the case study houses by sealing permanent ceiling penetrations—a relatively simple and inexpensive retrofit measure. Physical performance testing of case study houses, and statistical analysis of the correlation between reduction in air leakage and reduction in energy use, suggests that, for some houses, savings from draught sealing alone may be higher than 20%.

1 See the NatHERS at (www.nathers.gov.au) and the BERSPro at (www.solarlogic.com.au/bers-pro) for more information on star ratings.

Table 2 Star ratings of case study houses 1–8 before and after retrofitting

Case study number	Star rating pre-retrofit	Star rating post-retrofit	Retrofit measures
1	3.9	4.5	• Draught sealing • Pelmets to living areas
2	2.8	4.2	• Draught sealing • Curtains and pelmets to living areas
3	5.9	6.5	• Pelmets to living areas • Minor draught sealing • Filling gaps in ceiling insulation
4	2.9	4.7	• Draught sealing • Ceiling insulation top-up • Wall insulation
5	2.8	3.4	• Draught sealing • Ceiling insulation top-up • Curtains and pelmets to living areas
6	4.2	5.2	• Major draught sealing • Pelmets to living areas and bedrooms
7	3.3	4.9	• Draught sealing • Curtains and pelmets to living areas
8	2.8	3.4	• Draught sealing • Curtains and pelmets to living areas

Notes: Case studies 9, 10 and 11 were not included in the modelling because of scheduling constraints.Thermal performance was modelled using BERSPro 4.2 software (which is accredited under the Australian Government's Nationwide House Energy Rating Scheme [NatHERS]). In regulatory mode, energy efficiency rating software does not model window dressings, and star ratings are expressed in 0.5 increments. For the purpose of this project, the simulation software was run in non-regulatory mode to model the impact of changes to window dressings, and ratings are expressed in 0.1 increments to give a better indication of changes. Further details of actual and predicted heating and cooling loads can be found in Appendix A.

Only one case study house had wall insulation installed during the study. This occurred very late in the process and appears to have coincided with a significant change in household composition and energy-use behaviour, so it is not possible to draw firm conclusions about the effect of wall insulation from this study. However, wall insulation is well recognised as being extremely effective in a cool, temperate climate. The Building Code of Australia sets a minimum standard of R2.8 for external wall insulation systems in Canberra's climate zone.

The software provides an estimate of current thermal performance using the NatHERS star rating scheme and was also used to predict which building envelope improvements would be most effective for eight of the case study households. Predicted improvements varied:

- For case study 4, with uninsulated external walls, installing insulation was predicted to reduce energy requirements for heating and cooling by 26%. (Although wall insulation was not retrofitted to case studies 5 and 8, thermal modelling suggested it would result in reductions in energy use of nearly 30% for these houses.)
- For houses with large, inadequately furnished windows to living areas that do not benefit from passive solar heat gain (case studies 2 and 7), installing curtains and pelmets was predicted to reduce energy requirements by 16–19%.
- For houses with many ceiling penetrations and substantial air leakage (case studies 2, 4, 5, 6, 7 and 8), draught sealing was predicted to reduce energy requirements by 9–18%.
- For houses with thin or patchy ceiling insulation, estimated to be equivalent to R2 (case studies 4 and 5), topping up the ceiling insulation to R4 was predicted to reduce energy requirements by 30–40%.

3.3 Air leakage rate and location

When a house is depressurised, air flows in through any cracks or gaps in the internal building envelope. This air can often be cooler (e.g. air inflow from subfloor spaces or shaded walls) or warmer (e.g. air from roof spaces—even on cold Canberra days, it does not take much sunshine to heat the air in the roof space to temperatures higher than inside the home). This air inflow can create temperature differences inside the home as the air moves across internal surfaces, and create draughts.

The presence of draughts can affect a person's perceived temperature of a room. Draughts can make a person feel cold by removing heat from the body—when the draught is removed, the room can feel warmer even though the actual temperature may be the same.

Rates of air leakage

The number of air changes per hour at a pressure differential of 50 pascals (n50) is an internationally accepted standard for expressing the rate of air leakage in homes. Following the lead of the 2006 UK building standards,[2] it is suggested that houses in the Canberra climate should aim for an n50 of less than 10. Only two of the case study homes achieved an air leakage rate below 10 before retrofitting (Image 1). The majority had much higher rates of air leakage that were seriously compromising their energy efficiency and comfort.

Simple draught-sealing measures reduced the rate of air leakage in nine case study homes by an average of 34%. Statistical modelling of actual air leakage and energy consumption data suggests that draught sealing accounts for almost 40% of energy savings. The relationship between air leakage and energy use is described in Box 2.

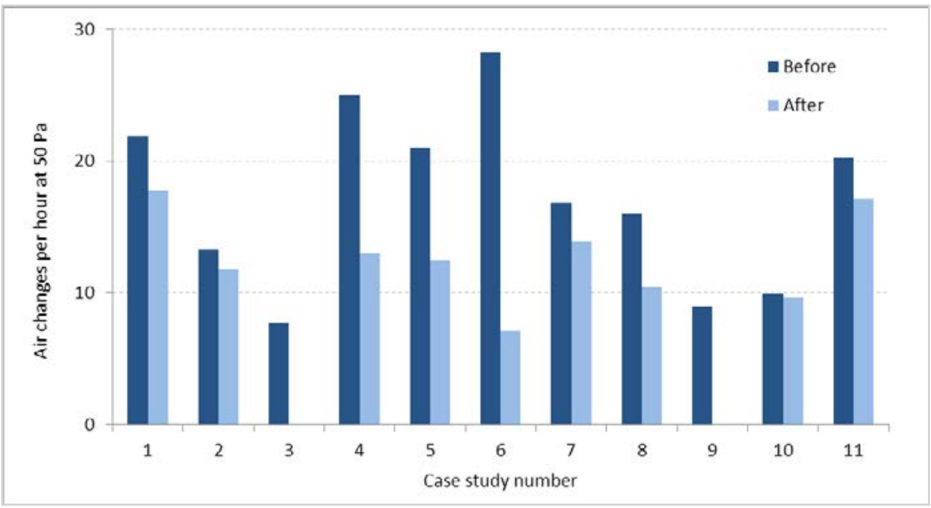
Location of air leaks

Many outdated measures intended to improve ventilation and minimise moisture levels and condensation were making these houses extremely leaky, difficult to heat and uncomfortable to live in. Air leakage via ceiling penetrations, such as unsealed exhaust fans, recessed lights, roof access holes, skylights and permanent vents, was common among the case study houses (see Image 2 for examples). Permanent wall vents, openings in bathroom and laundry windows, and gaps between window architraves and walls were also responsible for significant leakage. Most of these types of leaks can be sealed easily and cheaply.

Permanent passive ventilation should not be relied on to control moisture levels or maintain fresh air in Canberra homes. Instead, active ventilation—mechanical exhaust fans and the simple opening of windows—should be used to reduce moisture build-up in the areas where it is generated.

Temperature differences caused by air leaks can be visualised using an infra-red, or thermal, camera. Thermal images can show the fingers of blue (created by cooler air) or orange (created by warmer air) that occur next to air leaks (Image 2). These types of images are used to help locate and demonstrate air leaks, but they do not measure the rate of air leakage in particular locations

Image 1 Air leakage rates in case study homes before and after draught-sealing



Note:
Case studies 3 and 9 were not retested for air leakage after draught sealing because they were already below the target level of 10 air changes per hour at 50 Pa, and funds were better spent on homes that were further from this target.

2 Air Tightness Testing and Measurement Association, *Technical standard L1: measuring air permeability of building envelopes (dwellings)*, Air Tightness Testing and Measurement Association, Northampton, UK, 2010.

Box 2 The relationship between air leakage and energy use

Scinergy's experience is that the most substantial reductions in energy use in Canberra homes often occur after air leakage is reduced. Of the nine case study homes that were tested for air leakage before and after retrofitting, eight showed a positive relationship between reductions in air leakage and reduction in energy use, as shown in Image A.

Image A Relationship between reductions in air leakage and reductions in energy use for nine case study homes

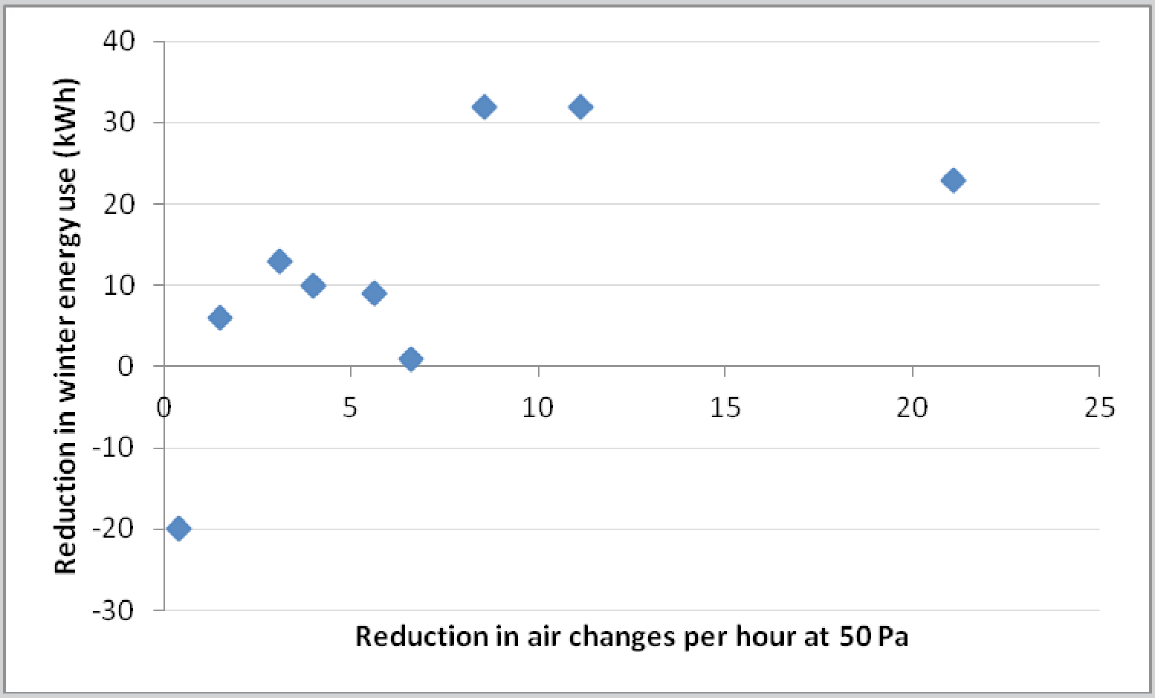
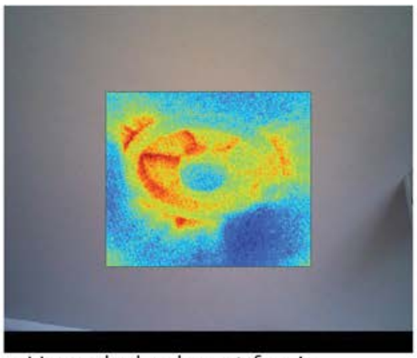
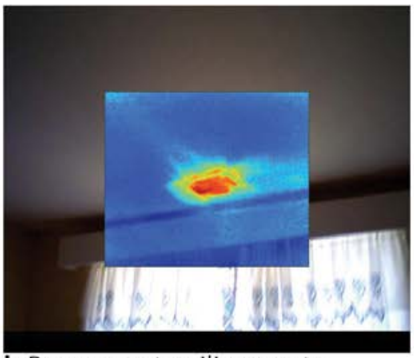


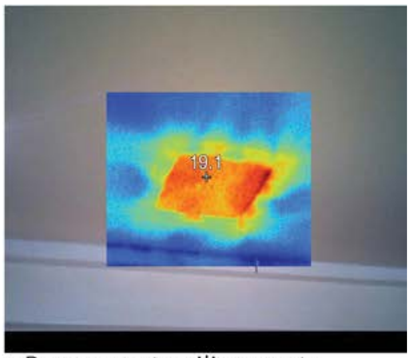
Image 2 Thermal images showing common sources of air leakage in case study houses



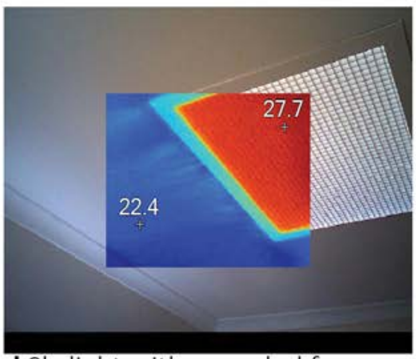
a Unsealed exhaust fan in kitchen, case study 1



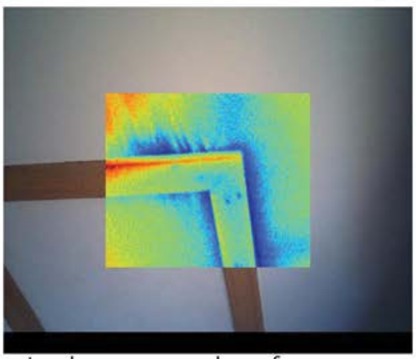
b Permanent ceiling vents, case study 4



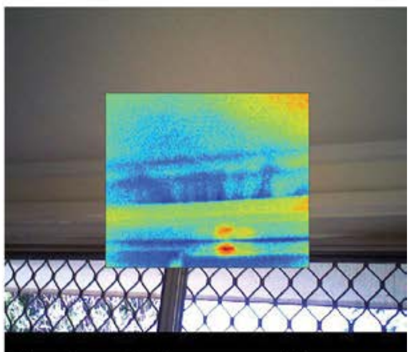
c Permanent ceiling vents, case study 5



d Skylight with unsealed fan, case study 6



e Leakage around roof access hole, case study 6



f Leakage between architrave and wall, case study 4

3.4 Thermographic inspection of insulation

Thermal imaging showed that the walls of most case study houses were uninsulated. Ceiling insulation, although present, appeared to be thin or patchy in some of the houses. Images 3 and 4 show examples from two case study houses; see Appendix A for more thermal images.

On a mild, sunny morning in March (temperature 10°C minimum to 20°C maximum), the uninsulated south-east and south-west facing walls of the main bedroom in case study 4 were at approximately 13°C; the thinly, but evenly, insulated ceiling was at 14.5°C. The bedroom had been heated overnight but was not heated at the time of testing. This house is uncomfortably cold without active heating because of its inadequate insulation and lack of passive solar heat gain.(see image 3)

No wall insulation was present in case study 5 (as expected in a house of this age; image 4a). The rock wool insulation in the ceiling was thin and unevenly installed, causing significant fluctuation in ceiling temperature throughout the house. Image 5b shows the thin or absent insulation at the edge of the roof space (dark orange areas indicate the ceiling heating up as a result of the sun striking the north-facing roof area). Image 5b also shows the upper parts of the uninsulated walls heating up as a result of the solar heat gain in the roof space—this can contribute to significant heat build-up in summer. Image 5c indicates the difference in temperature between the uninsulated roof access hole and the adjoining thinly insulated ceiling, illustrating that even a thin layer of ceiling insulation makes a significant difference to the rate of heat transfer.

Gaps in ceiling insulation of only 5% equate to a 50% reduction in effectiveness.[3] Filling gaps in existing insulation can significantly improve the energy efficiency of a home.

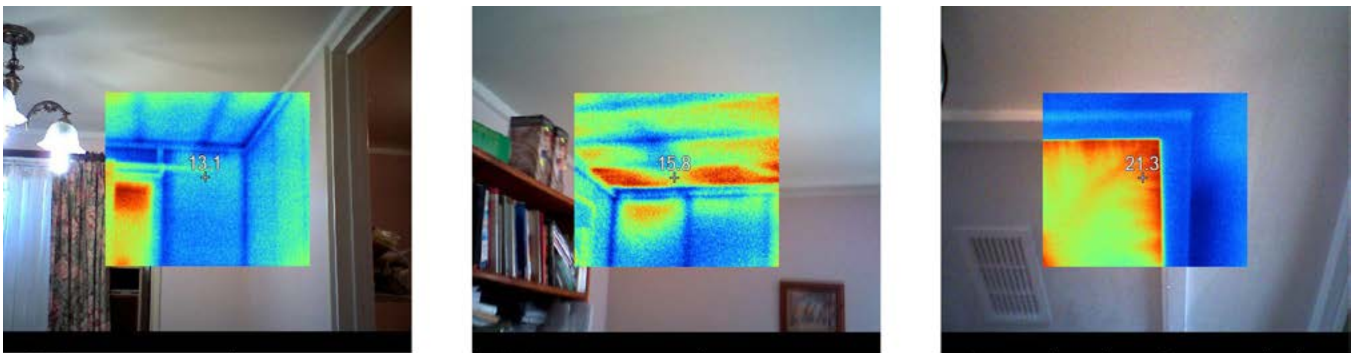
Image 3 Presence and effectiveness of insulation in case study 4

a Main bedroom south: thin ceiling insulation, no wall insulation

b Main bedroom south: no insulation

c Main bedroom south-west: no insulation

Image 4. Presence and effectiveness of insulation in case study 5



a Living room north: no wall insulation

b Living room north: patchy ceiling insulation

c Uninsulated roof access hole (and air leak)

3 US Building Performance Institute, *Effective R-values for batt insulation*, Building Performance Institute, Malta, New York, 2007, www.bpi.org/documents/Yellow_Sheet.pdf.

3.5 Temperature and energy monitoring

Temperature and household energy use varied with the design, age, construction, orientation, number of windows and types of window dressings of the case study houses; the size, age and behaviour of the households; and the heating needs and methods for each house. There were also differences between the case study houses in the timing of the project (start dates ranged from March to June), the relative timing of retrofit measures and steps in the method, and the availability of data from monitoring devices. Although these variations were expected, they made it difficult to assess the impact of individual measures such as education sessions or installation of curtains and pelmets.

Possible explanations for apparent trends or changes in individual case studies are based on informal observations made while visiting the houses. These data provide interesting insights into different households, but they cannot be relied on to support or reject the retrofit or educational measures. For data logging of temperature and energy use data to provide meaningful results, the 'assessment–education–retrofit' process needs to be much more controlled, and the data collected need to be more comprehensive and detailed.

The temperatures experienced in some houses are well below the levels suggested by the World Health Organization as necessary to maintain human health.[4] Retrofit measures to improve the thermal performance of such houses have the potential to result in significant positive health outcomes.[5]

Many of the case study households were experiencing extremely uncomfortable temperatures, but the better designed and insulated homes had more stable internal temperatures. Although no definitive conclusion can be made on the relative effects of retrofit and education measures without more controlled testing of the 'assessment–education–retrofit' process, the following observations on temperature can be made:

- Case study 2 showed a reduction in energy use after the draught sealing and a slight increase in internal temperatures. This household may be experiencing more comfortable internal temperatures than were possible in previous years.
- Case study 4 showed a decrease in electricity use after draught sealing, curtains and ceiling insulation, and the internal temperature was maintained. Electricity use increased after a fourth person moved into the home.
- Case study 5 showed a reduction in electricity use and warmer internal temperatures after the retrofit. However, the energy bills indicated that there was an increase in electricity for the 2012 autumn and winter periods compared with 2011, and a decrease in gas use. This indicates that short-term observations may not always correlate with the long-term trend in energy use.
- Case study 6 showed no change in electricity use, but internal temperatures increased after the retrofit.
- Case study 9 showed a reduction in electricity use, and internal temperatures were maintained. Billing data indicate that this household made the most significant savings in electricity from the winter of 2011 to winter 2012.

Case study 2 (Image 5 on next page) was a one-bedroom unit with neighbours to the north, south and above. Although the unit was poorly oriented and overglazed, it benefited greatly from the insulating effects of neighbouring units. Energy use decreased following draught sealing, even though internal temperatures were maintained or slightly increased. Internal temperatures in June were relatively stable at 14–17 °C in the bedroom and 17–20 °C in the living area.

Case study 4 (Image 6 on next page) was a small house with inadequate insulation and lack of passive solar heat gain. It was home to two infants with respiratory illnesses and had temperature fluctuations of 5–16 °C in the main living area and 8–18 °C in the main bedroom during June. A dramatic reduction in energy use occurred between mid-May and mid-July after education, draught sealing, curtain installation and ceiling insulation top-up, but house temperatures were maintained at very similar levels. This was the only case study house to have wall insulation retrofitted. Unfortunately, this was not installed until August, coinciding with Canberra's coldest weather and another adult moving into the house. Rather than the expected reduction in energy use or increase in internal temperatures, there was a dramatic increase in energy use. The increase in energy use does not appear to have been related to heating of the main living area and suggests significant behavioural changes in energy use due to the new resident.

Case study 6 (Image 7) was a 15-year-old, two-bedroom unit with neighbours to the west, and north-facing living areas. This unit experienced a temperature range of 15–20 °C in the living area and 12–22 °C in the bedroom in June. Room temperatures increased and electricity use decreased slightly after draught sealing and education.

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4 World Health Organization, *Health impact of low indoor temperatures*, report of a WHO meeting, Copenhagen, 11–14 November 1985, World Health Organization Regional Office for Europe, Copenhagen, 1987.

5 G Green and J Gilbertson, *Warm front, better health: health impact evaluation of the Warm Front Scheme*, Centre for Regional Economic and Social Research, Sheffield Hallam University, UK, 2008.

Images 5–7 show hourly temperatures (internal and external) in relation to daily electricity use in three of the case study homes, annotated with the time of significant events.

- The **red line** plots the electricity usage, while the other lines show the internal and external temperatures.
- The **horizontal axis** is the time line of events and daily monitoring.
- The **vertical axis** plots both temperature and kilowatt hours.

Images for other households can be found in Appendix A.

