TOWNSVILLE QUEENSLAND SOLAR CITY

CitySolar Community Capacity Building Program

Townsville Residential Energy Demand Program (TRED Program)

Monitoring and Evaluation 'Cool Roofs' Community Pilot Program

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Findings Report

Version:
Final

Australian Government
Solar Cities

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Introduction

This report provides a summary of the findings of the 'Cool Roof' community pilot program undertaken during the period between 2011-2013 in Townsville, Australia. The pilot program worked with industry and the community to investigate if cool roofs would reduce house temperatures and the associated electricity demand. The findings of the pilot showed that a 'cool roof' was effective in reducing internal temperatures in all of the participating dwellings, as shown in Table 1. These results are in line with other national and international studies on cool roofs.

Table 1: Summary of summer temperature reductions across participating pilot program houses

Comparison of two similar days (average of houses; n=11)	Temperature change (^{o}C)
Maximum roof cavity temperature reduction; ˚C	-9.5 to -17
Average daytime roof cavity temperature reduction; ˚C (9am-9pm)	-6.4 to -15.3
Maximum internal temperature reduction; ˚C	-1.2 to -2.5
Average daytime internal temperature reduction; ˚C, (9am-9pm)	-0.6 to -1.5

The monitoring and evaluation for the pilot has focused on four sets of results, namely: actual temperature data before and after the roof painting (via a temperature recorded located in the home as part of the research, provided by TCC), quarterly electricity consumption data (provided by Ergon Energy with residents' written approval), a check list of roofing conditions that may affect the study (undertaken by the painter), and a post program participant survey undertaken by the research team through telephone conversations with Pilot participants. As part of the Pilot residents were offered between a 15 and 25% discount on the cost of the roof painting, depending on participating painters.

> *"We had the roof painted in November when the weather was starting to warm up. We could not believe how much cooler the house was the day after it was painted. The house is normally all locked up during the day and use to be quite hot when we got home in the afternoon. After the painting the house was cool to walk into at the end of the day. Our carport and patio are just the bare metal colorbond roof. You can put your hand on the underside of the colorbond in the middle of a hot day and the metal is not hot at all, where before it would have burnt you. We found that when home we did not put the fans on until later in the day and there was reduced use of air-conditioning during the day, as it was only needed on the really hot, humid days. I have certainly passed the word onto friends and know of a couple that have had their roofs painted."*

Pilot Program Participant with a single story 1980s era low-set bessa-block house in Condon

The analysis and evaluation of the pilot included both quantitative and qualitative aspects. As such, feedback from surveys and interviews with participants (such as that above) have been used in conjunction with the measurements of temperature and energy demand in order to provide an insight into the performance of cool roofs in Townsville.

Townsville Solar City

In 2006, Townsville was announced as Queensland's only 'Solar City'. The Australian Government's Solar Cities program is a partnership between all levels of government, industry, business and local communities to trial sustainable energy solutions. In seven key locations, Solar Cities partnerships are helping to save energy, increase up-take of Australia's leading-edge solar technologies, reward energy efficiency and solar power generation, and showcase the economic and environmental benefits of wiser energy choices. Solar Cities initiatives are changing the way we view and use energy. Information collected will show how different approaches influence energy use and will inform future energy policies. Solar Cities is creating a new energy future for Australia.

Commencing in mid-2007 Townsville's Solar City initiative consists of several synergistic projects including: Magnetic Island (Solar Suburb), two Greenfield sites, and a sustainable CBD building, in addition to city-wide education and community capacity building. As part of the '*Townsville Queensland Solar City*' project, the Townsville City Council, working closely with the solar city consortium partners including Ergon Energy, initiated a program focused on community capacity building, named the '*CitySolar Community Capacity Building Program*'. This program includes a project to investigate methods of fostering sustainable behaviour related to residential energy demand. This project, the '*Townsville Residential Energy Demand Program*', seeks to identify and investigate a number of options to encourage residents (specifically home owners) to reduce household energy demand that are suitable for application in Townsville.

The program is intended to provide valuable information and guidance to the Council regarding effective methods to encourage and assist residents to reduce energy demand in the home. Reducing energy demand in the home has two main benefits to the home owner, firstly the reduction of direct energy costs, and secondly a reduction in the consumption of fossil based electricity and hence a reduced contribution to the generation of greenhouse gas emissions. Furthermore, such reductions can also provide a range of in-direct economic benefits such as reducing costs to energy utilities to provide energy during peak times, reducing costs related to maintenance of the electricity grid, creating new industries for low energy consuming products, and reducing future liability against costs related to carbon pollution abatement. Hence with strong benefits to both residents and businesses in Townsville the reduction of residential energy demand is an important consideration for the future of Townsville.