Image 5. Electricity use and temperature data in case study 2

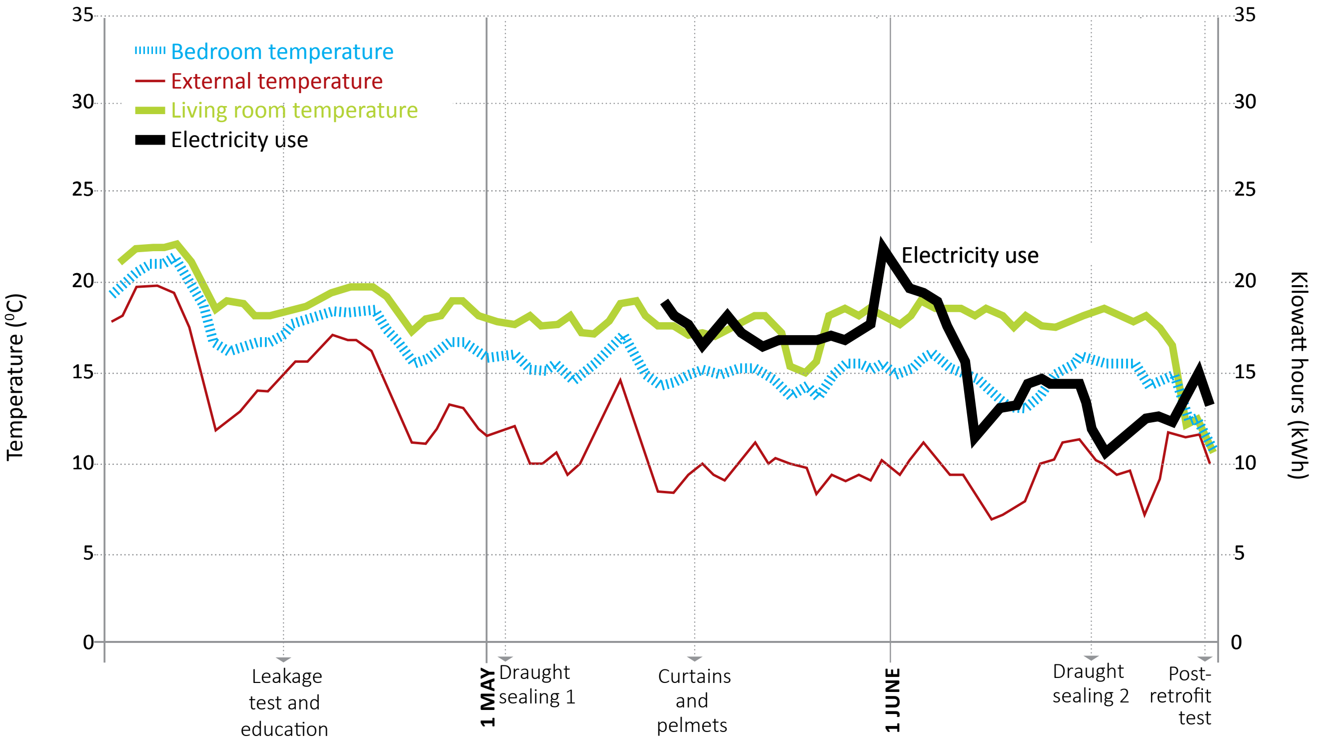


Image 6. Electricity use and temperature data in case study 4

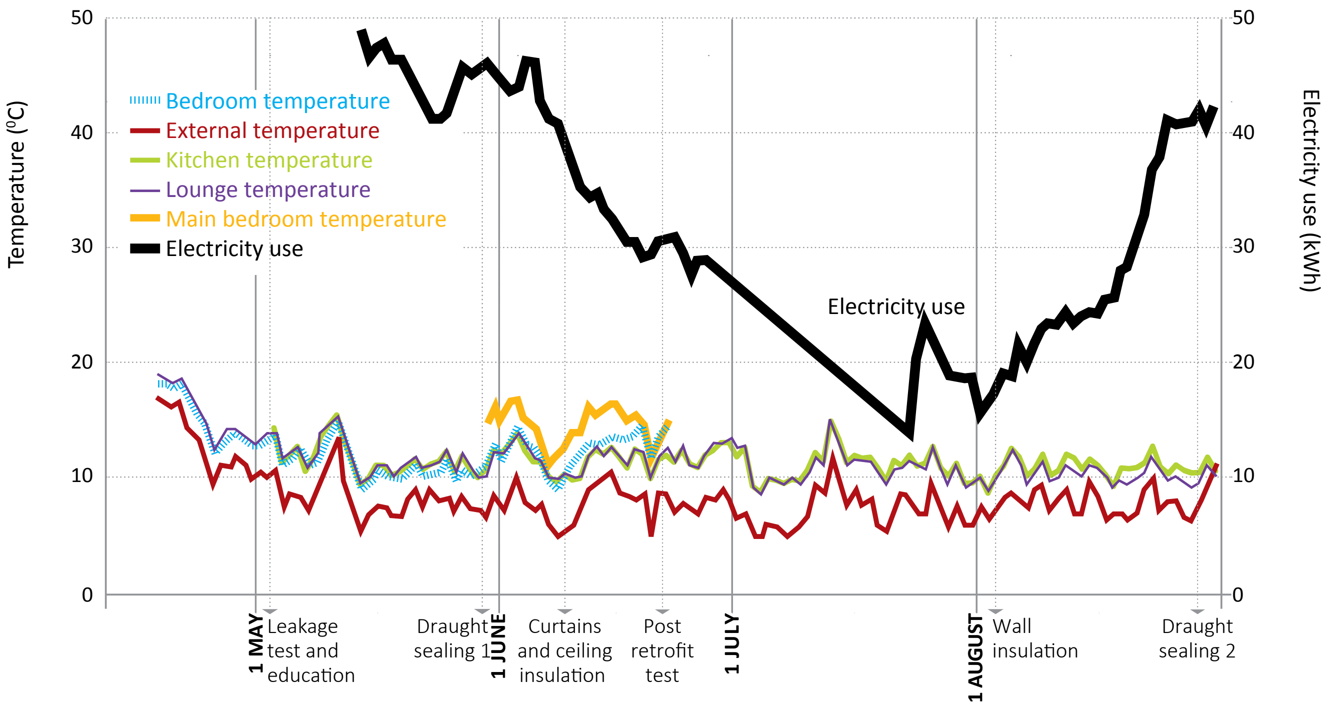
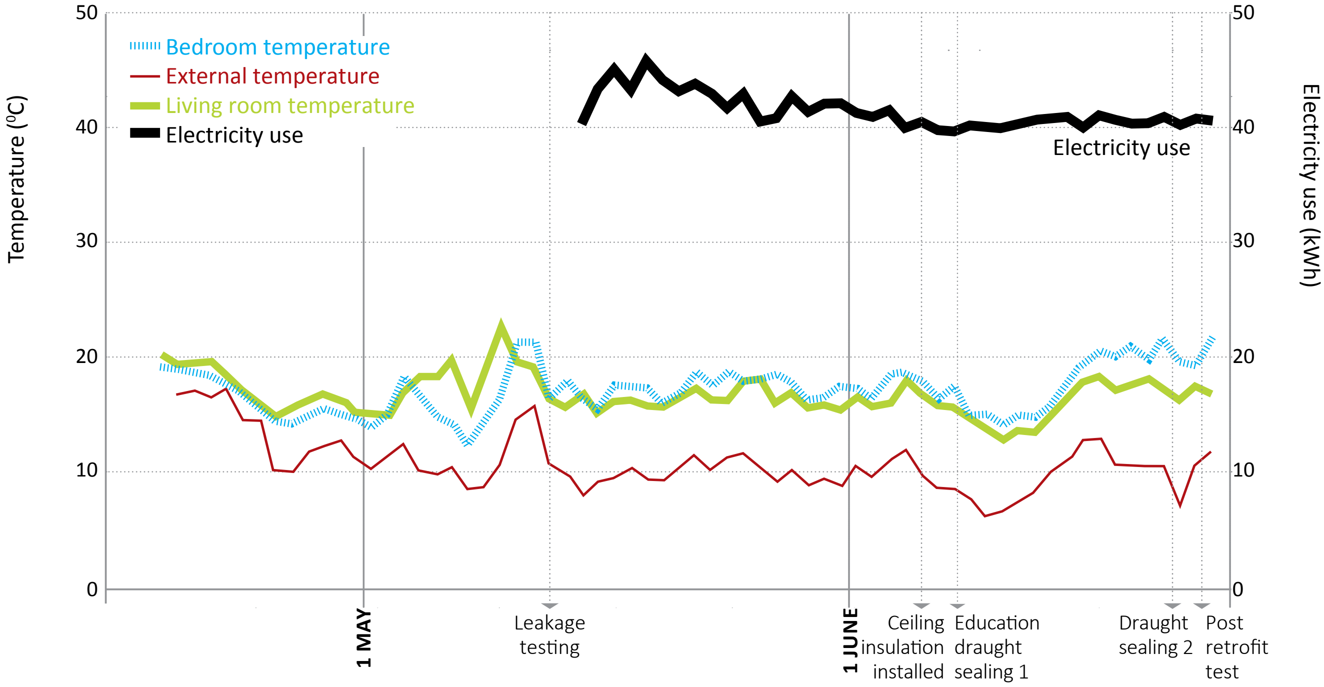


Image 7 Electricity use and temperature data in case study 6



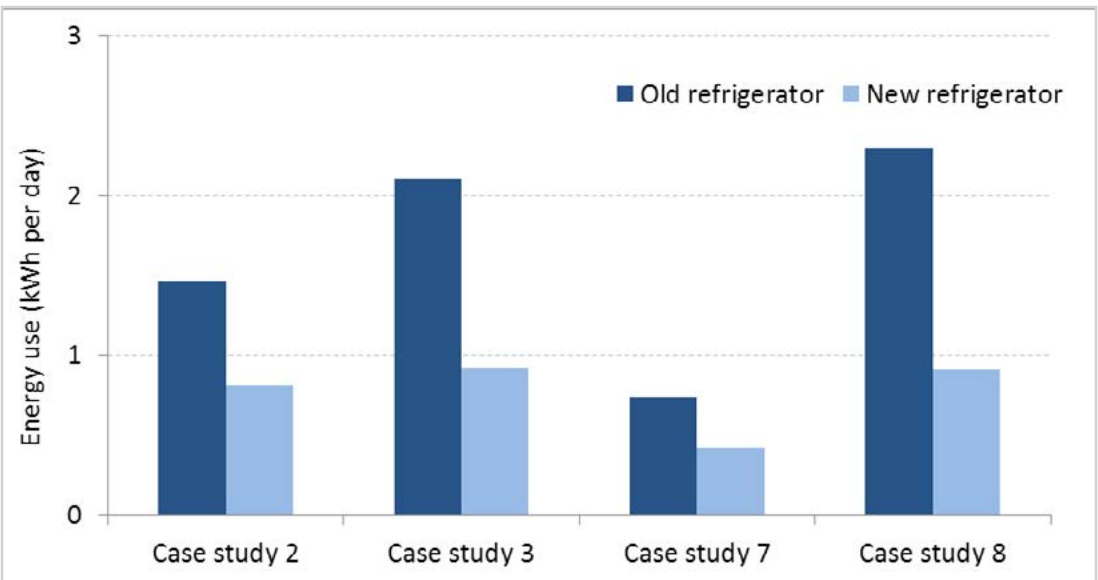
3.6 Appliance replacement

Refrigerators

All four refrigerators that were replaced were two-door appliances (fridge–freezer combination). The old refrigerators in case studies 2 and 3 were small–medium sized and made before 1996. Case study 7 had a small–medium sized refrigerator made in 2006, and case study 8 had a large (520 litre) refrigerator of unknown age. All of these were replaced with new refrigerators.

Electricity-use monitors showed that new refrigerators used an average of 54% less electricity than old refrigerators (Image 8). Data are only available from four households because some of the case study clients had their refrigerators replaced before the project started. Interestingly, the replacement refrigerator was the same model in case studies 3 and 7. The difference in consumption between the two new appliances highlights the challenge of collecting data at different times of year, and the effect of other factors on energy consumption, such as household composition, behaviour, and positioning and maintenance of the appliance.

Image 8. Average daily energy use of old refrigerators and new replacement refrigerators



Washing machines

The amount and quality of the data available regarding washing machine replacement were low. Only a few case study clients had their washing machines replaced, and data could only be collected from three households. Two households used very little energy for washing because the clients only operated the machines 2–3 times each week. In one case, the new washing machine used more energy per week than the old one during the period of monitoring, but this could have been because the client washed three loads rather than two that week. In another unusual household with very high washing and drying requirements, energy use in the laundry comprised a much higher proportion of overall energy use.

3.7 Household energy bills

Comparison of energy bills from 2011 and 2012 shows that energy consumption across the case study homes decreased by an average of 13% in the autumn quarter and 22% in the winter quarter (Table 3).

Most case study houses saved energy compared with the previous year, even though the winter of 2012 was the coolest winter for night-time temperatures since 1997, with the minimum overnight temperature averaging –0.3 °C.[6] Because the case studies were conducted without a control group that could help assess the average energy use of Canberra households, it is difficult to determine the relative energy savings made in the case studies compared with a control, or whether this was affected by the different temperatures.

The quarterly billing period varied by up to two months between case study houses, so for some houses the bill encompassed colder months. For example, some clients received autumn bills in June for the March–May billing period, and others in August for the May–July billing period. Billing periods beginning in autumn are described as the autumn quarter; billing periods beginning in winter are described as the winter quarter.

Table 3. Energy, greenhouse gas and cost savings for all case studies

	Total energy saving (kWh)	Total CO_2-e saving (kg)[a]	Total cost saving[b]	Average energy saving (%)	Average cost saving
Autumn	8017	7701.32	1055.04	13	$95.91
Winter	19054	18444.56	2976.63	22	$270.60

Autumn = billing periods beginning in March–May; winter = billing periods beginning in June–August

a Scope2 + Scope3 emission factor for electricity is 1.06 kg CO_2-e/kWh (source: Australian Government Department of Climate Change and Energy Efficiency, ***National Greenhouse Gas Accounts factors***, July 2012).

b Cost savings for gas usage calculated using 2.113 cents per megajoule

Electricity

Electricity bills showed an average 25% reduction in electricity consumption during the autumn quarter and an average 33% reduction in the winter quarter, compared with the previous year's bills (Table 4). In most cases, retrofitting and education sessions were conducted during the autumn quarter, so the impact of the program on energy use was smaller during the autumn period for most homes.

In the autumn period, 9 of the 11 households reduced their electricity use compared with the previous year (Image 9).

In the winter period, 8 of the 11 households reduced their electricity use compared with the previous year (Image 10).

Table 4 Electricity and greenhouse gas savings for all case studies

	Total electricity saving (kWh)	Total CO_2-e saving (kg)[a]	Average energy saving (%)
Autumn	7107	7533.34	25
Winter	17052	18074.99	33

Autumn = billing periods beginning in March–May; winter = billing periods beginning in June–August

a Scope2 + Scope3 emission factor for electricity is 1.06 kg CO_2-e/kWh (source: Australian Government Department of Climate Change and Energy Efficiency, ***National Greenhouse Gas Accounts factors***, July 2012).

6 Bureau of Meteorology, *Canberra in winter 2012: mild days and cold nights for Canberra,* Bureau of Meteorology, Melbourne, 2012. Available at www.bom.gov.au/climate/current/season/act/archive/201208.summary.shtml (accessed 21 March 2012).

Image 9 Electricity use during the 2012 autumn quarter compared with the same billing period in 2011

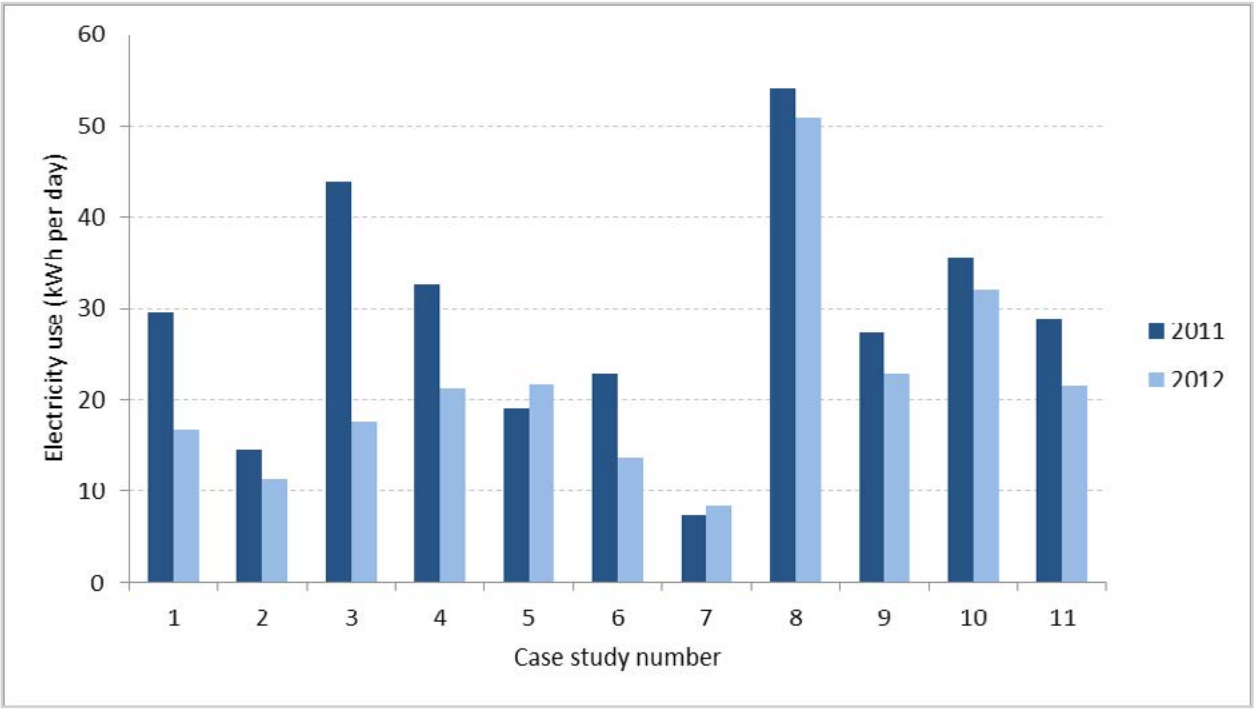
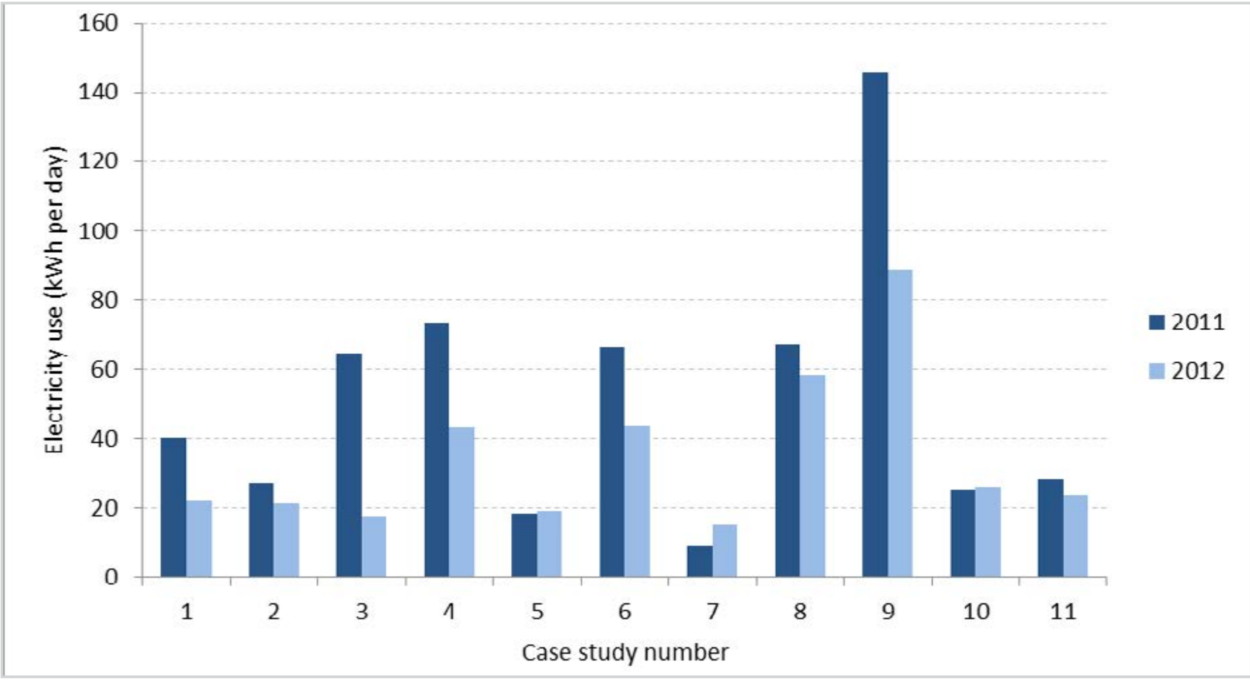


Image 10. Electricity use during the 2012 winter quarter compared with the same billing period in 2011



Gas

Five of the case study houses had gas connected. Gas consumption data showed an average 2.6% reduction in the autumn quarter (Image 11) and an average 5.9% reduction in the winter quarter (Image 12). For ease of comparison with electricity data, gas consumption was converted from MJ per day to kWh per day (Table 5).

Table 5. Gas and greenhouse gas savings for all case studies

	Total gas saving (kWh)	Total CO_2-e saving (kg)[a]	Average energy saving (%)
Autumn	910	168.16	2.6
Winter	2002	369.95	5.9

Autumn = billing periods beginning in March–May; winter = billing periods beginning in June–August
a Cost savings for gas usage calculated using 2.113 cents per megajoule

Image 11. Gas use during the 2012 autumn quarter compared with the same billing period in 2011

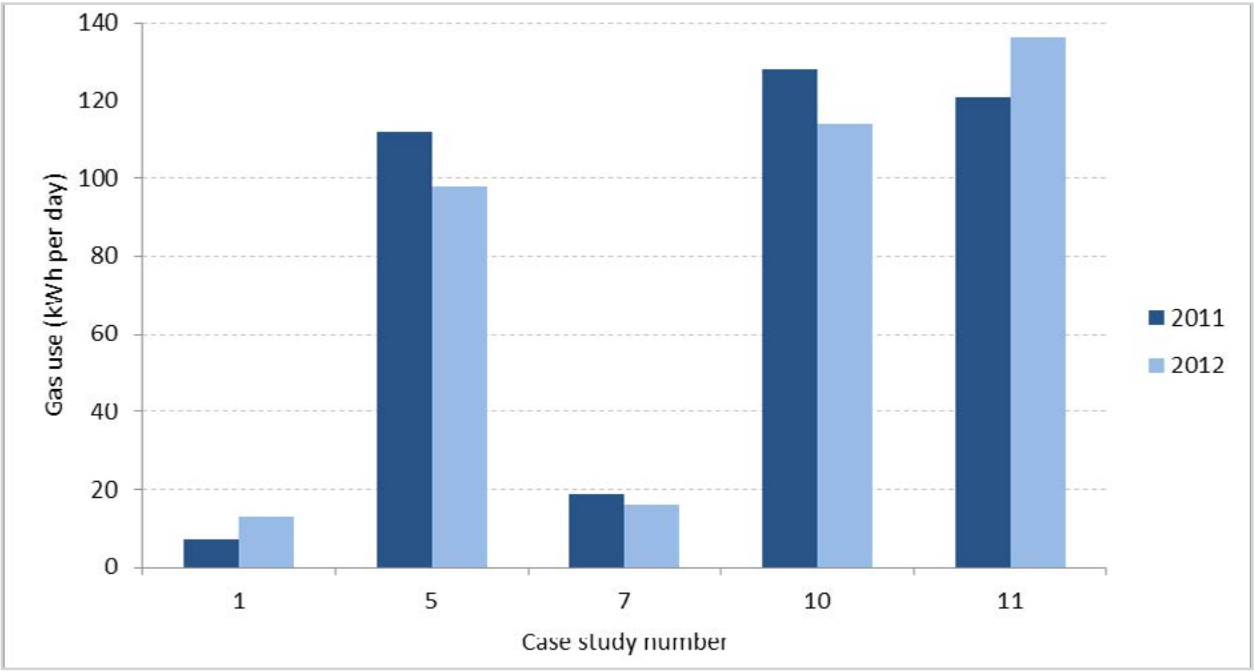
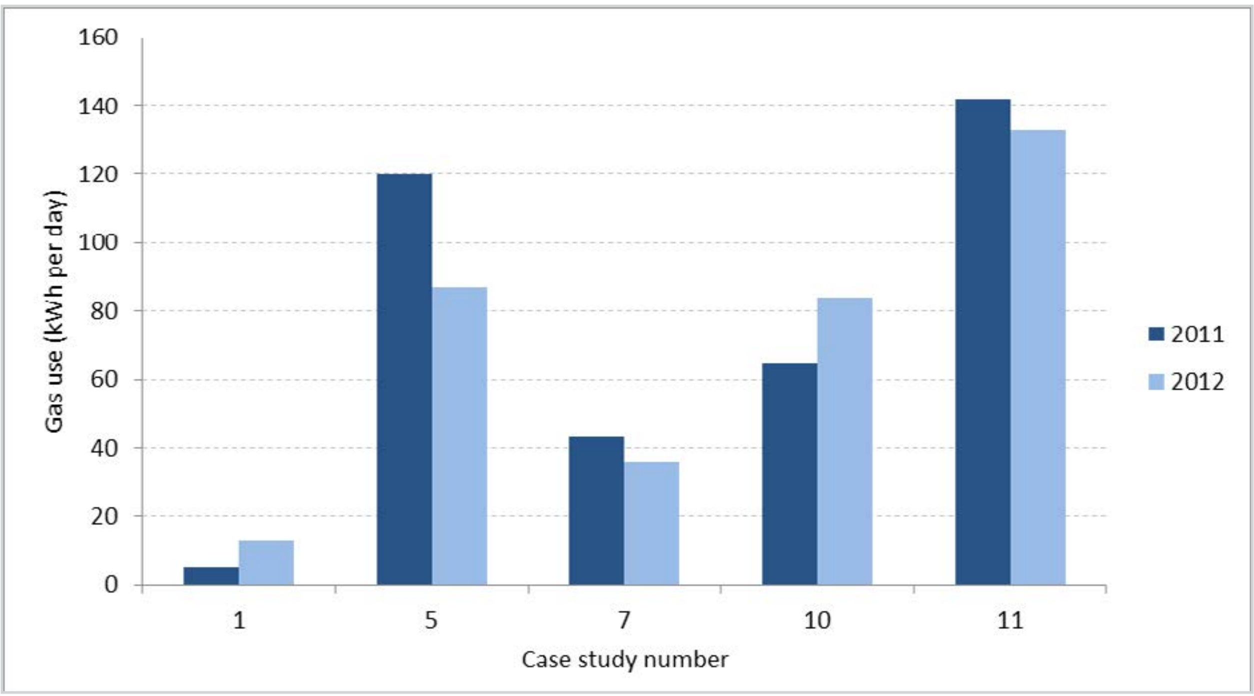


Image 12. Gas use during the 2012 winter quarter compared with the same billing period in 2011



3.8 Cost and greenhouse gas savings

Comparison of energy bills from 2011 and 2012 shows that the average net dollar saving per household was $95.91 in the autumn quarter of 2012 and $270.44 in the winter quarter of 2012. Ten of 11 case studies showed cost savings in their bill for winter 2012, and 9 of 11 case studies showed cost savings in their bill for autumn 2012, compared with their energy usage at the same time the previous year (Image 13). During this period, the electricity tariff increased by an average of 3 cents per kWh.

A total reduction of 7.7 tonnes of carbon dioxide equivalent (CO_2-e) was achieved in the autumn quarter and 18.44 tonnes of CO_2-e in the winter quarter of 2012. Nine of 11 case studies reduced greenhouse gas emissions for winter and autumn 2012 compared with the same time the previous year (Image 14).

Image 13 Cost savings per quarter in 2012, compared with 2011

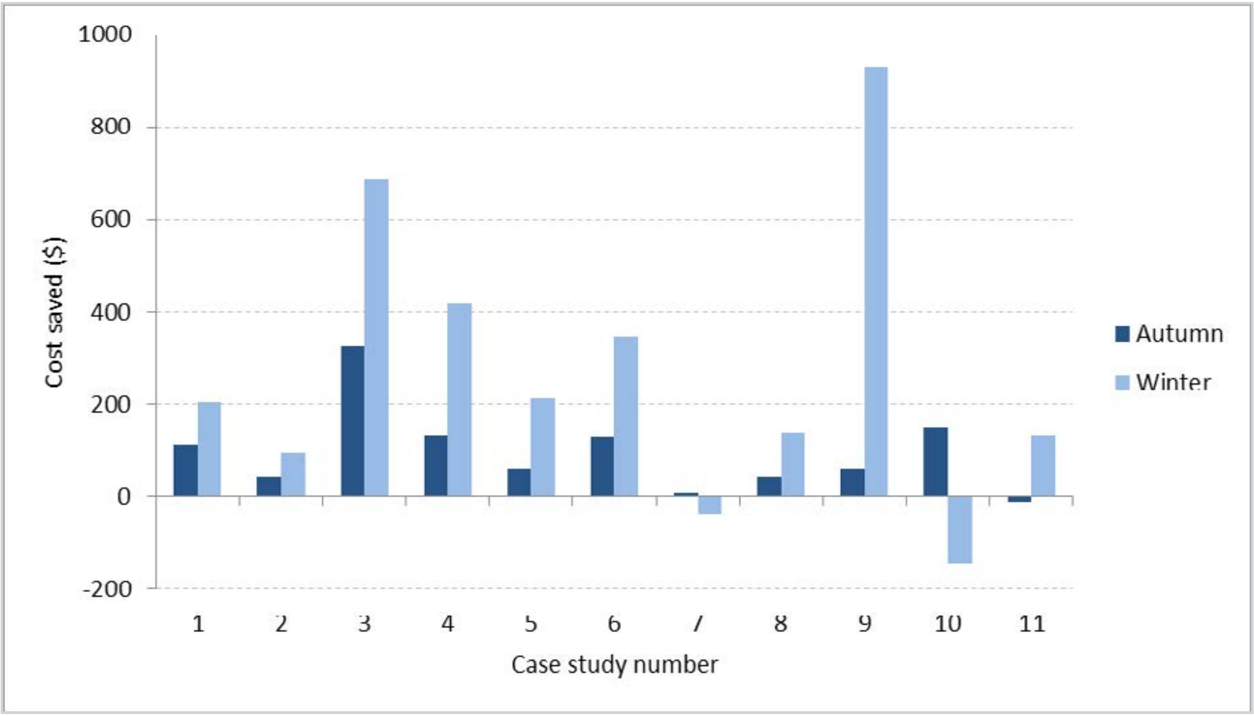
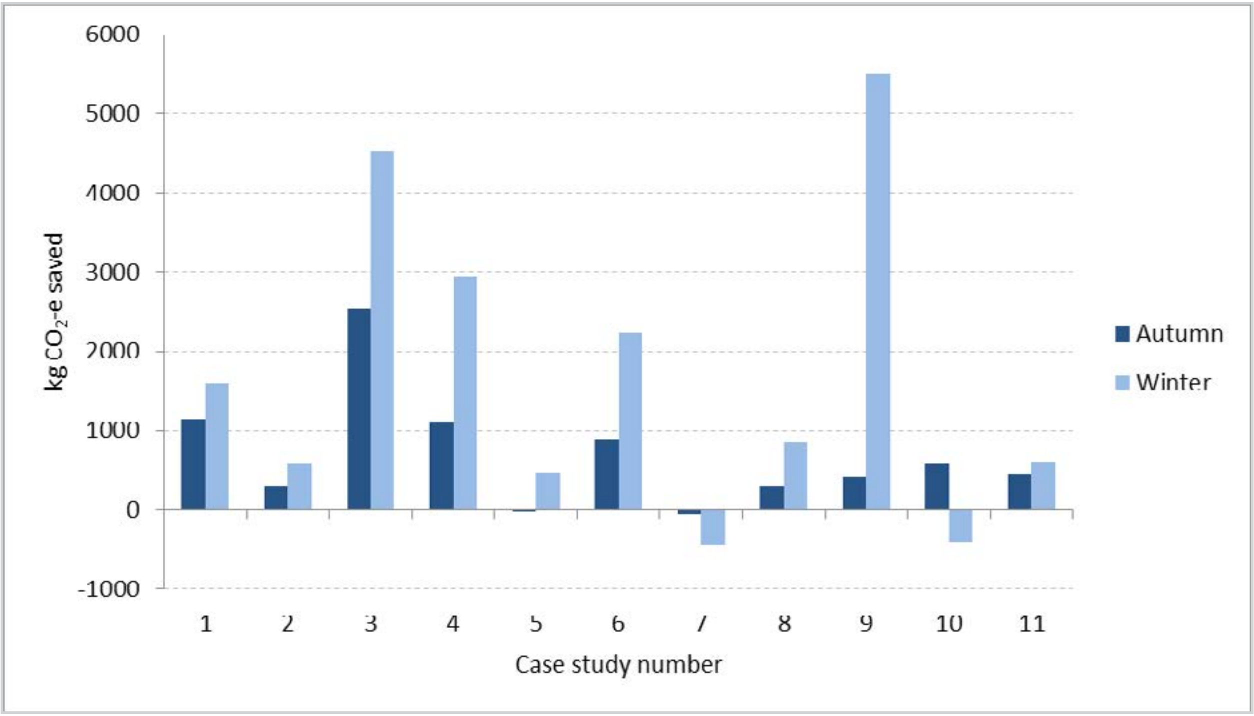


Image 14. Carbon dioxide equivalent (CO_2-e) savings per quarter in 2012, compared with 2011



3.9 Household composition and behaviour

Household composition and behaviour can play a significant role in how energy is used within a home. This is highlighted by the variety of case study households, the number of residents and the energy requirement of the residents. The amount of energy used is also affected by residents' health, such as respiratory conditions or health management appliances.

The case study households range from single-occupant households to groups of three or more. Several households have people who spend large amounts of time at home during the day, including retirees, families with small children and people with disabilities. These households are likely to have higher heating loads than households that spend most of the day away from the home.

Case study 10 is an atypical household with three residents who have moderate to severe disabilities and at least one staff member present in the household 24 hours per day. This household can typically have 4–7 people present at any one time, and the energy use is not entirely controlled by the residents.

Table 6 shows the differences between the reduction in energy used for heating and cooling predicted by the modelling and the actual change in energy use in the households. The actual change in energy use also includes energy used for appliances, lighting, hot water heating, and so on.

Table 6. Predicted vs actual change in energy use in case studies 1–8 using thermal modelling

Case study number	Predicted reduction in energy for heating and cooling by energy efficiency rating modelling (%)	Actual reduction in overall household energy use between winter 2011 and winter 2012 (%)
1	17	22
2	36	22
3	18	73
4	41	42
5	21	23
6	23	35
7	28	2
8	16	13

Note: Case studies 9, 10 and 11 were not included in the modelling because of scheduling constraints.

Differences between predicted energy reduction from thermal modelling and actual energy reduction (Table 6) could be explained by residents' behaviour. Cases where the actual energy reduction was less than the predicted reduction (case studies 2, 7 and 8) could be explained by residents enjoying more comfortable internal temperatures than they had previously experienced, rather than maintaining lower temperatures and reducing their bills.

Case studies 1, 3, 4, 5 and 6 saved more energy than the software predicted. This could be due to changes in behaviour and the use of lighting, hot water and other appliances. Case study 3 had the most significant reduction, mostly due to the resident restricting their use of the in-slab heating, which had been used for the entire house in 2011, to a smaller area in 2012. This household also had fewer people in the home between winter 2011 and winter 2012.

Case study 4 initially had a large reduction in energy use, but during the case study period a second adult moved into the home, and the energy use changed dramatically (see Image 6). The change in energy use did not appear to be associated with heating of the main living areas because the internal temperatures remained constant. This highlights the importance of behaviour in the context of energy reductions.

Refer to Appendix A for more details about household composition, health and behaviour that might affect energy use.

3.10 Type of heating system

The type of heating system can significantly affect energy use. For example, inefficient electric heating systems are often found in households participating in the Outreach Program. These systems can be expensive to operate and have minimal benefits, especially if the heaters are fixed electric systems that have been inappropriately positioned. This is particularly evident in case study 9, which is a single-occupant, three-storey home with inefficient electric resistance heating. This household had the highest energy consumption in the winter period of all the participating case studies, and electricity use increased more than fourfold from autumn to winter. The effect of differences in the type of heating system is also evident in case study 3, which has inefficient in-slab heating.

3.11 Client responses to energy monitors

Scinergy was not contracted to formally collect or analyse qualitative data. However, repeated enthusiastic anecdotal feedback was received from clients about the energy monitors. It seemed that energy monitors were not only useful as a means to collect daily energy-use data, but were also valuable educational tools and motivators of behavioural change. Several clients used them to measure the energy use of their appliances and understand how their actions affected energy use in detail (sometimes even before the service provider had shown them how to use the device). The presence of the energy monitors seemed to motivate clients to reduce their energy consumption by observing and limiting the use of certain high-energy appliances and behaviours. Perhaps not surprisingly, clients preferred to use the monitors on the ‘cost’ setting, which displayed energy use in dollars and cents rather than watts.

4 Findings and recommendations

The Outreach Program had a significant and measurable effect on the energy use of all of the households participating in the case studies. Importantly, household energy bills showed a substantial reduction in energy use after retrofitting compared with the previous year, and all houses increased their energy efficiency rating. This also correlated with cost savings on energy bills and reduced greenhouse gas emissions as a result of the program.

4.1 Thermal performance simulation

Finding

All eight case study houses that underwent thermal modelling increased their energy star rating after retrofitting.

Case study homes varied in their thermal potential as a result of differences in glazing (orientation, dressings and size relative to room floor area), insulation levels and air tightness. The most effective way to reduce energy use and increase comfort therefore also varied among case study houses: for some, simple draught sealing was the most effective option, while wall insulation was the best option for others. Heavy drapes and pelmets also significantly reduced energy use in some houses. When considering cost-effectiveness, draught sealing was consistently the best option, sometimes by as much as 5–10 times.

Recommendations

- Each household should continue to be assessed individually to accurately determine and prioritise the retrofit and education measures. Retrofit measures and education sessions must continue to be tailored to the individual home, and issues prioritised to maximise energy-saving potential for the lowest cost.
- Window drape replacement should be restricted to main living areas where current drapes are inadequate (unless otherwise justified).
- The use of cheap and effective pelmet options (such as corflute to seal the gap between the top of the curtain track and wall) should be encouraged.

4.2 Air leakage rate and location

Finding

Most case study houses had high rates of air leakage, and the majority of leaks were via ceiling penetrations. Simple draught-sealing measures reduced the rate of air leakage in nine case study homes, by an average of 34%. Statistical modelling of actual air leakage and energy consumption data suggests that draught sealing accounts for almost 40% of energy savings.

Draught sealing has proved to be the most effective retrofit measure for these case study homes. Not only does heated air remain in the home for longer, the client also feels much warmer.

Permanent passive ventilation should not be relied on to control moisture levels or maintain fresh air in Canberra homes. Instead, active ventilation—mechanical exhaust fans and the simple opening of windows—should be used to reduce moisture build-up in the areas where it is generated.

Recommendations

Draught sealing should continue to be a key element of retrofits. To optimise the benefit of draught sealing, the following procedures are a best-practice guide:

- Draught seal from the top down. Focus on extractor fans in heated areas, passive vents, wall vents and vented skylights.
- Remind clients of the importance of using extractor fans in the kitchen and bathroom following draught-sealing measures to prevent moisture accumulation and condensation. Extractor fans can also be used to vent hot air from a home in summer.
- Consider household behaviour and pets when prioritising the retrofit. There is little point in draught-proofing a home if external and internal doors and windows are left open to allow ventilation and movement of pets. Discuss options with the client that allow pet movement while keeping doors shut.

4.3 Insulation

Finding

Ceiling insulation is critical in the Canberra climate, and the majority of case study homes had at least R2.5 insulation installed. After this level of insulation, the simulation software indicated that the next most cost-effective measures for Canberra houses are draught sealing and wall insulation. Most case study houses had uninsulated walls, and gaps in their ceiling insulation.

Recommendations

- Ceiling insulation should be topped up where necessary.
- Wall insulation should be considered, where possible, and particularly for homes with very poor thermal performance. Although there are potential electrical issues and extra costs involved, in some cases the predicted benefit still outweighs the up-front cost.

4.4 Temperature

Finding

Before retrofitting, many case study houses experienced extremely uncomfortable temperatures that may compromise the health of residents.

Temperature monitoring indicated an improvement in the temperature in several of the case studies after retrofits; however, temperature and energy monitoring were complicated by external factors.

Recommendations

- Although useful for showing trends, temperature monitoring should be more tightly controlled to measure the effects of individual measures such as retrofits or education.
- A survey of comfort levels experienced by participants should be included in future studies.

4.5 Appliance replacement

Finding

Data from four case study homes showed that replacing old, inefficient refrigerators with new models can halve the energy used for refrigeration. Data for replacing washing machines were not sufficient to allow any conclusions to be drawn.

Recommendations

- Old refrigerators and freezers should continue to be replaced.
- Further research should be conducted to determine the energy and water savings achieved by washing-machine replacement.

4.6 Household energy use

Finding

Comparison of energy bills from 2011 and 2012 shows that energy consumption across the case study homes decreased by an average of 13% in the autumn quarter and 22% in the winter quarter. This decrease includes electricity and gas.

Comparison of energy bills from 2011 and 2012 shows that electricity consumption across the case study homes decreased by an average of 25% in the autumn quarter and 33% in the winter quarter.

In the five case study houses with gas connected, gas consumption decreased by an average of 2.6% in the autumn quarter and 5.9% in the winter quarter. However, variations in billing periods among households made direct comparisons difficult.

Recommendation

- Further case studies of houses with gas connections would help to understand why reductions in this form of energy were much less than for electricity.

4.7 Cost and greenhouse gas savings

Finding

Comparison of energy bills from 2011 and 2012 shows that the average net dollar saving per household was $95.91 in the autumn quarter of 2012 and $270.60 in the winter quarter of 2012.

A total reduction of 7.7 tonnes of CO_2-e was achieved in the autumn quarter and 18.44 tonnes of CO_2-e in the winter quarter of 2012.

Recommendation

- Greenhouse gas emissions and energy costs should continue to be monitored.

4.8 Household composition and behaviour

Differences between energy reduction predicted by thermal modelling and actual energy reduction could be explained by residents' behaviour. Several of the case studies varied significantly from the predicted energy reduction, which indicates the influence of behaviour on energy reduction. This is most notably demonstrated by case study 3, which saved 73% compared with a prediction of 18%.

Recommendations

- Education should continue to be provided to program participants to maximise opportunities for energy reduction.

4.9 Client responses to energy monitors

Finding

Repeated anecdotal evidence from multiple case study homes suggests that energy monitors may be used as a tool to support and motivate behavioural change.

Recommendation

- Formal trials of household energy monitors should be conducted to assess their impact on client behaviour.