The Cool Roof Pilot Program

Aims of the Cool Roof Pilot Program

The 'Cool Roof Pilot Program' was developed following extensive research conducted as part of the Solar City program (TRED project), which was based on world leading behaviour change methodologies, namely Community Based Social Marketing (CBSM), developed by Dr. Doug McKenzie-Mohr; Thematic Communication, developed by Prof. Sam Ham; and Collective Social Learning (CSL), developed by Prof. Valerie Brown. It was determined in the early phases of the project that a hybrid of these models had the potential to foster sustainable behaviour in the home in Townsville, and that the project could contribute to sustainable behaviour change by piloting and demonstrating this hybrid. Hence, the processes and outcomes have been well documented throughout the project to enable others to take advantage of the learning's developed.

There were several key aims of the 'Cool Roof' Pilot Program:

- To develop, trial and evaluate the role of communication material in raising awareness, educating and encouraging Townsville residents to choose cool roofs;
- To initiate communications and collaboration with cool roof related industry stakeholders, including encouraging cool roof pilot installation projects;
- To collect data from several pilot cool roof installations to inform further development of the program's communication materials; and
- To identify effective tools and strategies for encouraging the installation of cool roofs in Townsville, based on a review of the pilot installations and experiences of those involved.

Expanding some of these items the research team considered:

- Evaluation of the effectiveness of cool roofs in reducing internal temperatures in residential buildings in Townsville (This has been made possible by participating residents agreeing to allow the painters to install temporary temperature sensors to collect temperature data in their home before and after the application of the cool roof coating).
- Investigating the impact of cool roofs on energy demand in residential buildings in Townsville (This has been made possible by participants agreeing to allow the research team to confidentially access energy consumption data from the electricity utility for up to 5 years prior and 2 years after the roof painting).
- Inform thematic communications to be used by the program as part of a community wide program to provoke Townsville residents to think about cool roofs and re-evaluate beliefs that were identified as limiting the likelihood of having a cool roof;

Monitoring and Evaluation Methods

Monitoring temperature reductions from a 'Cool Roof'

Overview

The performance of '*cool roofs*' in reducing heat entering buildings has been demonstrated in various cases around the world, and locally through a trial on a single household in Townsville several years ago by JCU. However in order to provide confidence in promoting the benefits of cool roofs in Townsville a community pilot program was undertaken to monitor the performance before and after the application of a 'cool roof'. A secondary aim was to evaluate methods of data collection to determine whether these would be effective in the community-wide program (if necessary). This pilot was also called for by community members providing feedback on thematic communications as part of the 2011 Eco-Fiesta as they wanted to see Townsville verified results. Figure 1 below shows the results of a household that took part in the pilot program. The figure shows that after the application of the cool roof the maximum roof cavity temperature decreased significantly (9.4°C cooler). In the internal living area, prior to the cool roof the average temperature rise above the ambient temperature was 2.8°C, yet after the cool roof the average temperature rise above ambient conditions was only 1.26°C, resulting in an average cooling benefit of 1.54°C. Even seemingly small temperature reductions of only one or two degrees have been shown to have a noticeable impact on a persons' thermal comfort and can result in a reduced desire for air-conditioning.[1] During an interview with the resident of the abovementioned house the resident estimated the internal house temperature was about 5 degrees cooler on a summer's day; larger than the actual difference. The higher perceived thermal comfort impact might be related to the moderate to high humidity in Townsville, which tends to make it feel hotter. Temperature measurements showed that before the cool roof this house would get up to 3.6 degrees hotter than the ambient temperature, but after the cool roof the average temperature rise was only 1.26 degrees. Other houses in the pilot program experienced similar or even larger results.

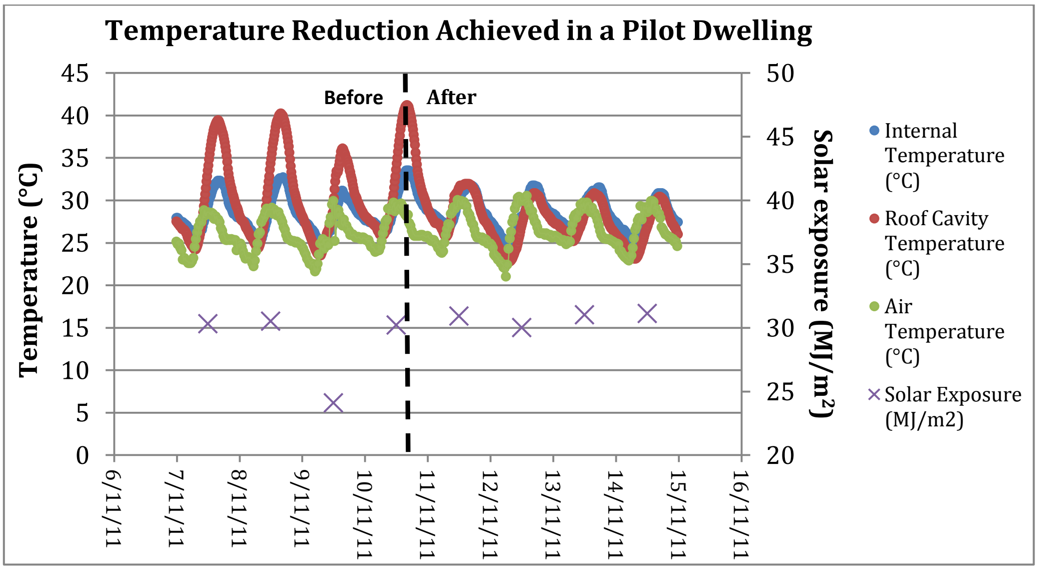


Figure 1: Sample temperature readings before and after application of cool roof coating in pilot

[1] Suerhcke, H., Peterson, E.L. and Selby, N. (2008) Effect of roof solar reflectance on the building heat gain in a hot climate, *Energy and Buildings,* Vol 40, Iss 12, P2224-2235

Benefits of Cool Roofs

Reducing the temperature of the roof cavity has multiple additional benefits including:

- Typically ducted air-conditioning is installed in roof cavities and the ducting has poor thermal performance meaning that a hotter roof cavity will heat the air-conditioned air in summer adding load to the air-conditioner.
- Reducing the roof cavity temperature will make the roof space a much more comfortable temperature (typically in the order of 40-45°C during summer) for tradespersons or for residents wishing to store items in the roof,
- Cool roofs are subject to less diurnal thermal expansion and contraction, due to their lower surface temperatures, and may consequently have a longer service life.[2]
- Reducing the temperature of the roof space will also reduce the drying of timber structural members in the roof that may result in reduced strength. Reduced strength of timber in the roof may make the roof more susceptible to cyclone damage.
- Typically the roof cavity contains the electrical wiring for the home and a hotter roof cavity will cause the wiring to be hotter and this will increase the resistance of the metal and increase the energy demand of the home. For a temperature rise of 1°C the electrical resistance of copper will increase around 0.4%, meaning that for an increased roof cavity temperature of 25°C the electrical resistance will increase by as much as 10%.
- Photovoltaic panels operate more efficiently at lower temperatures. A dark roof can reach temperatures approximately 50°C above ambient temperatures. Photovoltaic panels mounted on a roof will therefore become considerably hotter when mounted on a dark roof – decreasing their efficiency. A Cool Roof can help reduce roof temperatures and this may help improve photovoltaic panel efficiencies.

Capturing house and roof characteristics

The impact on heat transfer through the roof by switching to a 'cool roof' will differ depending on the characteristics of the roof and the house. Roof characteristic data was collected by the painter contracted to apply the cool roof coating to provide context for the analysis of the performance of the cool roof. Additional data was collected from the householder during the follow-up interview. To collect the data, painters were given a checklist, which can be found in Appendix A.

Data collected included:

- Location of the house (address), and contact information for the household;
- Roof characteristics, inducing material, pitch, orientation, shading, and insulation;
- Original roof coating type and colour, and
- Cool roof product, colour, solar reflectance value, and thermal emittance values.

[2] Akbari, H., Berhe, A., Levinson, R., Graveline, S., Foley, K., Delgado, A. and Paroli, R. (2006) 'Aging and Weathering of Cool Roofing Membranes', Department of Energy's Information Bridge, Oak Ridge, USA [www.osti.gov/bridge/servlets/purl/860745-BAdlvk/860745.PDF, accessed 04/01/2010.]

Table 2: Example building and roof profile from pilot program

Dwelling A	
House and roof characteristics	
Type	House
Suburb	Mundingburra
Roof materials	Tile
Original roof colour	Dark brown
Roof pitch	Steep
Insulation	None
Extent of shade	Negligible
Levels	One
Air-conditioned	Yes

Household Temperature Readings

Temperature data was collected for the pilot program period from each of the households, before and after application of the cool roof coating. The program was designed with each participating households having two temperature sensors installed; one in the roof cavity, and one in an internal non air-conditioned space. Where an internal non air-conditioned space was not available, both sensors were installed in the roof cavity with the second close to the ceiling. Where a dwelling had no roof cavity, both sensors were installed in an internal non air-conditioned area. The temperature sensors logged temperature data in 15-minute intervals. Temperature sensors were installed as far in advance of the coating application as possible and left in place for a minimum of two weeks following the application, after which they were removed and the data downloaded.