Appendix A Case studies

Case study 1

Community welfare organisation: Society of St Vincent de Paul

Service provider: C&J Group

Background information from Energy Efficiency Officer

Category	Client would benefit from an assessment, education and basic retrofit, such as curtains, blinds and draught sealing
Household occupants	3
Financial circumstance	Unemployed, full-time student, financial hardship
Type of residence	Owner–occupier
Products to be replaced	Washing machine
Client concerns	Overglazed brick-veneer house with a cape-cod extension/master bedroom upstairs. Approx. 16 m2 of living area and a granny flat that is rented out. The house has a small 2 kW photovoltaic system and flat-panel (two panels) solar hot water system, boosted by instantaneous gas. It has two large and segregated living rooms, both of which are heated and cooled by an undersized reverse-cycle air-conditioner in one of the rooms, in addition to the central gas heating. The house has very large south-facing windows and needs all-round draught-proofing and some additional proper curtains. The client is a single mother with two children, and two grandchildren who live there part-time. She is very interested in the subject matter and could greatly benefit from further education and retrofit.
Date of referral	12 February 2012

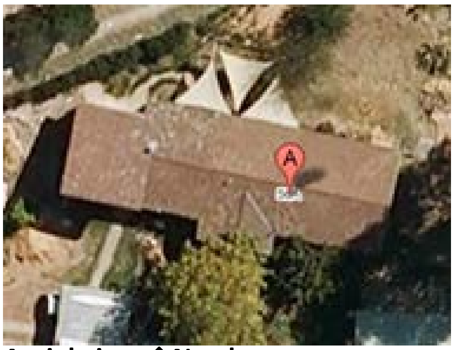
The house, its timeline of retrofitting activities and thermal performance

Extended, four-bedroom, two-bathroom, brick veneer, concrete slab, 150 m^2. Original house approximately 35 years old, extension approximately 20 years old.

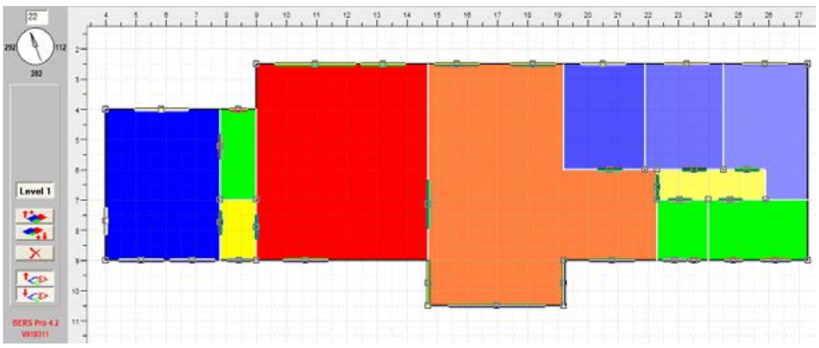
The potential for passive solar heat gain is high as a result of extensive glazing to the north in the living room, lounge room and bedrooms, allowing the sun to strike the concrete slab. However, there are also significant areas of glazing to the south in the main open-plan kitchen/ living area, which compromise the thermal performance of the home.

The client also has solar panels for electricity generation, and a solar hot water system with an instantaneous gas boost.

The thermal performance simulation indicates that draught sealing could be as much as 10 times more cost-effective than curtain replacement and pelmet installation in reducing the heating requirements for this home.



Aerial view ↑North



Modelled in BERS4.2 thermal simulation software
Orange: kitchen/dining/living; red: living; blue/purple: bedrooms; green: laundry/bathroom; yellow: corridor

Timeline of testing and retrofitting activities

Date	Action
22 March	Temperature and energy-use data loggers installed
12 April	Air leakage assessment and thermographic inspection and education
4 May	Draught sealing
10 May	Curtains and pelmets installed
17 May	Post-retrofit test and collection of temperature and energy-use data
28 May	DraftStoppa® over kitchen exhaust fan and internal draught-proofing
1 June	Recessed halogen lamps in kitchen replaced with compact fluorescent lamps
7 June	Final blower door test and data collection

Thermal performance simulation (energy efficiency rating) of proposed retrofit measures

Simulation and specifications	Star rating	Heating (MJ/m^2)	Cooling (MJ/m^2)	Total (MJ/m^2)	Predicted reduction (%)	Actual cost ($)	Cost per MJ reduction ($)
Starting conditions: • Ceilings R3; walls R1.5 to extension, R0 to original; floors R0 • Open exhaust fan and three vented down-lights in kitchen • Leaky old wall-mounted air-conditioning unit in lounge • Curtains but no pelmets to windows throughout	3.9	258	32	290			
Starting conditions plus: • Draught sealing	4.2	233	32	265	9	450	18
Starting conditions plus: • Curtains and pelmets to lounge and dining	4.2	238	32	270	7	4193	209
Complete retrofit: • Sealed exhaust fans • Sealed vents • Draught sealed • Curtains and pelmets to lounge and dining	4.5	210	31	242	17	4643	96

Air leakage results

Visual inspection suggested that the house would be very leaky, and this was confirmed by fan depressurisation testing. The building envelope had many obvious leakage points, including:

- unsealed exhaust fan in kitchen
- permanent vents in various parts of the home
- via plumbing and electrical penetrations behind kitchen joinery
- recessed lighting in ceiling

- unsealed ‘Tastic’ in bathroom
- unnecessary permanent vent in bedroom and living areas
- around doors and surrounding architrave
- around old wall-mounted heater
- around exposed beams and suspended flooring
- between windows and gyprock, wall junctions and roof beams.

The rate of air leakage was reduced by 18% after the following draught-sealing measures:

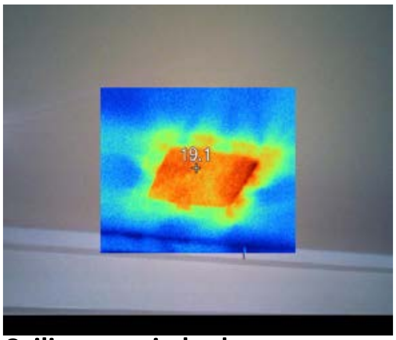
- installing a DraftStoppa® in the kitchen
- sealing unnecessary ceiling vents
- sealing around some architraves and windows
- installing a perspex panel on the front of the old wall-mounted heater
- replacing halogen down-lights with sealed compact fluorescent down-lights.

Result from air leakage testing

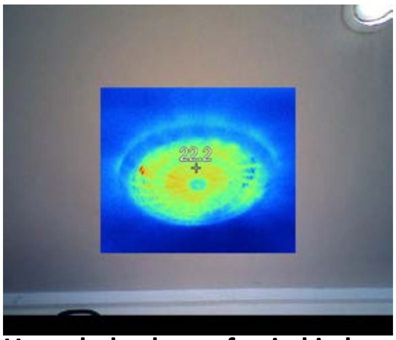
	Pre-retrofit	Post-retrofit	Difference
Air changes per hour at 50 Pa	21.8	17.82	–18.3%
Effective leakage area at 4 Pa (equivalent open square window)	45 cm x 45 cm	40 cm x 40 cm	21 cm x 21 cm

Note: A pressure difference of 4 Pa between inside and outside is close to the normal pressure differential experienced in the home on cold, windy Canberra days.

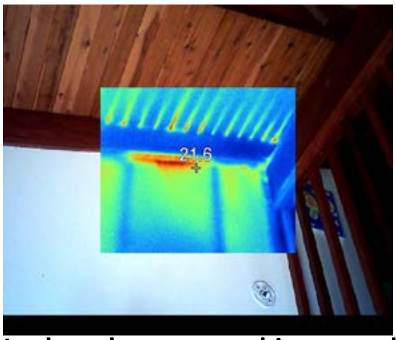
Air Leakage points



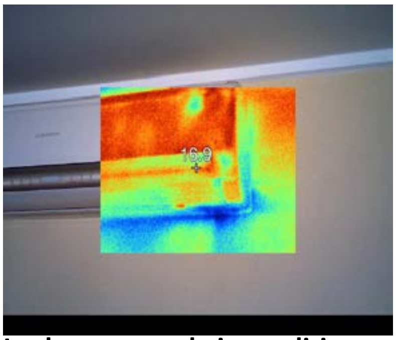
Ceiling vent in bedroom



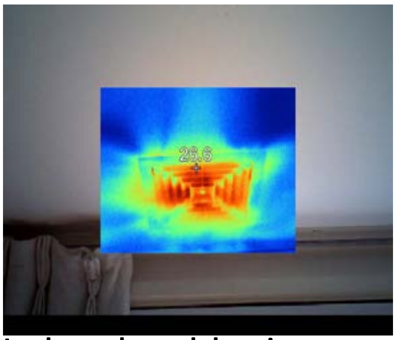
Unsealed exhaust fan in kitchen



Leakage between architrave and gyprock



Leakage around air-conditioner



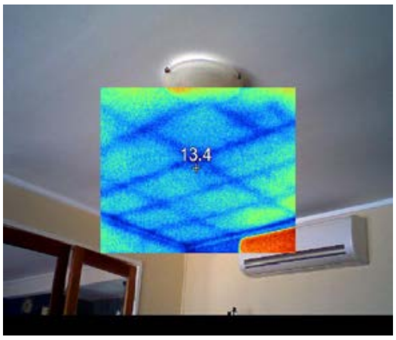
Leakage through heating vent

Insulation

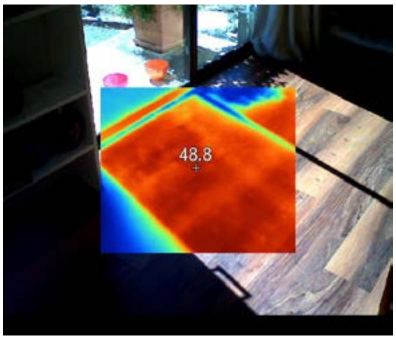
Ceiling insulation was present and mostly even; there were some inconsistent areas, mostly around the extremities of the house.

The house has excellent potential to use winter solar heat gain through the large glazed areas facing north. However, the house also has large areas of glazing facing south, which compromise its ability to retain heat. It also has a draughty loft area at one end of the house that acts to remove much of the accumulated heat and negates the passive solar heat gain.

Inadequate insulation



Inadequate insulation in living area



Solar heat gain through northern windows

Temperature and electricity use

The house experiences severely cold temperatures in June, with living areas ranging from 10–22 °C and bedrooms 6–15 °C.

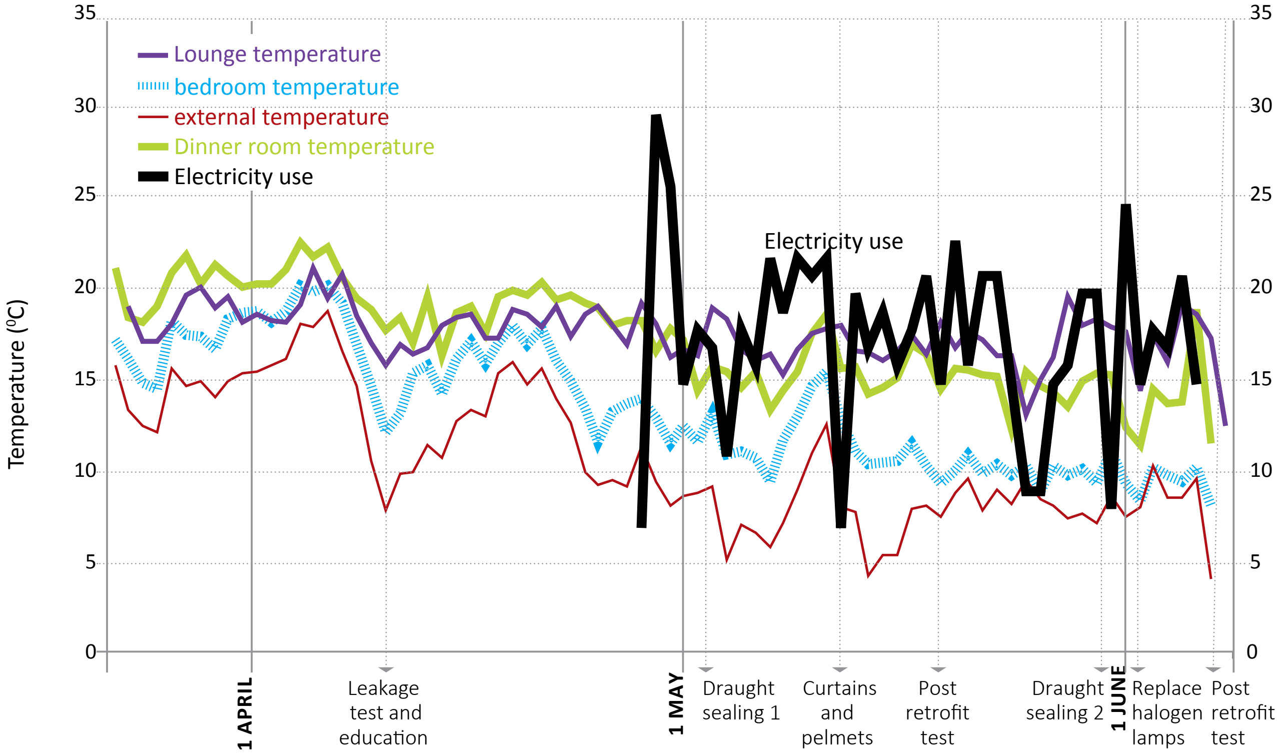
Data from thermochrons highlights the following:

- Little additional heating is used in the home during the evening. The family area is occasionally heated but not excessively.
- At some point in the middle of the day, the internal temperature reaches 25 °C as a result of the passive solar heat gain. However, because of glazing on the south side of the house, these rooms also drop as low as 10 °C at night.
- The overall temperature remained constant, despite a decrease in energy use by the client.
- The unheated north-facing bedroom, in which curtains were rarely opened but the window was left ajar, follows external temperatures very closely.

Client behaviour plays a large part in keeping this house warm and cold. Fresh air is flushed through the house throughout the day, which keeps the house cool, despite its having excellent solar access in the living and lounge rooms and some of the bedrooms.

The client really likes fresh air and, while the house is not as warm as it could be if it was closed and allowed to benefit from solar passive heat gain, she is using no additional heating during the day and therefore not wasting energy in the process.

Electricity use and temperature data in case study 1



Energy bills

While electricity decreased, gas consumption increased. This was for a variety of reasons:

- The broken instantaneous-boost hot water system was disconnected for several months in 2011 and then reconnected in 2012.
- The client was advised in the education session to boil water in a kettle on the gas stove rather than using an electric kettle. The client found this practice unsustainable and time consuming (waiting for the kettle to boil) and has switched back to the electric kettle.
- The mother said teenagers were taking longer hot showers than the year before.

Electricity usage

	Energy use 2011 (kWh/day)	Energy use 2012 (kWh/day)	Difference
Autumn*	30	17	–43%
Winter*	40	22	–45%

Gas usage

	Energy use 2011 (kWh/day)	Energy use 2012 (kWh/day)	Difference
Autumn*	7	13	+85%
Winter*	5	13	+160%

Electricity + gas usage

	Energy use 2011 (kWh/day)	Energy use 2012 (kWh/day)	Difference
Autumn*	37	30	–19%
Winter*	45	35	–22%

*Autumn = billing periods beginning in March–May; winter = billing periods beginning in June–August

Predicted versus actual reductions in energy use

Thermal simulation suggested that reductions in energy use of 17% for heating and cooling could be achieved via the draught-sealing and window-dressing measures implemented.

Actual energy consumption data from quarterly bills demonstrate a 22% reduction in overall household energy use (i.e. not just heating and cooling but also appliances, lighting, hot water heating, etc.) between winter 2011 and winter 2012. This suggests that education and associated behavioural change could account for the remaining 5% reduction in energy consumption.

Total energy, greenhouse gas and cost savings

	Energy saving (kWh)	CO_2-e saving (kg)[a]	Cost saving ($)[b]
Autumn*	625	1140.19	112.86
Winter*	903	1594.51	204.95

a Scope2 + Scope3 emission factor for electricity is 1.06 kg CO_2-e/kWh. Emission factor for natural gas is 51.33 kg CO_2-e /GJ (source: Australian Government Department of Climate Change and Energy Efficiency, ***National Greenhouse Gas Accounts factors***, July 2012).
b Cost savings for gas usage calculated using 2.113 cents per megajoule

*Autumn = billing periods beginning in March–May; winter = billing periods beginning in June–August

Case study 2

Community welfare organisation: Belconnen Community Service

Service provider: Cool Planet

Background information from Energy Efficiency Officer

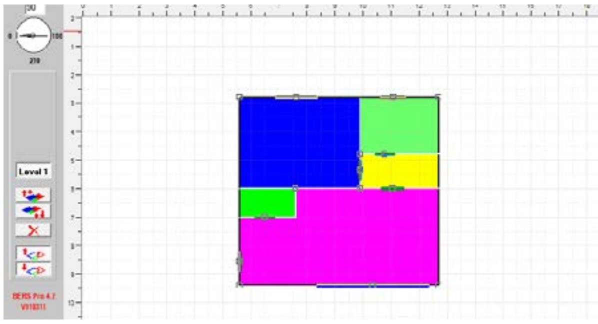
Category	Client would benefit from an assessment, education and basic retrofit, such as curtains, blinds and draught sealing
Household occupants	1
Financial circumstance	Disability support pension
Type of residence	ACT Housing, bottom storey, one-bedroom brick veneer
Products to be replaced	Washing machine and refrigerator
Client concerns	The client lives alone in this townhouse. He has chronic cardiac and respiratory health conditions and is vision impaired. He is very mindful of his energy use and uses a very old fan heater rather than the wall-mounted electric heater, and has 'door snakes' at some of his doors. He has curtains that are not block-out, and no pelmets. There are gaps around doors and windows. His old, inefficient refrigerator and washing machine will be replaced. The client is keen to reduce his bills, has agreed to take part in a case study and will greatly benefit from this exercise.
Date of referral	23 February 2012

The house, its timeline of retrofitting activities and thermal performance

This is a small one-bedroom unit.

The thermal performance simulation indicates that the draught-sealing measures implemented may be almost twice as cost-effective as the window dressing upgrades in reducing overall energy requirements for heating and cooling in this house.

Aerial view ↑North



Modelled in BERS4.2 thermal simulation software
Pink: kitchen/dining; blue: bedroom; green: laundry/bathroom; yellow: corridor

Timeline of testing and retrofitting activities

Date	Action
2 April	Temperature and energy-use data loggers installed
16 April	Air leakage assessment and thermographic inspection
20 April	Education
1 May	Draught-proofing external and internal doors
18 May	Curtains and pelmets installed
18 May	Post-retrofit test and collection of temperature and energy-use data
20 June	Further draught-proofing cavity door slider and wall–ceiling joins
22 June	Final blower door test and data collection

Thermal performance simulation (energy efficiency rating) of proposed retrofit measures

Simulation and specifications	Star rating	Heating (MJ/m^2)	Cooling (MJ/m^2)	Total (MJ/m^2)	Predicted reduction (%)	Actual cost ($)	Cost per MJ reduction ($)
Starting conditions: • Insulated by neighbours above, to north and south • Very draughty • Curtains, no pelmets	2.8	344	70	414			
Starting conditions plus: • Curtains and pelmets to lounge and bedroom	3.4	285	48	334	19	1509	19
Starting conditions plus: • Draught sealing	3.3	274	75	349	16	747	11
Complete retrofit: • Draught sealing • Curtains and pelmets	4.2	215	52	267	36	2256	15

Air leakage results

Initial testing of the building showed that it was comparatively well sealed. The building was constructed from brick and rendered cement, with few doors and windows, and had high thermal mass.

The building envelope had many obvious leakage points, including:

- around plumbing penetrations in bathroom
- between internal brick and cement-rendered walls
- between bricks and window frames, as well as sliding-door frame
- through internal-wall sliding-door frame
- through gaps where brickwork meets ceiling
- through unsealed exhaust fan in laundry
- permanent opening in bathroom window.

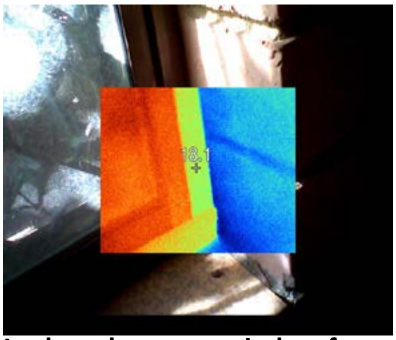
Silicon-based sealant was used to fill gaps between rendered concrete and brick walls in the living areas and bathroom, and around window and door frames. This was also used around plumbing penetrations. Doors were sealed with brush and tape sealing in the bathroom (which had a permanent window vent) and the laundry (which had an unsealed exhaust fan as a vent for the clothes dryer), to increase the airtightness of the conditioned space of the building. However, during testing, both these doors were left open, which means that the final air leakage test does not capture the full picture of the retrofitting measures put in place.

Result from air leakage testing

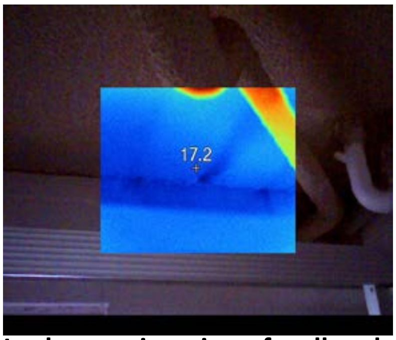
	Pre-retrofit	Post-retrofit	Difference
Air changes per hour at 50 Pa	13.3	11.8	–11%
Effective leakage area at 4 Pa (equivalent open square window)	25 cm x 25 cm	23 cm x 23 cm	11 cm x 11 cm

Note: A pressure difference of 4 Pa between inside and outside is close to the normal pressure differential experienced in the home on cold, windy Canberra days.

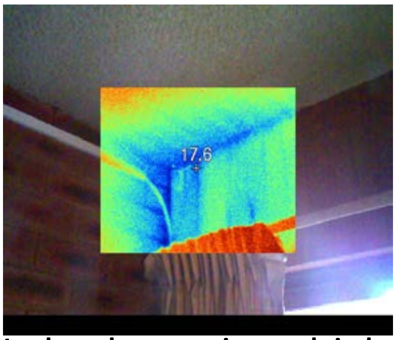
Air Leakage points



Leakage between window frame and internal brickwork



Leakage at junction of wall and ceiling in bathroom



Leakage between internal timber cladding, brickwork and ceiling

Insulation

As a ground-floor unit in a two-storey apartment complex, this residence benefited from insulation by neighbours to the north and south and above. The external, uninsulated and highly glazed eastern and western walls were by far the coolest parts of the house.