Climatic and Weather Conditions

To be able to compare the temperature readings from each of the houses, before and after installation of the cool roof, climatic information was obtained from the Bureau of Meteorology (BOM). Climate data for the Townsville region was accessed from the Townsville Aero weather station (station number 032040, Lat: -19.25 Lon: 146.77). A data set containing 30-minute climate data for the period 01/07/2011 to 30/06/2012 was used for comparison. Measured parameters included:

- Date/Time (Eastern Standard Time),
- Temperature (°C),
- Relative Humidity (%),
- Wind (m/s),
- Precipitation (mm), and
- Total daily solar radiation (MJ/m^2).

Considering household electricity consumption reductions from 'Cool Roof'

The pilot program aimed to investigate the impact a 'cool roof' coating could have on household electricity consumption. A cool roof will predominately reduce energy consumption in the home by the amount that the household reduces their use of air conditioners, or other mechanical cooling devices. It is noted that having lower temperatures inside the home will also reduce the cooling load, so that even if the household runs the air conditioner for the same amount of time, the air conditioner will have to work less to maintain the desired temperature. However, it is assumed that the greatest benefit would occur if the household also changed their air conditioner usage patterns due to their house being cooler as a result of the cool roof.

The pilot program sought to evaluate a cost-effective method for measuring changes in household electricity consumption in collaboration with the energy utility to see whether this would be a viable component of a community-wide program. Household electricity consumption data for each location was accessed through the local utility, Ergon Energy, to determine whether there was a decrease in household electricity consumption after the cool roof was installed. Participants provided permission for the research team to access this information for each participating address, which provided a history of electricity use for up to 2-3 years prior to the cool roof application, up to and including the most recent data available. Electricity data was only available in 3-monthly (quarterly) intervals. On average the participants in the cool roof pilot program used 32.3 per cent less electricity in the summer period following the cool roof application. It should be noted that energy use would likely have been impacted by a variety of factors, therefore this reduction cannot be attributed solely to the cool roof, hence this is a secondary finding.

Community perceptions of cool roof performance (participant survey)

The temperature inside the home is affected by several factors, including: downward heat flow through the roof; Heat flow through the walls, windows, doors and other building surfaces and cavities; and use of air conditioners and other cooling mechanisms in the home. Hence, it is not possible to accurately predict what cooling effect a cool roof will have on an individual home. It is only possible to demonstrate that cool roofs reduce the heat transfer process into a dwelling, and will thus reduce internal temperatures.

In terms of measuring human comfort, it can be more useful to consider the apparent temperature, rather than the actual temperature. Human comfort is influenced by multiple climatic factors, including airflow (wind), air temperature, air humidity, and radiation from the sun and nearby hot surfaces. Personal comfort is also generally affected by the type of clothing a person is wearing, how well adapted they are to the climate, and how physically active they are. The impact of these factors on personal comfort is evident when considering the human body's mechanisms for maintaining a desirable internal temperature, which is primarily by releasing heat through evaporation of sweat from the skin. How easily the body can do this depends on the air temperature, humidity, and wind speed, as well as whether clothing is impeding this action.

In addition, air temperatures, radiation and physical activity will increase the body's temperature. Wind and radiation tend to vary significantly by location, even over short distances. Hence, these are often discounted, and humidity and air temperature are often used to compare the apparent temperature between locations. Further, air temperature is often used as a proxy measurement to determine the effect of the environment on personal comfort, and in the tropics this is a reasonably appropriate assumption, as humidity levels tend to be relatively constant. For the purposes of this report, this has been the case. However, it is important to note that the relationship between air temperature, and apparent temperature (for a constant humidity) is not linear. Indeed, reducing internal temperatures inside the home can reduce apparent temperatures by a larger amount. Hence, even for relatively small temperature decreases, personal comfort in the home is likely to be impacted.

To complement the investigation into temperature reductions inside the home from the cool roof, the research team conducted a series of interviews with program participants to see what impact this had on their comfort and experience in the home. As noted above, it has been found that there is a non-linear relationship between actual air temperature and apparent temperature, such that people often feel much more comfortable in a room that has a marginally lower air temperature. It is hence important to not only have an idea of how many degrees cooler a house could be with a cool roof, but also what a difference that would make to the comfort of people in the house.

To provide insight into these areas, a post program participant survey was conducted with pilot program participants. The survey is designed to provide insights into several key questions, including:

- Has the household noticed a difference in comfort levels in their home from having their roof painted with cool roof coating? (With one participant saying '*It has exceeded my expectations. Estimate it has dropped the temperature of the house by 5°C. Difference is phenomenal*'.)
- Does the household feel that they are using their air conditioner less since the cool roof? (With one participating saying to the interviewer that that *'they don't use it as much, for two reasons, the first being that they don't need it as much, and since they've noticed how much of an impact it makes on their electricity bill, they have further reduced the use*').
- Would they recommend a cool roof to others, and would they do this again if they moved to another house? (With one participant saying '*Yes, Already told several work colleagues – main interest is from the lower power bill*'.)

The survey was designed to be able to be conducted by phone or in person, and a copy can be found in Appendix B.

Assumptions in evaluating temperature reductions

In evaluating the data from the community pilot, from before and after the roof was painted with cool roof coating, several key assumptions have been made. This study considers only the heat flow through the roof, and how the addition of a cool roof coating impacts on this heat flow into the home through the roof. It is acknowledged that the heat flow through other building surfaces and cavities will also impact on the temperature readings obtained from participating households, and the following assumptions have been made:

- The heat flow through other building surfaces and cavities is constant for a given ambient air temperature;
- Air conditioner usage in the house hasn't affected temperature readings, due to sensors being located either in roof cavities or in a room inside the house which isn't air conditioned;
- The temperature readings given by the internal sensors are a good proxy measurement to determine how the cool roof will impact on occupant experience in the home; and
- There are other factors which will influence the transfer of heat through the roof into the home, including whether the ceiling cavity is ventilated, and the amount of insulation.

General Assumptions and Considerations of Pilot Program

In considering the analysis of the data, the following points are important to note:

- The turnaround time between providing a quote and the application of the cool roof coating was often only one or two days. In such cases the cool roof painters installed the temperature sensors as soon as was practice and in some cases temperature data was recorded for one or two days prior to the roof being painted. Further, in some cases, these were overcast days with lower solar insolation and may not have given a suitable baseline prior to the application of the cool roof.

- One of the painters asked some of his customers that had contracted him to apply a cool roof coating on their roof whether they would be interested in participating in the program. Hence, contact details are available for these households, and the research team can conduct a participant survey with them. However, as the painters invited the households to participate after having applied the cool roof, it is not possible to obtain temperature from these households, this data has been noted in the assessment. To provide an adequate comparison, a 'like-day' comparison has been used; comparing before and after data for dates with similar climatic conditions (temperature, solar radiation, precipitation). These 'like-days' were taken as close together as possible.

Findings of Cool Roof Pilot Program in Townsville

Dwelling A (a single story brick house in Mundingburra)

Background Information

Dwelling A is a single story brick house in Mundingburra. The original roof was a dark brown tiled roof, in reasonably good condition, with no shading. The new cool roof coating was applied on 13/10/2011 and 14/10/2011. A summary of the dwelling characteristics is presented below.

Table 3: Building and roof profile for Dwelling A

Dwelling A - House and roof characteristics	
Type	House (Brick)
Suburb	Mundingburra
Roof materials	Tile
Original roof colour	Dark brown
Roof pitch	Steep
Insulation	None
Extent of shade	Negligible
Levels	One
Air-conditioned	Yes

Temperature Performance Outcome

Figure 2 below shows a comparison of temperature data before and after the application of the cool roof coating. There was no appropriate internal non air-conditioned location available for placement of an internal temperature sensor in this dwelling so both sensors were installed in the roof cavity; one just above the ceiling, and one near the roof. Temperature data logging began on 12/10/11 and the cool roof coating was applied on 13/10/2011 and 14/10/2011.