Refrigerator replacement

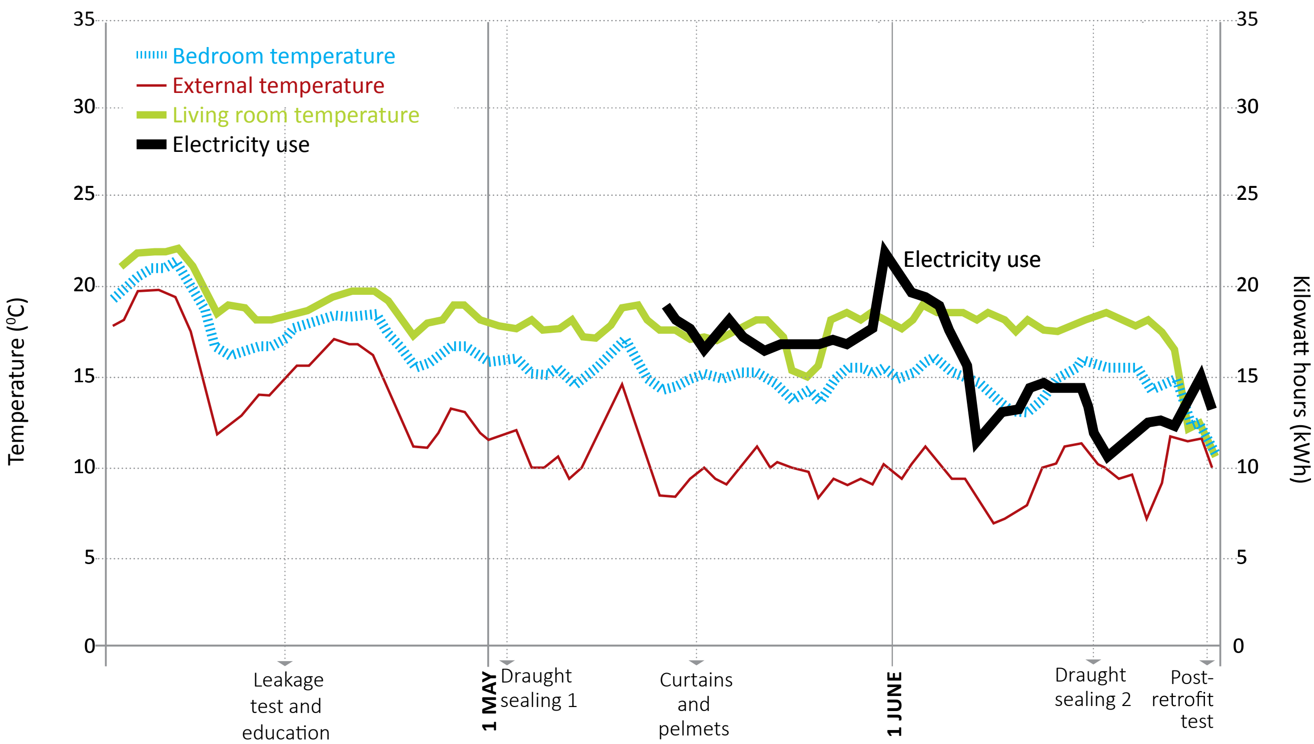
Energy usage results for old and new refrigerators

	Energy use (kWh/day)	Energy use (kWh/year)	CO_2-e (kg/year)[a]	Difference
Old	1.47	537	569	
New	0.81	295	313	–45%

a Scope2 + Scope3 emission factor for electricity is 1.06 kg CO_2-e/kWh (source: Australian Government Department of Climate Change and Energy Efficiency, *National Greenhouse Gas Accounts factors*, July 2012).

Temperature and electricity use

Electricity use and temperature data in case study 2



Energy bills

Electricity usage

	Energy use 2011 (kWh/day)	Energy use 2012 (kWh/day)	Difference
Autumn*	15	11	–22.1%
Winter *	27	21	–22.1%

Predicted versus actual reductions in energy use

Thermal simulation suggested that reductions in energy use of 36% for heating and cooling could be achieved using the draught-sealing and window-dressing measures implemented.

Actual energy consumption data from quarterly bills demonstrate a smaller, but still very significant, 22% reduction in overall household energy use (i.e. not just heating and cooling but also appliances, lighting, hot water heating, etc.) between winter 2011 and winter 2012.

The client may be using the remaining potential reductions in energy use (suggested by the thermal modelling) to maintain much more comfortable temperatures than possible in previous years. Rather than taking all the benefit in the form of reduced bills, this client is probably enjoying the benefit of increased comfort.

Total energy, greenhouse gas and cost savings

	Energy saving (kWh)	CO_2-e saving (kg)[a]	Cost saving ($)[b]
Autumn*	294	312.08	44.60
Winter*	550	583.53	94.71

a Scope2 + Scope3 emission factor for electricity is 1.06 kg CO_2-e/kWh (source: Australian Government Department of Climate Change and Energy Efficiency, *National Greenhouse Gas Accounts factors*, July 2012).

b Cost savings for electricity calculated using 15.15 (autumn) and 17.21 (winter) cents per kilowatt hour

*Autumn = billing periods beginning in March–May; winter = billing periods beginning in June–August

Case study 3

Community welfare organisation: Belconnen Community Service

Service provider: Cool Planet

Background information from Energy Efficiency Officer

Category	Client would benefit from an assessment, education and basic retrofit, such as curtains, blinds and draught sealing
Household occupants	1
Financial circumstance	Retired 65+ man, on aged pension. Has old inefficient whitegoods and large heating bills. Difficulty paying bills, unable to afford to replace whitegoods.
Type of residence	Home owner, single storey, brick veneer, south facing, kitchen and dining area north facing
Products to be replaced	Refrigerator, freezer and washing machine
Draught sealing required?	Feels his home is pretty tightly sealed
Client concerns	The client has lived in this four-bedroom home for about 15 years. He tries to avoid using underfloor heating as much as possible, because electricity bill spikes in winter. The client has net and light block-out curtains in most of the rooms, but no pelmets. The client is conscious of energy efficiency and is keen to see how much he can save money and improve the comfort of his home, particularly in winter. He is very open to being part of the case study.
Date of referral	4 April 2012

The house, its timeline of retrofitting activities and thermal performance

The thermal performance simulation indicates that this house was already performing very well thermally and that funds would have been better directed to other homes that performed less well. Although the house was not very leaky compared with other case study homes, draught sealing was still the most cost-effective retrofit measure.

Aerial view ↑North

Modelled in BERS4.2 thermal simulation software
Pink: kitchen/dining/living area; brown: secondary living area; blue/purple: bedrooms; green: laundry/bathroom

Timeline of testing and retrofitting activities

Date	Action
18 April	Temperature and energy-use data loggers installed
20 May	Air leakage assessment and thermographic inspection
19 May	Education
10 June	Draught-proofing external and internal doors
22 June	Curtains and pelmets installed

Thermal performance simulation (energy efficiency rating) of proposed retrofit measures

Simulation and specifications	Star rating	Heating (MJ/m^2)	Cooling (MJ/m^2)	Total (MJ/m^2)	Predicted reduction (%)	Actual cost ($)	Cost per MJ reduction ($)
Starting conditions: • Ceilings R3—some gaps • Walls R1.5 • Open exhaust fans in bathrooms, otherwise well sealed Good curtains, no pelmets	5.9	160	9	170			
Starting conditions plus: • Draught sealing	6.2	146	9	155	9	423	28
Starting conditions plus: • Ceiling insulation gaps filled	6.0	157	8	165	3	220	44
Starting conditions plus: • Pelmets to living areas	6.2	149	9	157	8	1100	85
Complete retrofit: • Pelmets to living areas • Blind to kitchen • Ceiling insulation gaps filled • Sealed exhaust fan • Sealed external doors	6.5	132	8	140	18	1743	58

Air leakage results

Result from air leakage testing

	Pre-retrofit	Post-retrofit	Difference
Air changes per hour at 50 Pa	**7.72**	–	–

Notes: Case study 3 was not retested for air leakage after draught sealing because it was already below the target level of 10 air changes per hour at 50 Pa, and funds were better spent on homes that were further from this target.

Refrigerator replacement

Energy usage results for old and new refrigerators

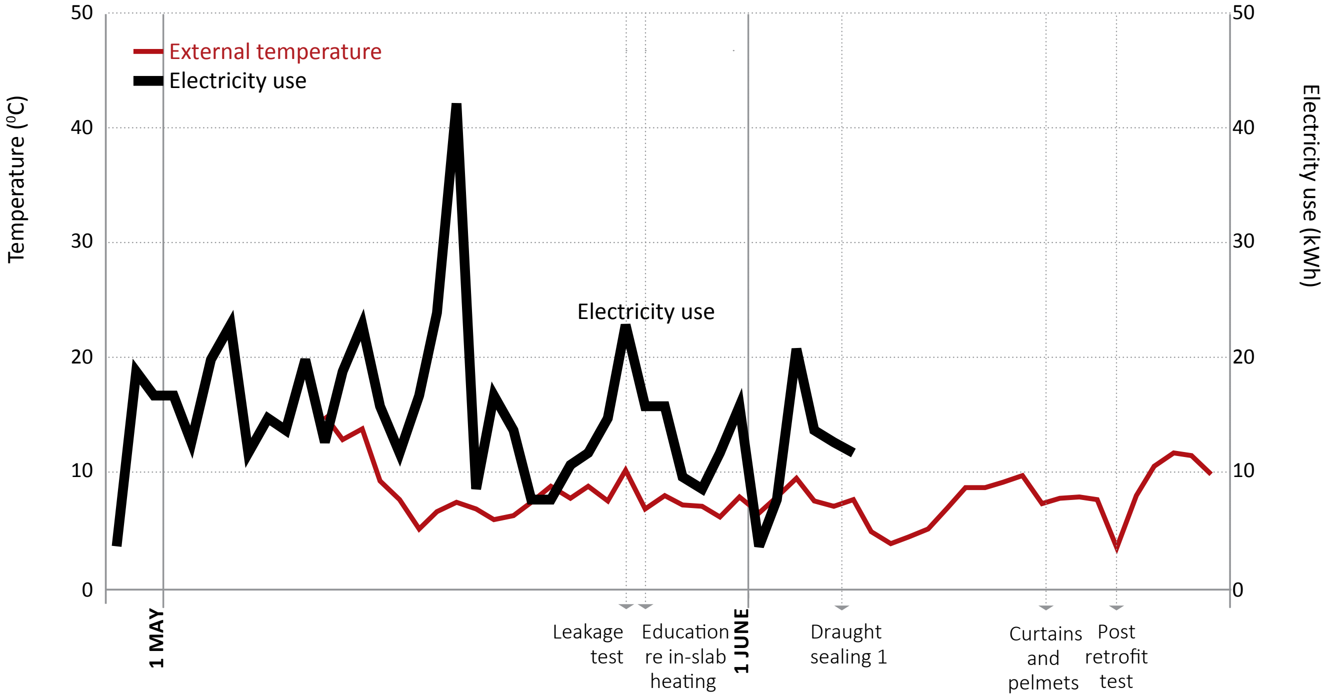
	Energy use (kWh/day)	Energy use (kWh/year)	CO_2-e (kg/year)[a]	Difference
Old	2.1	766	812	
New	0.92	329	349	–57%

a Scope2 + Scope3 emission factor for electricity is 1.06 kg CO_2-e/kWh (source: Australian Government Department of Climate Change and Energy Efficiency, *National Greenhouse Gas Accounts factors*, July 2012).

Temperature and electricity use

Energy consumption clearly dropped following the education session and explanation of the energy-use monitor.

Electricity use and temperature data in case study 3



Energy bills

Electricity usage

	Energy use 2011 (kWh/day)	Energy use 2012 (kWh/day)	Difference
Autumn*	44	18	–60%
Winter*	65	18	–73%

Predicted versus actual reductions in energy use

Thermal simulation suggested that reductions in energy use of 18% for heating and cooling could be achieved via the draught-sealing and window-dressing measures implemented.

Actual energy consumption data from quarterly bills demonstrate a 73% reduction in overall household energy use (i.e. not just heating and cooling but also appliances, lighting, hot water heating, etc.) between winter 2011 and winter 2012. This suggests that education and associated behaviour change could account for most of the reduction in energy consumption. In 2011, the client had been unwell and had another family member staying in the house. As a result, the inefficient electric slab heating system had been used throughout the whole house rather than being zoned for use in the end of the house occupied by the resident on his own.

Total energy, greenhouse gas and cost savings

	Energy saving (kWh)	CO_2-e saving (kg)[a]	Cost saving ($)[b]
Autumn*	2395	2538.76	326.87
Winter*	4269	4525.82	685.84

a Scope2 + Scope3 emission factor for electricity is 1.06 kg CO_2-e/kWh (source: Australian Government Department of Climate Change and Energy Efficiency, *National Greenhouse Gas Accounts factors*, July 2012).

b Peak/off-peak rate is used to calculate cost savings for electricity usage.

*Autumn = billing periods beginning in March–May; winter = billing periods beginning in June–August

Case study 4

Community welfare organisation: Society of St Vincent de Paul

Service provider: C&J Group

Background information from Energy Efficiency Officer

Category	Home is draughty, with no curtains or blinds, and the client either has high bills or is living in impoverished conditions. Client would benefit greatly from an assessment, education and basic retrofit.
Household occupants	3
Financial circumstance	Centrelink—single parent
Type of residence	ACT Housing
Products to be replaced	Refrigerator and washing machine already replaced
Draught sealing required?	Not sure
Client concerns	Very cold house; the client is concerned about winter bill affordability. The house has pelmets but no curtains. The open-plan living/dining area is a priority.
Date of referral	27 March 2012

The house, its timeline of retrofitting activities and thermal performance

Three-bedroom brick veneer, 98 m^2, approximately 35 years old.

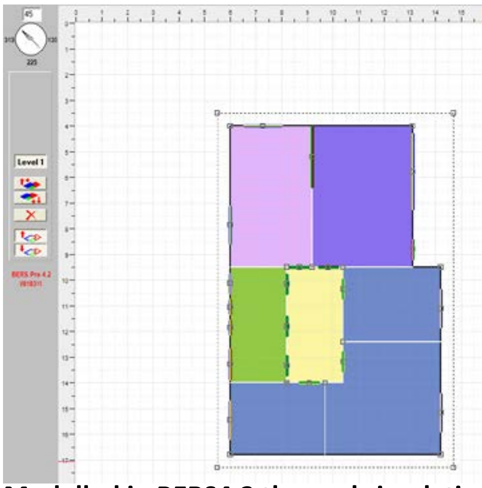
The potential for passive solar heat gain to this house is limited. The large area of glazing in the main living area and the windows of bedrooms 2 and 3 face south-west. The small amount of solar heat gain possible via the dining window is quickly lost through the leaky building envelope to the surrounding uninsulated walls. The main bedroom on the southernmost corner of the house is extremely cold, with two large uninsulated external walls and no opportunity for solar heat gain.

The thermal performance simulation showed that:

- retrofitting wall insulation is the single most effective retrofit measure for this home, with a predicted 27.9% reduction in energy requirements for heating and cooling
- draught sealing ceiling vents and fitting dampers to exhaust fans is the most cost-effective option at only $14 per MJ/m^2 reduction in predicted energy requirements.

The best allocation of the retrofit budget was $500—draught seal; $3100—draught seal and insulate walls; $5100—draught seal, insulate walls and top-up ceiling insulation.

Aerial view ↑North



Modelled in BERS4.2 thermal simulation software
Pink: kitchen/dining; purple: living; blue: bedrooms; green: laundry/bathroom; yellow: corridor

Timeline of testing and retrofitting activities

Date	Action
18 April	Temperature and energy-use data loggers installed
3 May	Air leakage assessment and thermographic inspection
7–11 May	Education
29 May – 1 June	Draught-proofing
6 June	Ceiling insulation installed
7 June	Holland blinds installed
22 June	Post-retrofit test and collection of temperature and energy-use data
22 June onwards	Temperature data loggers lost in client's home
2 August	Wall insulation installed
28 August	Draught-proofing internal bathroom and toilet doors

Thermal performance simulation (energy efficiency rating) of proposed retrofit measures

Simulation and specifications	Star rating	Heating (MJ/m^2)	Cooling (MJ/m^2)	Total (MJ/m^2)	Predicted reduction (%)	Actual cost ($)	Cost per MJ reduction ($)
Starting conditions: • Ceilings R2, walls/floors R0 • Multiple ceiling vents • Open exhaust fan in kitchen • Light curtains (2 layers)	2.9	354	35	390			
Starting conditions plus: • Draught sealing • DraftStoppa® to kitchen exhaust	3.3	321	34	355	9	311	9
Starting conditions plus: • New blinds to lounge and dining	2.9	354	35	390	0	1292	No value
Starting conditions plus: • Wall R2 insulation • Associated electrical upgrade	3.9	259	29	288	26	4127	40
Starting conditions plus: • Ceiling R4 insulation • Removal of old insulation	4.2	244	23	267	32	2045	16
Complete retrofit: • Sealed exhaust fans • Sealed vents • Draught sealed • DraftStoppa® to kitchen exhaust • New blinds to lounge and dining • R2 in walls and R4 in ceiling	4.7	211	21	232	41	7775	49

Air leakage results

Visual inspection suggested that the house would be very leaky, and this was confirmed by fan depressurisation testing. The building envelope had many obvious leakage points, including:

- unsealed exhaust fan in kitchen and bathroom
- permanent ceiling vents in every room
- permanent opening in toilet window
- around doors and surrounding architraves
- between window architraves and gyprock
- via plumbing and electrical penetrations behind kitchen joinery.

The rate of air leakage was nearly halved after the following draught-sealing measures were implemented:

- installing DraftStoppa® on kitchen and bathroom fans
- caulking around some doorways and windows frames
- sealing of the permanent ceiling vents.

Although unwanted air leakage was significantly reduced, there is scope for further retrofitting work on the building envelope. More time and budget given to sealing the building envelope would yield further gains in airtightness, improvements in comfort and reductions in energy use.

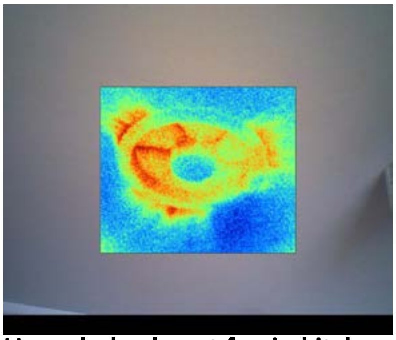
Although the thermachron data (see 'Temperature and electricity use') do not show an increase in internal temperatures, the client is sure that the house feels much more comfortable.

Result from air leakage testing

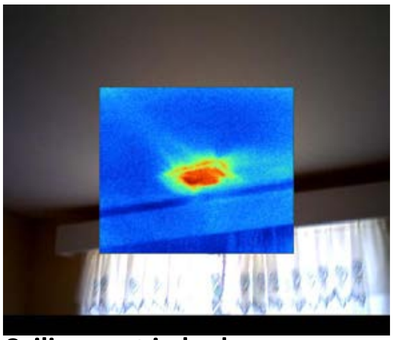
	Pre-retrofit	Post-retrofit	Difference
Air changes per hour at 50 Pa	25.01	13.89	–45%
Effective leakage area at 4 Pa (equivalent open square window)	51 cm x 51 cm	37 cm x 37 cm	35 cm x 35 cm

Note: A pressure difference of 4 Pa between inside and outside is close to the normal pressure differential experienced in the home on cold, windy Canberra days.

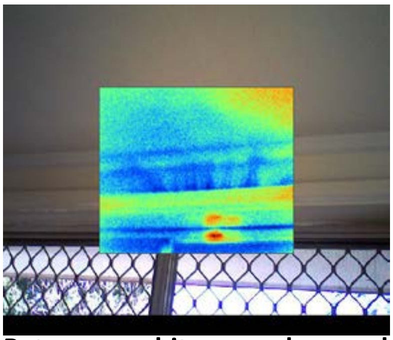
Air Leakage points



Unsealed exhaust fan in kitchen



Ceiling vent in bedroom



Between architrave and gyprock

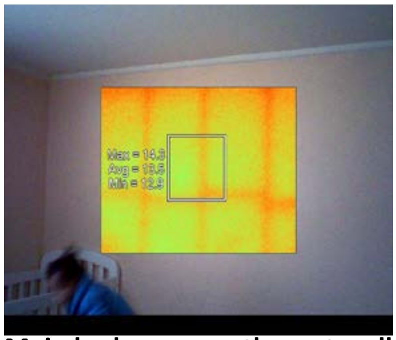
Insulation

Thermal imaging showed that the walls were uninsulated. Ceiling insulation, although present, appeared to be thin and patchy in some areas. On a mild, sunny day in March, the walls of the master bedroom were at approximately 13 °C; the ceiling was at 14.5 °C.