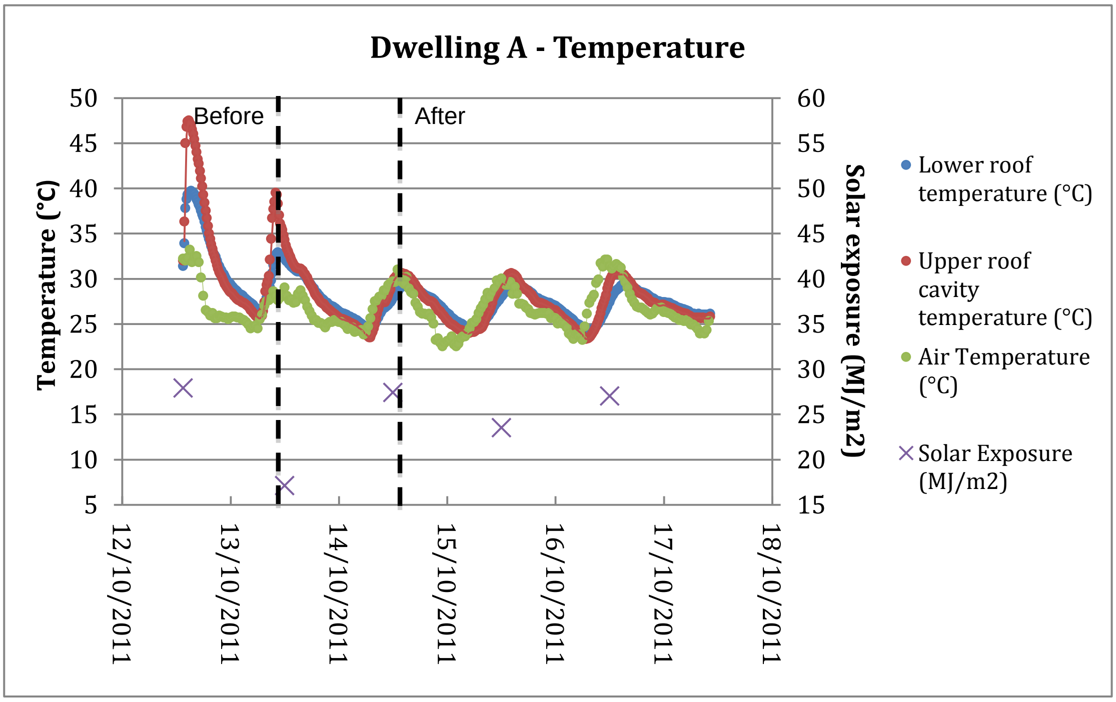


Figure 2: Dwelling A - Temperature readings before and after application of cool roof coating

Data for the 'Before' period consists of only one day due to the short turn-around time between the resident deciding to get a cool roof (12/10/2011) and the roof being painted (13/10/2011). Comparing the data for the 'Before' period to a similar day with comparable climatic conditions (ambient temperature, solar insolation, and precipitation) after application of the cool roof coating, maximum roof cavity temperatures have been reduced by between 10.3°C (sensor near the ceiling) to 17.0°C (sensor near the roof). Average daytime roof cavity temperatures were reduced by 9.4 - 15.3°C, for the sensor located near the roof and the sensor located just above the ceiling respectively (see Table 4 below). Note that the date used for comparison after application of cool roof (16/10/11) had a maximum temperature 1.1°C cooler than the baseline date (12/10/11), and this may have contributed to the temperature reductions recorded.

Table 4: Dwelling A - summary of cool roof performance, comparing two similar days

Comparison of two similar days			
	Before	After	Difference
	12/10/2011	16/10/2011	
Maximum roof cavity temperature; ˚C	47.5	30.5	-17.0
Average roof cavity temperature; ˚C, (12pm-9pm)*	39.9	24.7	-15.3
Maximum roof near ceiling temperature; ˚C	39.7	29.4	-10.3
Average roof near ceiling temperature; ˚C, (12pm-9pm)*	34.7	25.5	-9.4
Daily solar exposure; MJ/m^2	27.9	27.0	-0.9
Maximum ambient temperature; ˚C	33.2	32.1	-1.1
Precipitation (mm)	0.0	0.0	0.0
Average wind speed (km/h)	12.7	12.4	-0.4

*Note: data from 6am-11:59am is not available for this trial on 12/10/2011

The cool roof has significantly reduced roof cavity temperatures. Comparing temperature data in the dwelling with ambient temperature data before and after application of the cool roof coating it can be seen that upper roof cavity temperatures were previously on average 5.2 - 12.4˚C hotter than ambient conditions (see Figure 3 and Figure 4). Roof cavity temperatures after the cool roof was installed were reduced significantly, averaging 0.1 – 0.7˚C cooler than ambient temperatures. This has resulted in average maximum temperature reductions of 5.9 – 12.5˚C relative to ambient temperatures.

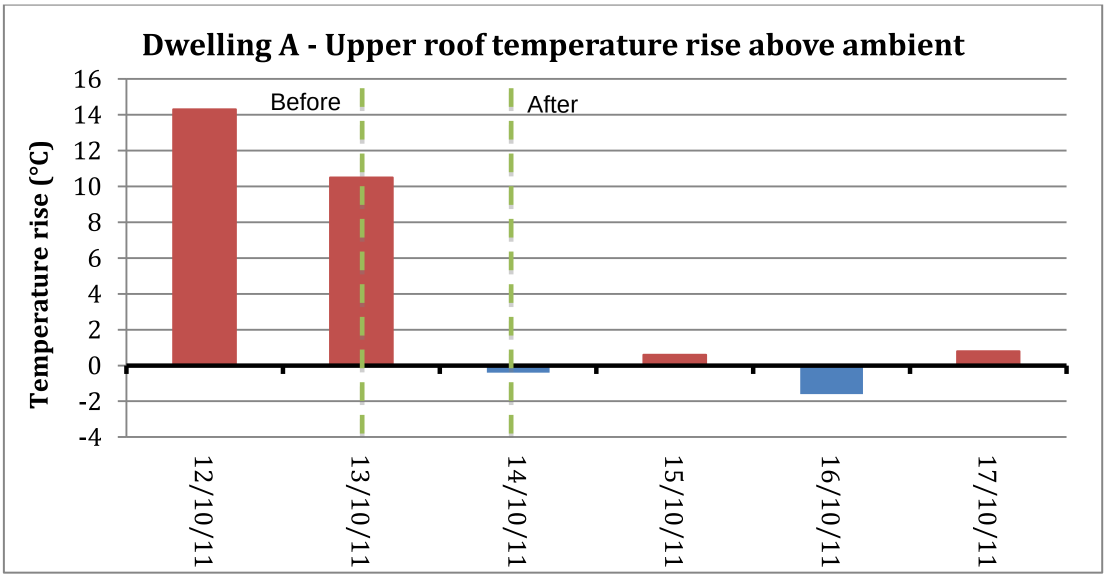


Figure 3: Dwelling A - Upper roof temperature rise above ambient temperatures

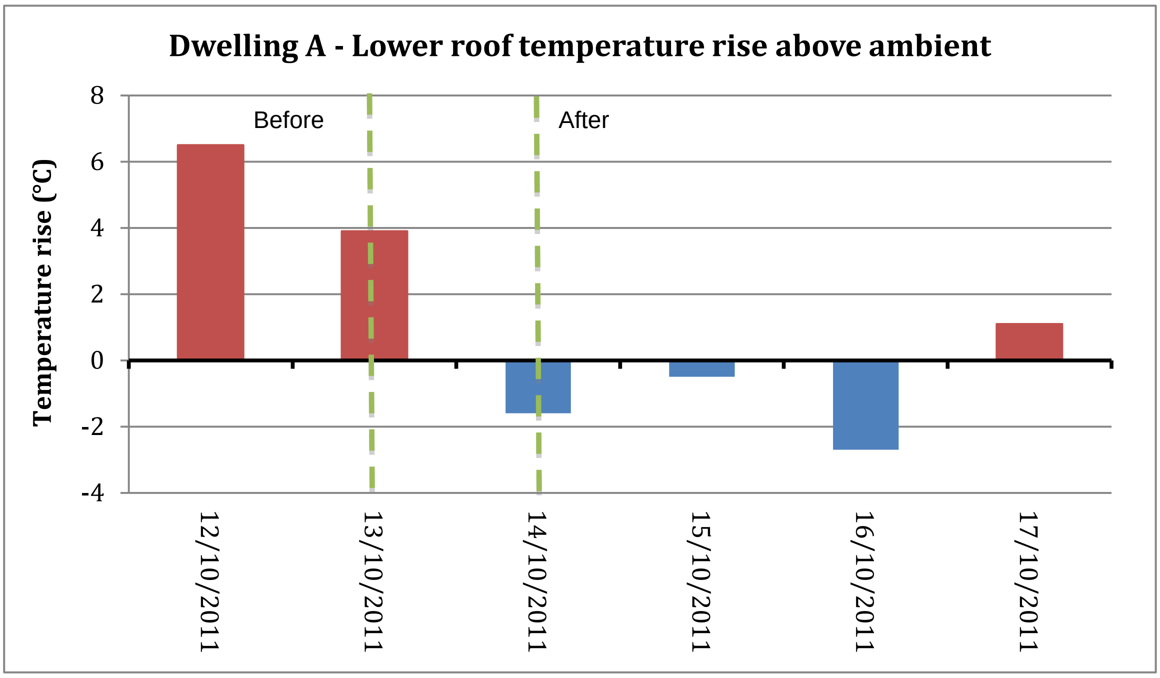


Figure 4: Dwelling A - Lower roof temperature rise above ambient conditions

Electricity Consumption

The cool roof coating was applied during Q4 2011. In order to compare electricity consumption before and after the application of the cool roof product, Q1 and Q2 were chosen for comparison as these two quarters are most representative of the summer cooling-demand period for this dwelling. For this dwelling, Q1 covers the period late-October to early-February; Q2 covers the period early-February to early-May. For the purposes of this analysis, the 2010-11 summer period has been used as the baseline period for comparison as this is the only data available.