Inadequate insulation

Main bedroom, south corner, ceiling 5 March 2012, 10:28:37 am

Main bedroom, south corner, walls 5 March 2012, 10:28:46 am



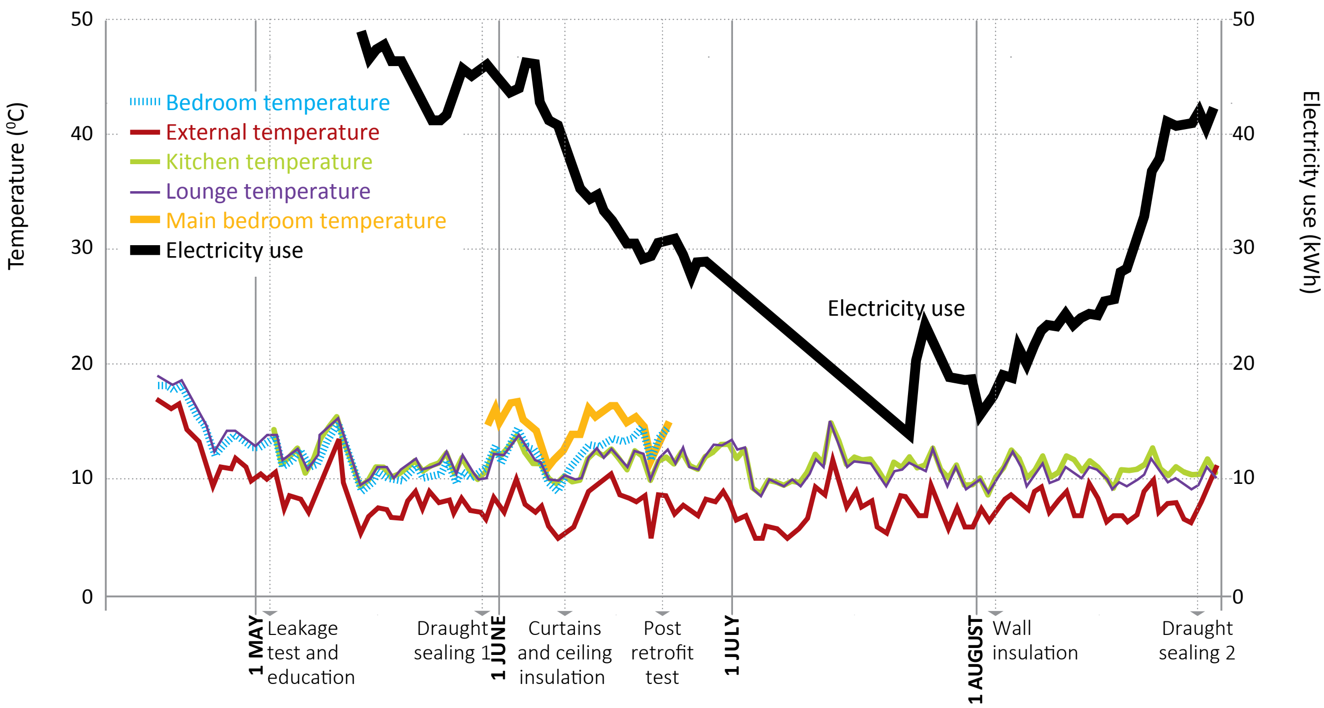
Main bedroom, south-west wall 5 March 2012, 10:51:47 am

Temperature and electricity use

Results from the temperature data loggers highlight the following:

- This is a very cold house. The internal temperature is only 5 °C higher than the external temperature. At some point in the middle of the day, the external temperature almost matches the internal temperature.
- Post-retrofitting, internal temperatures remained constant despite a decrease in energy use by the client. This indicates that the house maintains temperature as a result of improved insulation and draught-proofing.
- Unfortunately, around the same time that wall insulation was installed, another person moved into the house, and the energy-use profile of the house changed dramatically. The increased energy use was not associated with heating.

Electricity use and temperature data in case study 4



Energy bills

Electricity usage

	Energy use 2011 (kWh/day)	Energy use 2012 (kWh/day)	Difference
Autumn*	33	21	–35%
Winter*	74	42	–42%

Other observations

As a result of her involvement with the program, the client has made a great effort to reduce her energy bills. She says she is much more conscious of energy use and how to reduce it. Following her education session—and learning the difference between peak and off-peak power—she has changed some well-worn routines and now does her washing at night.

Other changes the client has made include:

- turning heating on only in the morning and evening
- turning heating off in the bedroom overnight
- turning appliances off at the wall
- closing curtains to keep the heat inside
- dressing for the climate
- talking with Spotless about possible upgrading of heating to an efficient split-system for the lounge/dining area.

Total energy, greenhouse gas and cost savings

	Energy saving (kWh)	CO_2-e saving (kg)[a]	Cost saving ($)[b]
Autumn*	1056	1119.80	133.41
Winter*	2780	2947.20	418.30

a Scope2 + Scope3 emission factor for electricity is 1.06 kg CO_2-e/kWh (source: Australian Government Department of Climate Change and Energy Efficiency, ***National Greenhouse Gas Accounts factors***, July 2012).

b Peak /off-peak rate is used to calculate cost savings for electricity usage.

*Autumn = billing periods beginning in March–May; winter = billing periods beginning in June–August

Case study 5

Community welfare organisation: Northside Community Service

Service provider: C&J Group

Background information from Energy Efficiency Officer

Category	Client would benefit from an assessment, education and basic retrofit, such as curtains, blinds and draught sealing
Household occupants	3
Financial circumstance	Disability support pension
Type of residence	Owner–occupier
Products to be replaced	Washing machine, refrigerator and freezer
Draught sealing required?	Could benefit from pelmets. Sensor light stays on all the time. Gas heating settings are faulty. Insulation in ceiling is almost non-existent, and there is no insulation in walls.
Date of referral	11 April 2012

The house, its timeline of retrofitting activities and thermal performance

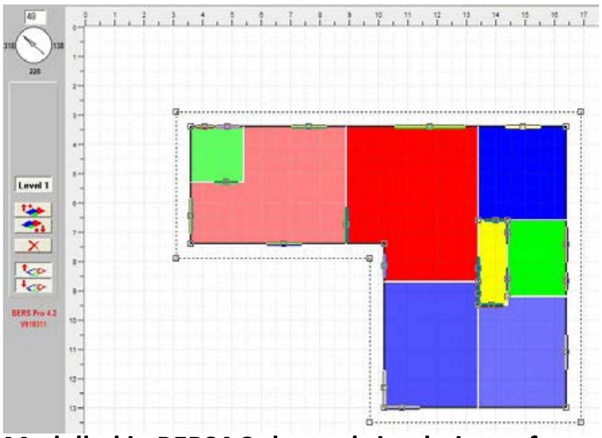
Three bedrooms, one bathroom, brick veneer, suspended timber floor, 100 m^2, 35 years old.

The main living room has glazing to the north-east, with good potential for passive solar heat gain to the area of greatest energy use. However, the living area is open to the adjoining dining area, which is glazed to the south and west. This additional space and the orientation of the windows reduce the ability of the joint living/dining areas to retain heat. The largest bedroom has a relatively high glazing-to-floor-area ratio, and the windows are oriented to the west and south—these features make it a thermal weak point. Uninsulated walls, a large number of ceiling penetrations and patchy ceiling insulation significantly affect the amount of energy required to maintain comfortable temperatures.

This client has recently connected solar panels, and the solar feed-in tariff is offsetting any bills.

The thermal performance simulation indicated that draught sealing would provide a 16% reduction in energy use for a low cost.

Aerial view ↑North



Modelled in BERS4.2 thermal simulation software
Pink: kitchen/dining; red: living; blue/purple: bedrooms; green: laundry/bathroom; yellow: corridor

Timeline of testing and retrofitting activities

Date	Action
9 May	Temperature and energy-use data loggers installed
21 May	Education
23 May	Air leakage assessment and thermographic inspection
29 May	Draught-proofing
31 May	Top-up insulation, curtains and pelmets installed
17 June	Post-retrofit test and collection of temperature and energy-use data
22 June	Final blower door test and data collection

Thermal performance simulation (energy efficiency rating) of proposed retrofit measures

Simulation and specifications	Star rating	Heating (MJ/m^2)	Cooling (MJ/m^2)	Total (MJ/m^2)	Predicted reduction (%)	Actual cost ($)	Cost per MJ reduction ($)
Starting conditions: • Ceilings R2, walls/floors R0 • Multiple ceiling vents (each room) • Open exhaust fan in kitchen • Light curtains/blinds	2.8	396	34	430			
Starting conditions plus: • Draught sealing	3.2	329	34	363	16	675	10
Starting conditions plus: • Insulation R2 in ceiling	2.7	385	27	412	4	1920	106
Starting conditions plus: • Curtains and pelmets to lounge, dining and kitchen	2.8	386	34	420	2	2720	272
Complete retrofit: • Sealed exhaust fans • Sealed vents • Draught sealed • R4 in ceiling • Curtains and pelmets to lounge, dining and kitchen	3.4	313	26	339	21	5315	58

Air leakage results

Sources of air leakage included:

- permanent ceiling vents in every room, including large ceiling vent directly above flued gas heater in living room
- open exhaust fan in kitchen
- unsealed 'Tastic' in bathroom
- around doors and window frames
- around ceiling and wall penetrations, such as roof access hole and wall-mounted air-conditioning systems.

The rate of air leakage was reduced by 41% by installing a DraftStoppa® in the kitchen, sealing off unnecessary ceiling vents and sealing around external doors.

The permanent vents and other penetrations in the ceiling seriously compromised the potential of the house to stay warm. Heated air from within the home was rising and rapidly escaping into the roof space via the holes in the ceiling.

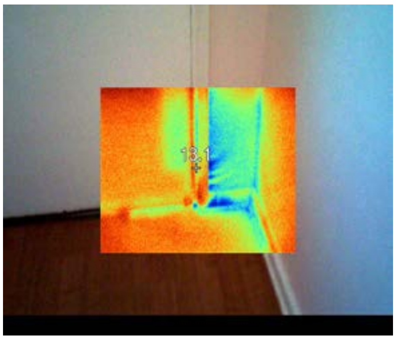
The reduction in air leakage achieved in this home, by focusing mainly on the holes in the ceiling, is equivalent to closing a 31 cm x 31 cm window in the building envelope.

Result from air leakage testing

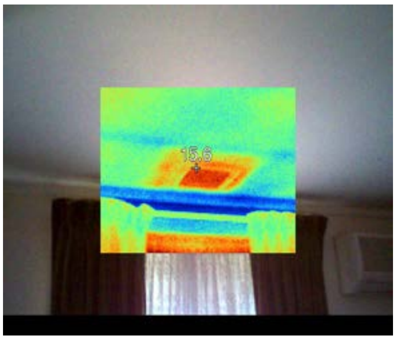
	Pre-retrofit	Post-retrofit	Difference
Air changes per hour at 50 Pa	21.02	12.46	–41%
Effective leakage area at 4 Pa (equivalent open square window)	49 cm x 49 cm	38 cm x 38 cm	31 cm x 31 cm

Note: A pressure difference of 4 Pa between inside and outside is close to the normal pressure differential experienced in the home on cold, windy Canberra days.

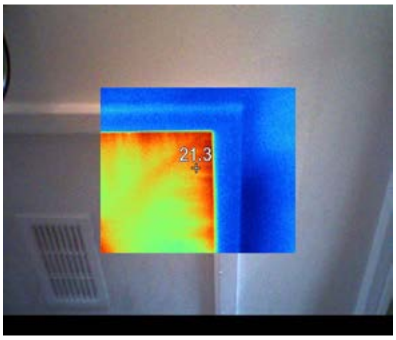
Air Leakage points



Gap through architrave and around door



One of many ceiling vents

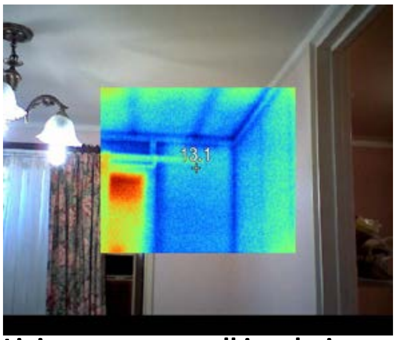


Leakage around roof access hole

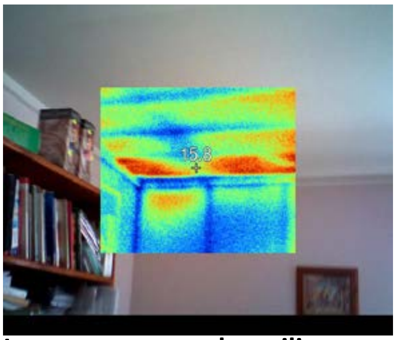
Insulation

The roof had rock wool insulation that was thin and unevenly installed. This caused significant fluctuations in ceiling temperature throughout the house. Thermal imaging indicated that no wall insulation was present (as expected in a house of this age).

Inadequate insulation



Living area, no wall insulation



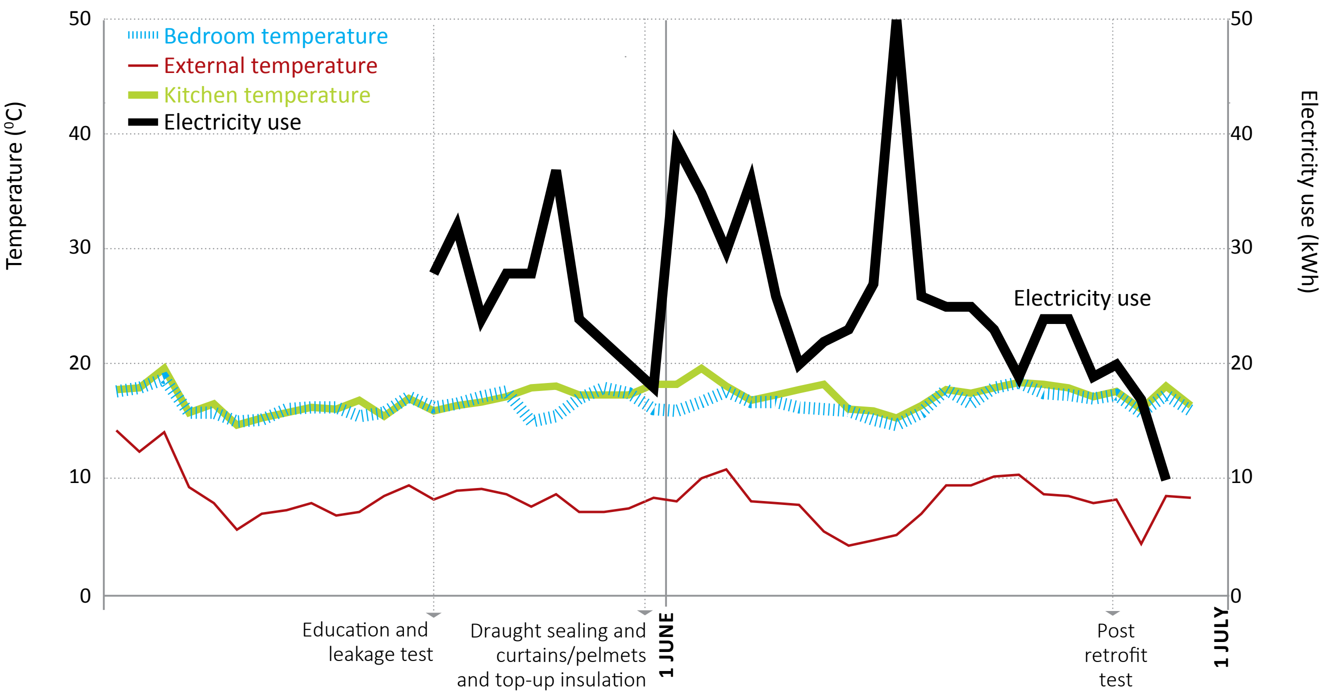
Lounge area, patchy ceiling insulation

Temperature and electricity use

Passive ventilation throughout this home via multiple ceiling vents and other unsealed penetrations is responsible for the large fluctuations in internal temperature. Data from the thermochrons highlight the following:

- Before the retrofit, internal temperatures were regularly only 8 °C warmer than the external temperature. After the retrofit, they were regularly 10 °C warmer than the external temperature.
- The kitchen/dining area is warmer after retrofitting and reaches a maximum temperature above 20 °C more often.
- Following the retrofit, the home maintains higher temperatures and experiences less fluctuation in temperature, but energy use has decreased.

Electricity use and temperature data in case study 5



Energy bills

A gas heater is used to maintain the living areas at comfortable temperatures. Electric reverse-cycle systems are used in the bedrooms. Gas consumption decreased, but electricity consumption was stable.

Electricity usage

	Energy use 2011 (kWh/day)	Energy use 2012 (kWh/day)	Difference
Autumn	19	22	+14%
Winter	18	19	+5%

Gas usage

	Energy use 2011 (kWh/day)	Energy use 2012 (kWh/day)	Difference
Autumn	112	98	–12.5%
Winter	120	87	–27.5%

Electricity + gas usage

	Energy use 2011 (kWh/day)	Energy use 2012 (kWh/day)	Difference
Autumn	131	120	–8%
Winter	138	106	–23%

* Autumn = billing periods beginning in March–May; winter = billing periods beginning in June–August

Predicted versus actual reductions in energy use

Thermal simulation suggested that reductions in energy use of 21% for heating and cooling could be achieved via the draught-sealing and window-dressing measures implemented.

Actual energy consumption data from quarterly bills demonstrate a 23% reduction in overall household energy use (i.e. not just heating and cooling but also appliances, lighting, hot water heating, etc.) between winter 2011 and winter 2012. This suggests that education and associated behavioural change could account for the extra reduction in energy consumption.

Total energy, greenhouse gas and cost savings

	Energy saving (kWh)	CO_2-e saving (kg)[a]	Cost saving ($)[b]
Autumn*	1038	–14.84	61.18
Winter*	2921	467.85	213.82

a Scope2 + Scope3 emission factor for electricity is 1.06 kg CO_2-e/kWh. Emission factor for natural gas is 51.33 kg CO_2-e/GJ (source: Australian Government Department of Climate Change and Energy Efficiency, ***National Greenhouse Gas Accounts factors***, July 2012).

b Cost savings for gas usage calculated using 2.113 cents per megajoule

*Autumn = billing periods beginning in March–May; winter = billing periods beginning in June–August

Case study 6

Community welfare organisation: Belconnen Community Service

Service provider: Cool Planet

Background information from Energy Efficiency Officer

Category	Client would benefit from an assessment, education and basic retrofit, such as curtains, blinds and draught sealing
Household occupants	2
Financial circumstance	Young single mother on part pension and part-time work; large energy bills
Type of residence	Housing ACT single storey, 2 bedrooms, brick veneer, north facing
Products to be replaced	Refrigerator and washing machine already replaced
Draught sealing required?	Contractor engaged
Client concerns	The client has lived in this home for one year. She reports that the home is very cold in winter and very hot in summer. There is a wall-mounted electric heater, which she tries not to use because of costs. There are light block-out curtains in all rooms, but no pelmets. There are three large vents throughout the home: two are for ventilation and the other is a skylight. The client reports massive draughts from these. There are also gaps around and under doors, which she blocks with 'door snakes'. She has energy-efficient lighting in her home and is aware of energy efficiency, but would like further education and information to make choices about her heating. Energy Efficiency Officer talked about the use of passive heating through north-facing windows, a heated throw rug and column-heater use, as well as highlighting the potential for the retrofit to increase the comfort of her home.
Date of referral	6 April 2012

The house, its timeline of retrofitting activities and thermal performance

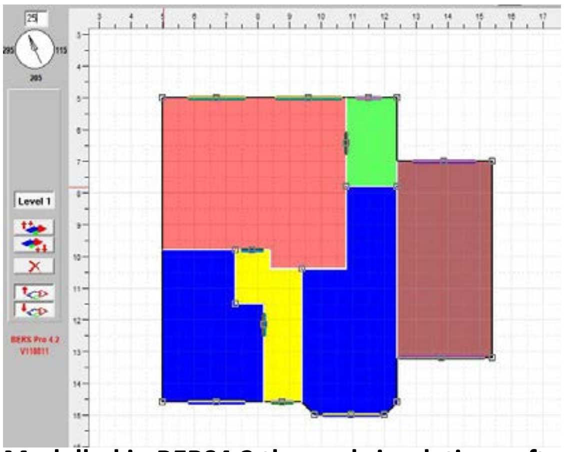
Two-bedroom, brick-veneer townhouse.

The potential for passive solar heat gain to this house is good as a result of the large area of north-facing glazing in the lounge/living/kitchen area. The two bedrooms have south-facing windows. The main issue with this house is the vented skylights used in the kitchen and bathrooms for ventilation and light.

The thermal performance simulation indicates that draught sealing ceiling vents and fitting dampers to exhaust fans is the single most effective retrofit measure for this home, with a predicted 21% reduction in energy requirements for heating and cooling.

The best allocation of the retrofit budget was $700—draught seal; $1700—draught seal and top-up insulation in ceiling.

Aerial view ↑North



Modelled in BERS4.2 thermal simulation software
Pink: kitchen/dining/living; brown: garage; blue: bedrooms; green: laundry/bathroom; yellow: corridor

Timeline of testing and retrofitting activities

Date	Action
18 April	Temperature and energy-use data loggers installed
10 May	Air leakage assessment and thermographic inspection
6 June	Ceiling insulation installed
11 June	Draught-proofing
12 June	Education
20 June	Draught-proofing bathroom, new extractor fan installed, and investigation of damp in child's bedroom
22 June	Post-retrofit test, and collection of temperature and energy-use data

Thermal performance simulation (energy efficiency rating) of proposed retrofit measures

Simulation and specifications	Star rating	Heating (MJ/m²)	Cooling (MJ/m²)	Total (MJ/m²)	Predicted reduction (%)	Actual cost ($)	Cost per MJ reduction ($)
Starting conditions: • Ceilings R3.5, walls R1.5 • Open exhaust fan • Draught sealed • No pelmets, light dressing • Open-shaft skylights x 3	4.2	252	16	268			
Starting conditions plus: • Pelmets x 6	4.4	237	16	253	6	720	48
Starting conditions plus: • Sealed exhaust fan • Sealed skylights	4.9	204	17	221	18	1578	34
Complete retrofit: • Sealed exhaust fans • Sealed skylights • Pelmets x 6	5.2	189	17	206	23	2298	37

Air leakage results

The overall condition and build of the house was reasonably good, as expected for a house less than 10 years old. The initial air leakage data showed higher than average air exchange rates for Canberra homes. This was mainly due to three vented-shaft skylights in the bathrooms and the open-plan kitchen/living area. These were vented to the roof cavity and allowed large volumes of air to rise and escape.

This simple building oversight and design flaw was easily rectified by adding sealed exhaust fans in each bathroom and sealing the shafts with removable perspex.

The images below show the air exchange occurring through the skylights. It is interesting to note the difference in temperature between the air in the skylight shaft and the surrounds—the air in the shaft is warmer, partly as a result of the stack effect, as well as the solar heat gain through the shaft from the morning sun.

Air infiltration can also be seen around the roof access hole and doors. These gaps account for the bulk of the remaining unwanted air exchange.

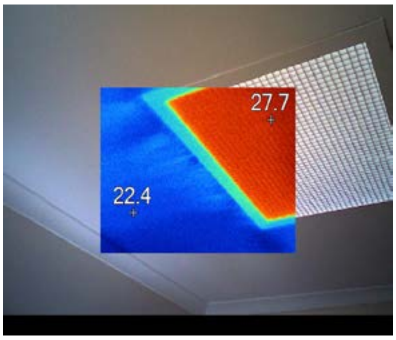
The rate of air leakage was reduced by 75% after draught sealing the vented skylights and around the external doors. The reduction in air leakage achieved in this home, by focusing mainly on the holes in the ceiling, is equivalent to closing a 25 cm x 25 cm window in the building envelope.

Result from air leakage testing

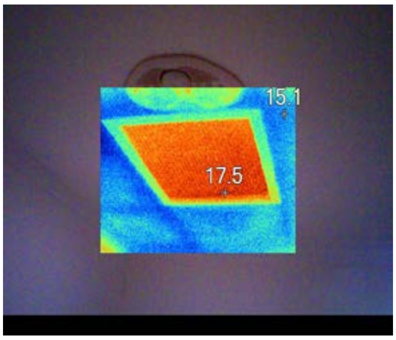
	Pre-retrofit	Post-retrofit	Difference
Air changes per hour at 50 Pa	28.2	7.1	–75%
Effective leakage area at 4 Pa (equivalent open square window)	48 cm x 48 cm	23 cm x 23 cm	42 cm x 42 cm

Note: A pressure difference of 4 Pa between inside and outside is close to the normal pressure differential experienced in the home on cold, windy Canberra days.

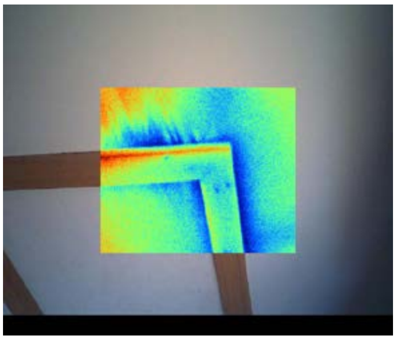
Air Leakage points



Vented skylight in kitchen



Vented skylight and fan in bathroom



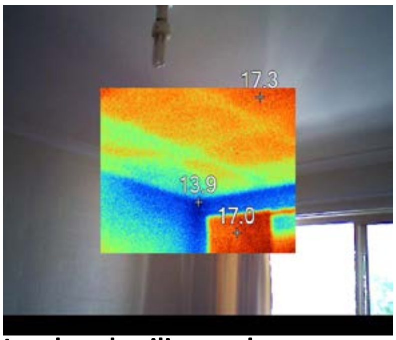
Leakage around roof access hole in laundry

Insulation

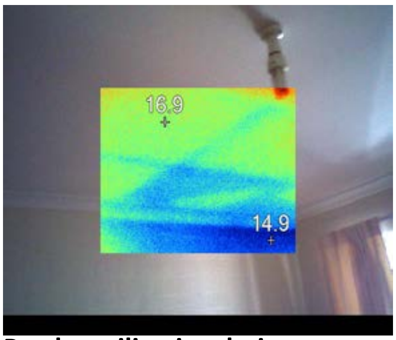
The roof was reasonably insulated, but the walls had no insulation. The images below indicate the temperature differences between:

- the walls and the ceiling (showing the effect of insulation)
- insulated and uninsulated sections of the ceiling
- internal and external walls (where the internal walls are protected from large temperature fluctuations by the semi-conditioned space of the garage).

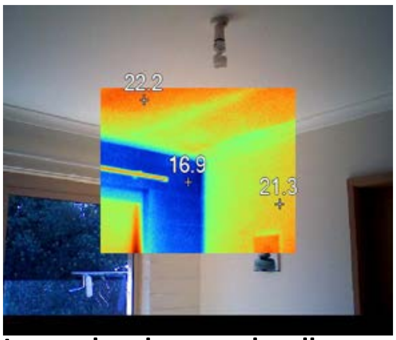
Inadequate insulation



Insulated ceiling and uninsulated wall



Patchy ceiling insulation
5 October 2012, 10:36:38am



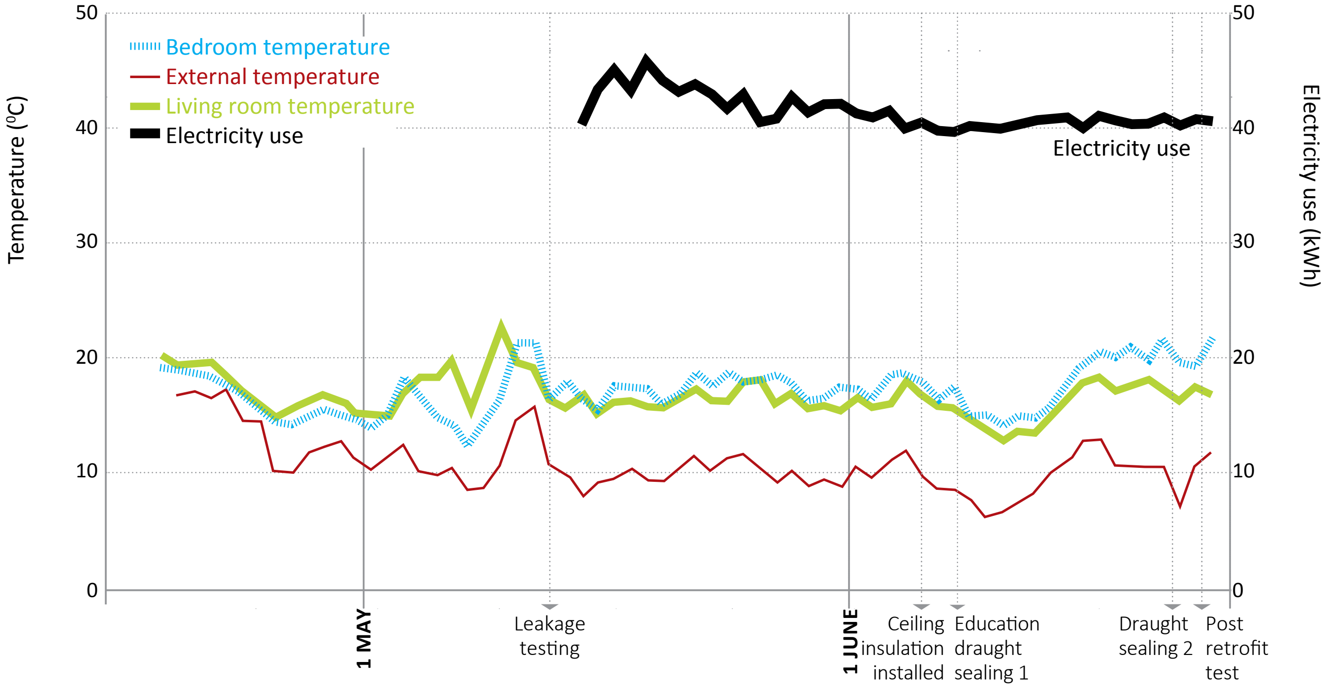
Internal and external walls
5 October 2012, 10:45:31am

Temperature and electricity use

The data gathered show that energy use stayed the same (around 40 kWh/day) following retrofitting.

Passive ventilation throughout this home via multiple vented skylights and other unsealed penetrations is responsible for the large fluctuations in internal temperature. The energy use is the same following retrofit, but the internal temperature of the home has dramatically increased. This may be due to the client enjoying the feeling of warmth in her home or not being fully aware that heating is still being used and the need to lower the thermostat. This highlights the need for follow-up education sessions following retrofitting measures so that clients are aware of how they can reduce their energy use.

Electricity use and temperature data in case study 6



Energy bills

Electricity usage

	Energy use 2011 (kWh/day)	Energy use 2012 (kWh/day)	Difference
Autumn*	23	14	–40%
Winter*	67	44	–35%

Predicted versus actual reductions in energy use

Thermal simulation suggested that reductions in energy use of 23% for heating and cooling could be achieved via the draught-sealing and window-dressing measures implemented.

Actual energy consumption data from quarterly bills demonstrate a 35% reduction in overall household energy use (i.e. not just heating and cooling but also appliances, lighting, hot water heating, etc.) between winter 2011 and winter 2012. This suggests that education and associated behavioural change could account for the extra reduction in energy consumption.

Total energy, greenhouse gas and cost savings

	Energy saving (kWh)	CO_2-e saving (kg)[a]	Cost saving ($)[b]
Autumn*	845	895.79	128.03
Winter*	2103	2229.09	345.65

a Scope2 + Scope3 emission factor for electricity is 1.06 kg CO_2-e/kWh (source: Australian Government Department of Climate Change and Energy Efficiency, *National Greenhouse Gas Accounts factors*, July 2012).

b Actual rates for autumn and winter 2012 were used to calculate the cost savings for electricity usage.

*Autumn = billing periods beginning in March–May; winter = billing periods beginning in June–August

Case study 7

Community welfare organisation: Communities@Work

Service provider: Cool Planet

Background information from Energy Efficiency Officer

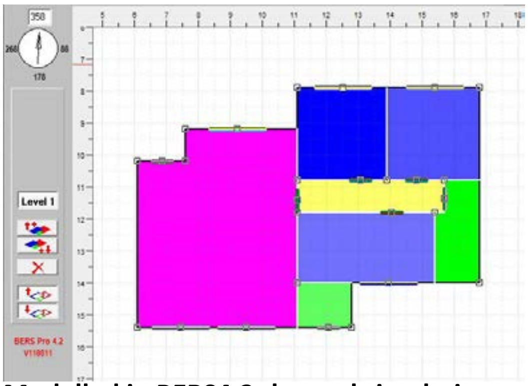
Category	Home is draughty, with no curtains or blinds, and the client either has high bills or is living in impoverished conditions. Client would benefit greatly from an assessment, education and basic retrofit.
Household occupants	3
Financial circumstance	Low-income household
Type of residence	Owner–occupier
Products to be replaced	Refrigerator and washing machine
Draught sealing required?	Requires draught-proofing to address air leakage. Requires window furnishing, including pelmets, to reduce current high loss through aluminium-framed single-glazed windows. Insulation to ceiling and walls requires survey and subsequent rectification—minimum R5 to ceilings, R3 to walls.
Client concerns	Cold in winter, hot in summer
Date of referral	5 May 2012

The house, its timeline of retrofitting activities and thermal performance

Two-bedroom, brick-veneer townhouse.

The thermal performance simulation indicates that draught sealing should be twice as cost-effective as window-dressing upgrades in this house.

Aerial view ↑North
Case study 7 is the unit in the centre



Modelled in BERS4.2 thermal simulation software
Pink: kitchen/dining/living; blue/purple: bedrooms; green: laundry/bathroom; yellow: corridor

Timeline of testing and retrofitting activities

Date	Action
18 May	Temperature and energy-use data loggers installed
7 June	Air leakage assessment and thermographic inspection
12 July	Draught-proofing
24 July	Education
27 July	Post-retrofit test and collection of temperature and energy-use data
July–September	Further draught-proofing cavity door slider and wall–ceiling joins (exact date unclear)
19 September	Curtains and pelmets installed

Thermal performance simulation (energy efficiency rating) of proposed retrofit measures

Simulation and specifications	Star rating	Heating (MJ/m^2)	Cooling (MJ/m^2)	Total (MJ/m^2)	Predicted reduction (%)	Actual cost ($)	Cost per MJ reduction ($)
Starting conditions: • Ceilings R3.5 • Down-lights x 4 • Open exhaust fan in kitchen, open-shaft skylight in bathroom • Very draughty	3.3	290	18	309			
Starting conditions plus: • Curtains to living areas • Blind to kitchen	4.3	244	19	260	16	1720	35
Starting conditions plus: • Exhaust fan cover • Down-light covers x 4 • Sealed skylight • Draught sealing 2 x doors/ windows	4.2	256	19	274	11	561	16
Complete retrofit • Curtains to living areas • Blind to kitchen • Exhaust fan cover • Down-light covers x 4 • Sealed skylight • Draught sealing 2 x doors/ windows	4.9	207	15	222	28	2282	26

Air leakage results

The house was built in the last 10–20 years and is in reasonable condition. It has a good northerly aspect to the living room and two bedrooms. The house performed reasonably well during initial testing with respect to air leakage. However, given the small size of the house and the orientation, there was plenty of scope for improvement.

Initial testing of the building showed a reasonably tight building envelope, with some major pitfalls. The main leakage was a result of an open-shaft skylight, wall-mounted panel heater and vented refrigerator space. Other areas of leakage include:

- between internal brick and plasterboard internal walls
- between bricks and window frames, as well as sliding-door frame
- through internal-wall sliding-door frame
- gaps where brickwork meets ceiling
- unsealed exhaust fan in kitchen
- permanent opening above fridge
- unsealed open-shaft skylight
- cavity sliding door
- wall-mounted panel heater
- roof access hole.

Air leakage was reduced by:

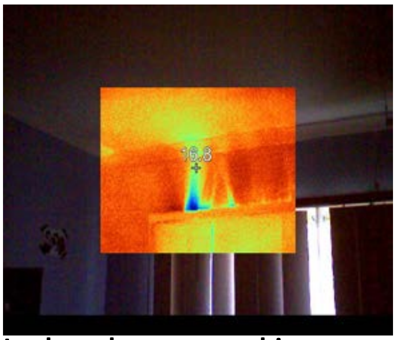
- sealing between the internal brick wall and adjoining walls and cornicing
- installation of a DraftStoppa® above the toilet fan
- sealing around door frames and catches
- sealing around architraves and door frames
- sealing the skylight in the bathroom.

Result from air leakage testing

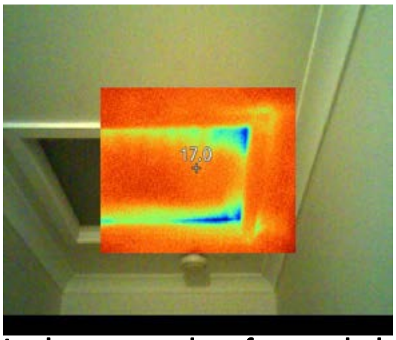
	Pre-retrofit	Post-retrofit	Difference
Air changes per hour at 50 Pa	16.8	10.19	–40%
Effective leakage area at 4 Pa (equivalent open square window)	34 cm x 34 cm	23 cm x 23 cm	25 cm x 25 cm

Note: A pressure difference of 4 Pa between inside and outside is close to the normal pressure differential experienced in the home on cold, windy Canberra days.

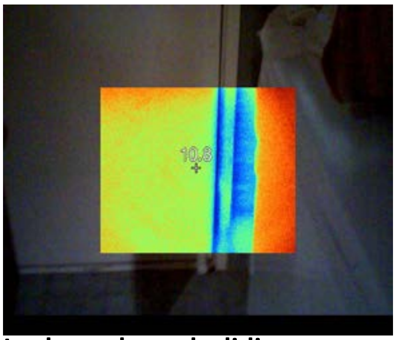
Air Leakage points



Leakage between architrave and gyprock



Leakage around roof access hole

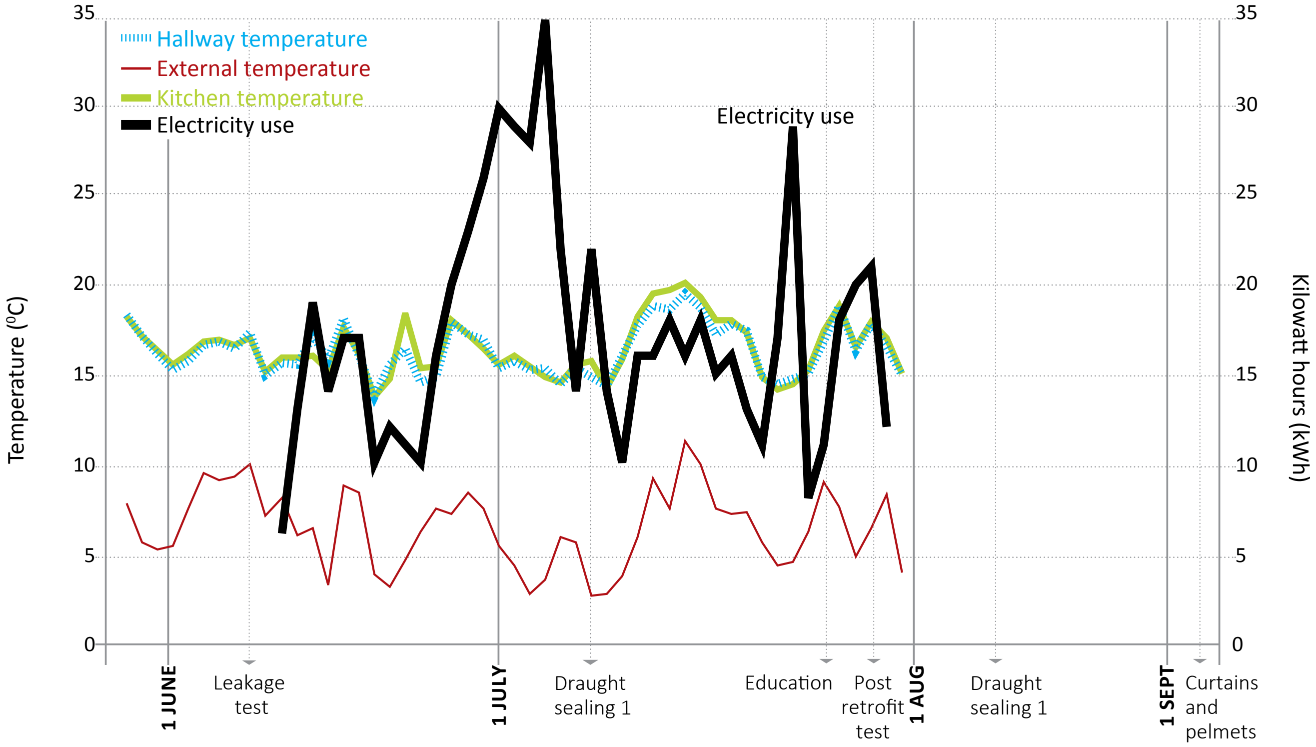


Leakage through sliding cavity door

Temperature and electricity use

The results suggest that energy use decreased, and internal temperatures increased in mid-July following draught sealing. The results are very erratic, however, and this is thought to be related to the homeowner frequently going away for extended periods.

Electricity use and temperature data in case study 7



Energy bills

Electricity usage

	Energy use 2011 (kWh/day)	Energy use 2012 (kWh/day)	Difference
Autumn*	7	8	14%
Winter*	9	15	62%

Gas usage

	Energy use 2011 (kWh/day)	Energy use 2012 (kWh/day)	Difference
Autumn*	19	16	–16%
Winter*	43	36	–16%

Electricity + gas usage

	Energy use 2011 (kWh/day)	Energy use 2012 (kWh/day)	Difference
Autumn*	28	24	–14%
Winter*	52	51	–2%

Total energy, greenhouse gas and cost savings

	Energy saving (kWh)	CO_2-e saving (kg)[a]	Cost savings ($)[b]
Autumn*	176	–52.25	6.1
Winter*	117	–434.05	–38.47

a Scope2 + Scope3 emission factor for electricity is 1.06 kg CO_2-e/kWh. Emission factor for natural gas is 51.33 kg CO_2-e/GJ (source: Australian Government Department of Climate Change and Energy Efficiency, *National Greenhouse Gas Accounts factors*, July 2012).

b Cost savings for gas usage calculated using 2.113 cents per megajoule

*Autumn = billing periods beginning in March–May; winter = billing periods beginning in June–August

Case study 8

Community welfare organisation: Communities@work

Service provider: Cool Planet

Background information from Energy Efficiency Officer

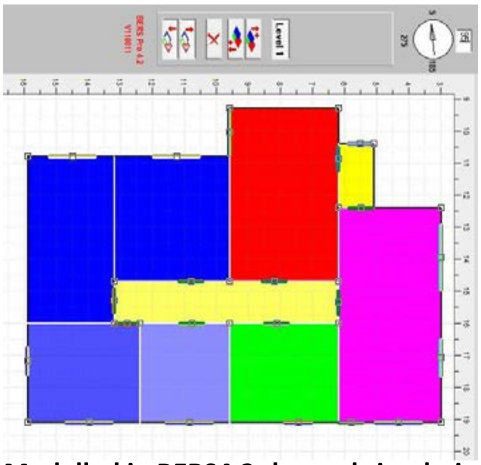
Category	Home is draughty, with no curtains or blinds, and the client either has high bills or is living in impoverished conditions. Client would benefit greatly from an assessment, education and basic retrofit.
Household occupants	3
Financial circumstance	Low-income household
Type of residence	Housing ACT tenant
Products to be replaced	Nil—awaiting case study
Draught sealing required?	Draughty, high air leakage home, requires door-base and door-frame sealing
Client concerns	Cold in winter, hot in summer, high energy bills
Date of referral	17 May 2012

The house, its timeline of retrofitting activities and thermal performance

Four-bedroom, brick veneer townhouse, approximately 40 years old.

The thermal performance simulation indicates that draught sealing would be five times more cost-effective than window-dressing upgrades in this house.

Aerial view ↑North



Modelled in BERS4.2 thermal simulation software
Pink: kitchen/dining; red: living; blue/purple: bedrooms; green: laundry/bathroom; yellow: corridor

Timeline of testing and retrofitting activities

Date	Action
24 May	Temperature and energy-use data loggers installed
7 June	Air leakage assessment
7 July	Draught-proofing
12 July	Draught-proofing of bathroom exhaust fan/skylight
27 July	Post-retrofit test and collection of temperature and energy-use data
5 December	Curtains and pelmets installed

Thermal performance simulation (energy efficiency rating) of proposed retrofit measures

Simulation and specifications	Star rating	Heating (MJ/m²)	Cooling (MJ/m²)	Total (MJ/m²)	Predicted reduction (%)	Actual cost ($)	Cost per MJ reduction ($)
Starting conditions: • Ceilings R3 • Unsealed exhaust fan in kitchen and bathroom • Very draughty	2.8	318	28	346			
Starting conditions plus: • Curtains to living areas	2.9	303	25	328	5	1570	87
Starting conditions plus: • Exhaust fan covers • Draught sealing	3.1	282	28	310	10	575	16
Complete retrofit: • Curtains to living areas • Exhaust fan covers • Draught sealing	3.4	267	25	291	16	2145	39

Air leakage results

This house had a surprisingly tight building envelope for its age, mainly as a result of its lack of ceiling and wall vents, which can be common in these houses, and its architraves and cornicing, which were in reasonable condition.

Measures to reduce air leakage included:

- sealing two exhaust fans using DraftStoppas®
- resealing some architraves using sealant
- sealing external doorways around the sides and at the bottom.

With these fairly minor modifications, the house reached close to 10 air changes per hour at 50 Pa. To further reduce air leakage, the house would require new windows that seal more effectively.

Result from air leakage testing

	Pre-retrofit	Post-retrofit	Difference
Air changes per hour at 50 Pa	16.03	10.42	–36%
Effective leakage area at 4 Pa (equivalent open square window)	40 cm x 40 cm	33 cm x 33 cm	23 cm x 23 cm

Note: A pressure difference of 4 Pa between inside and outside is close to the normal pressure differential experienced in the home on cold, windy Canberra days.

Refrigerator replacement

Energy usage results for old and new refrigerators

	Energy use (kWh/day)	Energy use (kWh/year)	CO_2-e (kg/year)[a]	Difference
Old	2.3	839	889	
New	0.91	334	354	–61%

a Scope2 + Scope3 emission factor for electricity is 1.06 kg CO_2-e/kWh (source: Australian Government Department of Climate Change and Energy Efficiency, *National Greenhouse Gas Accounts factors*, July 2012).

Energy bills

Electricity usage

	Energy use 2011 (kWh/day)	Energy use 2012 (kWh/day)	Difference
Autumn*	54	51	–6%
Winter*	67	58	–13%

Predicted versus actual reductions in energy use

Thermal simulation suggested that reductions in annual energy for heating and cooling of 16% could be achieved via the draught-sealing and window-dressing measures implemented.

Actual energy consumption data from quarterly bills demonstrate a 13% reduction in overall household energy use (i.e. not just heating and cooling but also appliances, lighting, hot water heating, etc.) between winter 2011 and winter 2012. The difference between actual and predicted energy savings is likely to be due to client behaviour.

Total energy, greenhouse gas and cost savings

	Energy saving (kWh)	CO_2-e saving (kg)[a]	Cost saving ($)[b]
Autumn*	291	308.19	44.05
Winter*	804	852.23	138.62

a Scope2 + Scope3 emission factor for electricity is 1.06 kg CO_2-e/kWh (source: Australian Government Department of Climate Change and Energy Efficiency, *National Greenhouse Gas Accounts factors*, July 2012).

b Autumn and winter 2012 rate is used to calculate cost savings for electricity usage.

*Autumn = billing periods beginning in March–May; winter = billing periods beginning in June–August

Case study 9

Community welfare organisation: YWCA of Canberra

Service provider: C&J Group

Background information from Energy Efficiency Officer

Category	Client would benefit from an assessment, education and basic retrofit, such as curtains, blinds and draught sealing
Household occupants	1
Financial circumstance	Centrelink
Type of residence	ACT Housing
Products to be replaced	Refrigerator
Draught sealing required?	Recommended to client to contact Spotless. Draught sealing required and insulation check. House looks draughty.
Client concerns	Draughty house, which gets hot and cold. Curtains exist but are dirty; the client is concerned about privacy, because living room windows face onto a major road. Possibly could also improve the curtain currently used to zone the living area.
Date of referral	10 April 2012

The house, its timeline of retrofitting activities and thermal performance

Two-bedroom, three-storey, brick-veneer apartment, with neighbours to the north and south, approximately 50 years old. Case study 9 was not modelled in BERS4.2 thermal simulation software because it was recruited late to the program and was already a 6-star house.

Thermal performance simulation (energy efficiency rating) of proposed retrofit measures

Thermal performance simulation was not performed because of the complexity, and difficulty in accessing all areas, of the old three-storey unit.

Aerial view ↑North

Timeline of testing and retrofitting activities

Date	Action
18 April	Temperature and energy-use data loggers installed
11 May	Education
11 May	Air leakage assessment
25 June	Curtains, pelmets, lighting and draught sealing completed
13 July	Final collection of data

Air leakage results

A pressure difference of 4 Pa between inside and outside is close to the normal pressure differential experienced in the home on cold, windy Canberra days.

The overall leakage rate of this building was low compared with other case study houses because the external wall and roof area was relatively small as a result of its three-storey, multi-unit construction. Because the air leakage rate was already below our target of 10 air changes per hour at 50 Pa, and it was difficult to test in a confined entrance way in the three-storey apartment, a post-retrofit test was not conducted. However, there were significant leaks that could be sealed, including:

- unsealed exhaust fan in kitchen
- permanent openings in walls above windows in kitchen, bathroom and living areas
- plumbing and electrical penetrations behind kitchen joinery
- around doors and surrounding architrave, particularly in the staircase
- around old wall-mounted heater
- between windows and gyprock, wall junctions and roof beams.

Measures to address some of these leaks included:

- using perspex to seal around plumbing penetrations under the kitchen sink (although there were still noticeable leaks around these penetrations)
- adding some sealant around architraves
- sealing various doors.

The main living areas downstairs had a permanent open door frame, allowing any warm air to rise up the stairs and vent out the upstairs permanent openings.

The roof lacked insulation, and hence any warm air contained was quickly cooled by the surrounding cold walls.

Result from air leakage testing

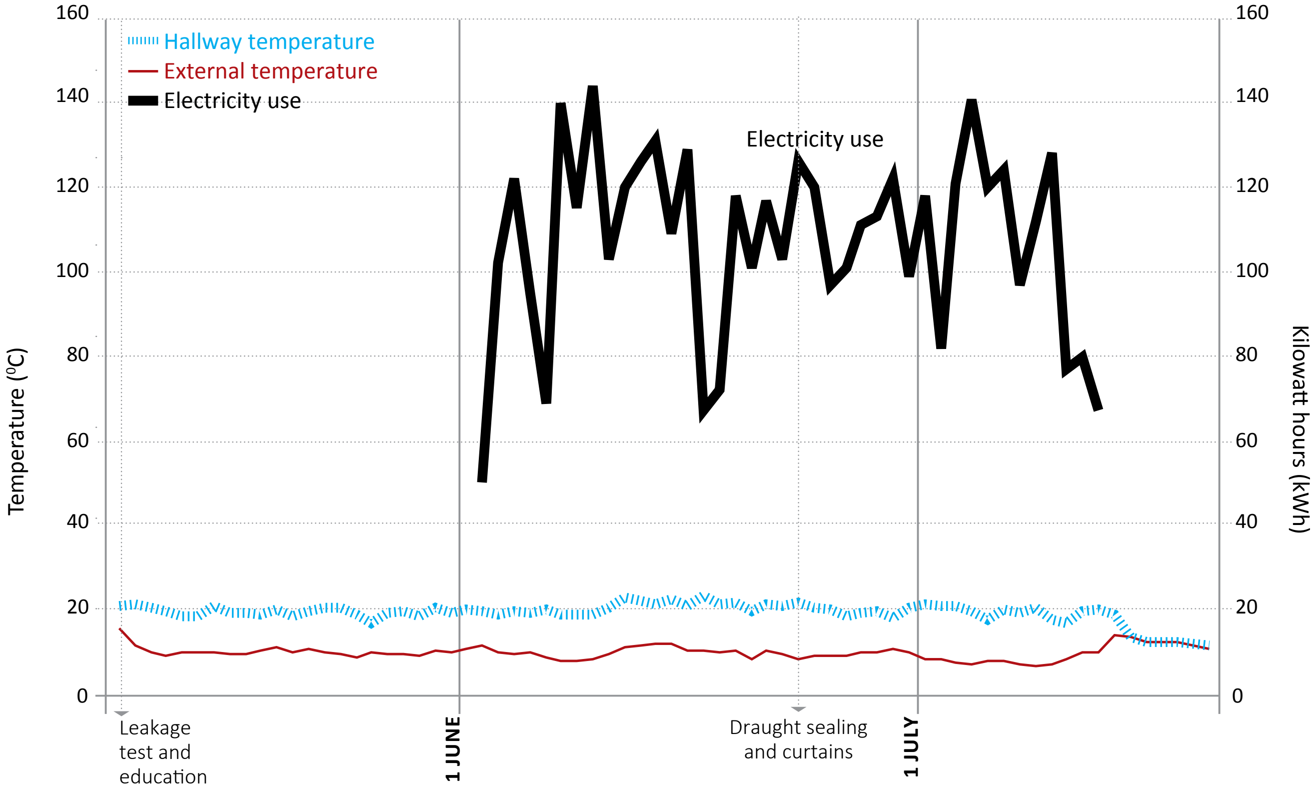
	Pre-retrofit	Post-retrofit	Difference
Air changes per hour at 50 Pa	9.4	–	–
Effective leakage area at 4 Pa (equivalent open square window)	25 cm × 25 cm	–	–

Notes: Case study 9 was not retested for air leakage after retrofitting because it was already below the target level of 10 air changes per hour at 50 Pa, and funds were better spent on homes that were further from this target.

Temperature and electricity use

This apartment uses a very inefficient heating system to keep internal temperatures 10 °C higher than external temperatures.

Electricity use and temperature data in case study 9



Energy bills

Electricity

	Energy use 2011 (kWh/day)	Energy use 2012 (kWh/day)	Difference
Autumn*	27.3	23	–16%
Winter*	146	89	–39%

Total energy, greenhouse gas and cost savings

	Energy saving (kWh)	CO_2-e saving (kg)[a]	Cost saving ($)[b]
Autumn*	399	422.84	60.43
Winter*	5185	5496.05	928.10

a Scope2 + Scope3 emission factor for electricity is 1.06 kg CO_2-e/kWh (source: Australian Government Department of Climate Change and Energy Efficiency, ***National Greenhouse Gas Accounts factors***, July 2012).

b Variable rates are used to calculate cost savings for electricity usage.

*Autumn = billing periods beginning in March–May; winter = billing periods beginning in June–August

Case study 10

Community welfare organisation: Belconnen Community Service

Service provider: Cool Planet

Background information from Energy Efficiency Officer

Category	Client would benefit from an assessment, education and basic retrofit, such as curtains, blinds and draught sealing
Household occupants	Three tenants with moderate to profound disabilities; 1–2 staff on 24/7, and other casual staff throughout the day
Financial circumstance	All tenants on disability support pension
Type of residence	ACT Housing, single-storey brick-veneer four-bedroom new home; side of house is north facing, but there is a large home next door, and a veranda blocks most of sun.
Products to be replaced	Monitors placed on second refrigerator and washing machine. (Appliances may be replaced but are relatively new.) EarthSmart powerboard, electric throw and outdoor clothes line to be provided. Clothes line pending approval from Environment and Sustainable Development Directorate.
Draught sealing required?	Inadequate insulation; contractor has checked and will upgrade insulation.
Client concerns	Concerns raised about the high cost of energy bills. The family of the clients is sure that energy use can be decreased. There is gas ducted heating throughout the home. It is difficult to change the heating situation because the tenants have varying degrees of physical disability. Block-out curtains are on most of the windows, but there are no pelmets. The washing machine is used several times per day. Staff and family are very open to further education and retrofitting, and have agreed to be part of a case study.
Date of referral	4 May 2012

The house, its timeline of retrofitting activities and thermal performance

Four-bedroom, brick-veneer house built in 2009. Excellent solar access to main living areas.

Thermal performance simulation (energy efficiency rating) of proposed retrofit measures

Thermal performance simulation was not conducted for case study 10 because, when the house was built in 2009, the design was required to meet minimum 6-star standards. The certified energy rated plans were provided and showed that the total predicted heating and cooling load for the house was just 146 MJ/m^2.

Aerial view ↑North (at 45-degree angle)

Timeline of testing and retrofitting activities

Date	Action
15 May	Temperature and energy-use data loggers installed
21 May	Education
31 May	Air leakage assessment
18 June	Draught-proofing and curtain installation
13 July	Follow-up air leakage, and data collection

Air leakage results

The internal building envelope of this recently built house was relatively well sealed to begin with.

The areas where leakage was occurring included:

- around sliding door frames
- exhaust vents in the bathroom and laundry
- open ventilation behind refrigerator and oven
- small gaps in and around windows and door frames
- ceiling-mounted air-conditioning vents.

The laundry door was sealed using brush stripping, and foam was used to seal around the sides of the refrigerator to limit air circulation to the area behind the refrigerator where it is most effective.

Significant effort and budget would be required to further seal a house of this size. It is also unlikely to return significant benefits. The energy usage of the house could be better reduced with further attention to insulation, heating management and energy-efficient whitegoods.

Result from air leakage testing

	Pre-retrofit	Post-retrofit	Difference
Air changes per hour at 50 Pa	9.99	9.60	–4%
Effective leakage area at 4 Pa (equivalent open square window)	48 cm x 48 cm	47 cm x 47 cm	10 cm x 10 cm

Note: A pressure difference of 4 Pa between inside and outside is close to the normal pressure differential experienced in the home on cold, windy Canberra days.

Energy bills

This is not a typical house in terms of energy use because the residents require constant assistance. There are usually 4–7 people in the house at any one time.

Electricity usage

	Energy use 2011 (kWh/day)	Energy use 2012 (kWh/day)	Difference
Autumn*	36	32	–10%
Winter*	25	26	+4%

Gas usage

	Energy use 2011 (kWh/day)	Energy use (kWh/day)	Difference
Autumn*	128	114	–11%
Winter*	65	84	+30%

Total energy, greenhouse gas and cost savings

	Energy saving (kWh)	CO_2-e saving (kg)[a]	Cost saving ($)[b]
Autumn*	1602	582.57	149.59
Winter*	–1817	–412.76	–145.71

a Scope2 + Scope3 emission factor for electricity is 1.06 kg CO_2-e/kWh (source: Australian Government Department of Climate Change and Energy Efficiency, *National Greenhouse Gas Accounts factors*, July 2012).
b 2012 rate is used to calculate cost savings for gas usage.

*Autumn = billing periods beginning in March–May; winter = billing periods beginning in June–August

Case study 11

Community welfare organisation: Northside Community Service

Service provider: C&J Group

Background information from Energy Efficiency Officer

Category	Client would benefit from an assessment, education and basic retrofit, such as curtains, blinds and draught sealing
Household occupants	2
Financial circumstance	Disability support pension
Type of residence	Home owner
Products to be replaced	–
Draught sealing required?	Yes. Gaps in doors and windows, vents, down-lights.
Client concerns	Client gets very cold in winter. Possible upgrade of insulation. Window coverings are inadequate in parts of the property where heat is lost.
Date of referral	27 April 2012

The house, its thermal performance and timeline of retrofitting activities

Four-bedroom, brick-veneer house.

Thermal performance simulation (energy efficiency rating) of proposed retrofit measures
Thermal performance simulation was not conducted for case study 11 because of time constraints.

Aerial view ↑North

Timeline of testing and retrofitting activities

Date	Action
9 May	Temperature and energy-use data loggers installed
25 May	Air leakage assessment
6 June	Education
8 June	Draught-proofing
19 July	Follow-up air leakage, and data collection
23 August	Curtain and pelmet installed

Air leakage results

The thermal performance of the house was significantly compromised by a range of penetrations and openings in the building envelope, including:

- several unsealed exhaust fans in kitchen, toilet and bathroom
- permanent vents in the walls in most rooms
- recessed lighting in ceiling
- unsealed 'Tastic' in bathroom
- leakage around doors and surrounding architrave in front extension room, as well as between the brick wall and ceiling gyprock
- leakage around and through window frames
- leakage between window architraves and gyprock
- permanent openings in toilet door
- leakage through sliding door openings in bathroom
- gaps around ceiling vents
- gaps through and around doorways
- gaps around sliding door in bathroom.

Measures to reduce air leakage included:

- placing DraftStoppas® over the bathroom and kitchen fans
- sealing the permanent wall vents (the recessed lighting was unable to be sealed as the light fittings were too large)
- siliconing ceiling vents, where possible
- sealing doorways with sealing tape and door stops.

The retrofit made a small difference but, given the size of the house and the number of problems, it would greatly benefit from further time and budget being allocated to reduce further air leakage, particularly through the bathroom via the unsealed Tastic. The recessed lights should be removed, and the evaporative cooling system should have vents placed over the system because it is particularly leaky.

Result from air leakage testing

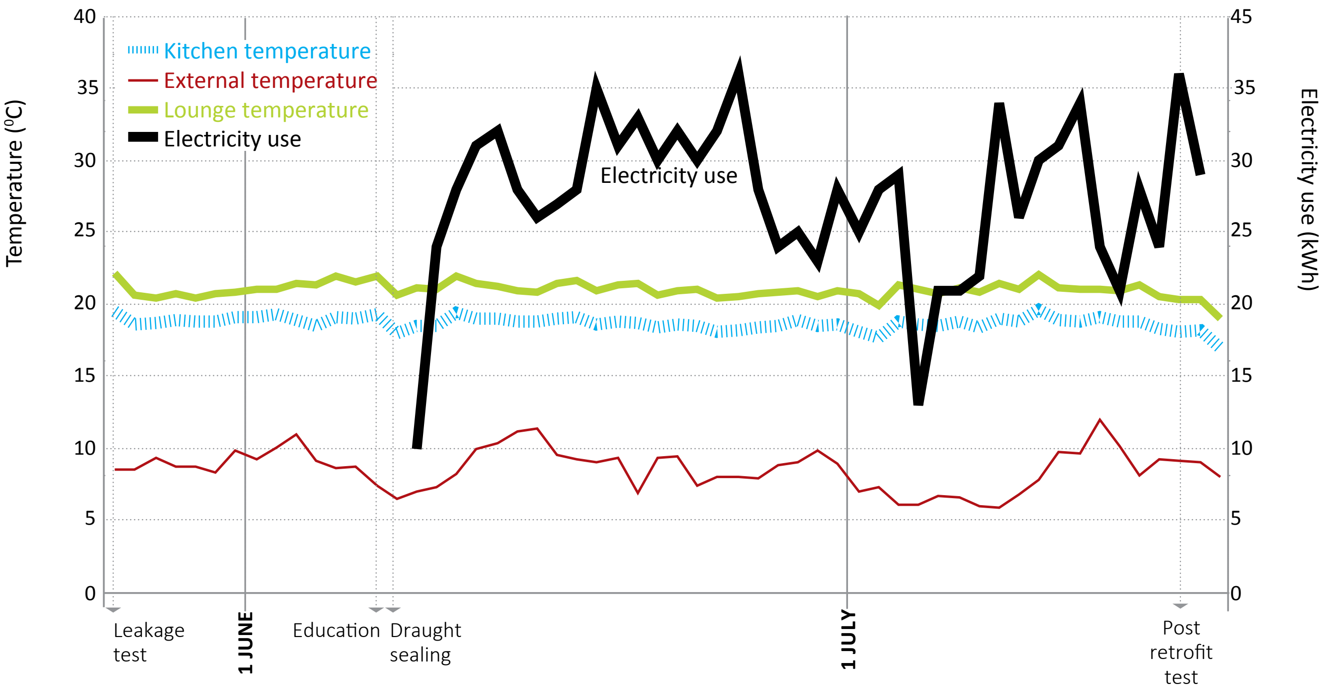
	Pre-retrofit	Post-retrofit	Difference
Air changes per hour at 50 Pa	20.24	17.14	–15%
Effective leakage area at 4 Pa (equivalent open square window)	48 cm x 48 cm	46 cm x 46 cm	14 cm x 14 cm

Note: A pressure difference of 4 Pa between inside and outside is close to the normal pressure differential experienced in the home on cold, windy Canberra days.

Temperature and electricity use

The house uses central gas heating to maintain very comfortable temperatures relative to external temperatures. The poor health of the residents and the fact that they are home all day increases their energy requirements.

Electricity use and temperature data in case study 11



Energy bills

Electricity usage

	Energy use 2011 (kWh/day)	Energy use 2012 (kWh/day)	Difference
Autumn*	29	22	–25%
Winter*	28	24	–16%

Gas usage

	Energy use 2011 (kWh/day)	Energy use 2012 (kWh/day)	Difference
Autumn*	121	136	+12%
Winter*	142	133	–6%

Electricity + gas usage

	Energy use 2011 (kWh/day)	Energy use 2012 (kWh/day)	Difference
Autumn*	150	158	+5%
Winter*	170	157	–8%

Total energy, greenhouse gas and cost savings

	Energy saving (kWh)	CO_2-e saving (kg)[a]	Cost saving ($)[b]
Autumn*	–704	448.19	–12.08
Winter*	1237	595.07	130.81

a Scope2 + Scope3 emission factor for electricity is 1.06 kg CO_2-e/kWh. Emission factor for natural gas is 51.33 kg CO_2-e/GJ (source: Australian Government Department of Climate Change and Energy Efficiency, *National Greenhouse Gas Accounts factors*, July 2012).

b Cost savings for gas usage calculated using 2.113 cents per megajoule

*Autumn = billing periods beginning in March–May; winter = billing periods beginning in June–August