An average kWh/day figure was determined by averaging the total energy consumption over the total number of days in these two quarters. At the time of writing, Q2 2013 data was not available and therefore only Q1 2013 data was used for this summer period.

Average daily electricity demand prior to application of the cool roof product was 57.2 kWh/day in the 2010/2011 summer period. Following the application of the cool roof product, average daily electricity consumption has fallen to 45.4 kWh/day in the 2011/2012 summer period, and 42.9 kWh/day in Q1 2013 (see Figure 5). Comparing electricity consumption data after application of the cool roof product with the 2011-12 baseline, this dwelling has achieved a reduction in average daily energy consumption of approximately 21 per cent.

Comparing the 2012/13 summer period against the 2011/12 summer period, it appears that following the application of the cool roof product, energy reductions have been maintained and further reduced. Analysing Q1 2012 against Q1 2013, it can be seen that average daily electricity use has fallen from 49.0 kWh/day in 2012 down to 42.9 kWh/day in 2013, equivalent to a further reduction on approximately 12 per cent.

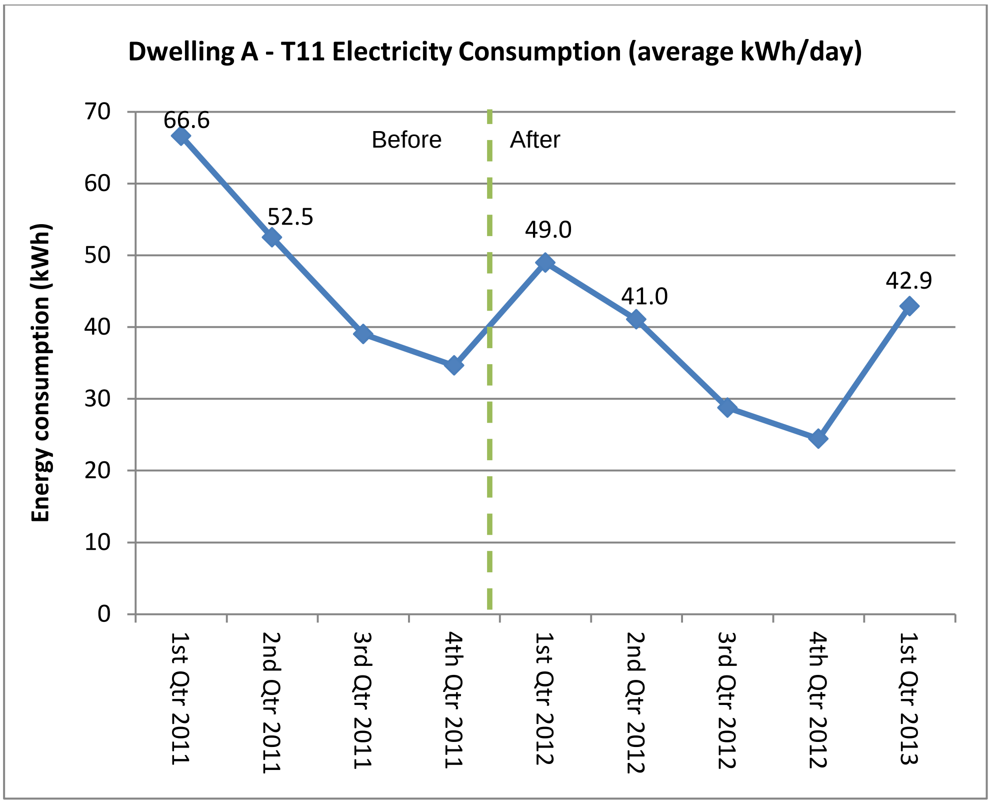


Figure 5: Dwelling A – Average daily T11 electricity consumption

Occupant Experience of the Cool Roof

An interview was conducted with the resident to obtain feedback about the pilot program and about their experience with their new cool roof. The resident reported that the cool roof was performing as expected and has helped reduce the temperature inside the house. The occupant self-initiated roof painting after witnessing media coverage and advertising of the benefits of cool roofs. At the time they were completely unaware of the pilot program, and later reported that they were somewhat hesitant to proceed due to the limited choice of colours (white being the only colour available in Australia at present). The tiled roof was originally dark brown which matched the exterior red brick walls, and the occupant was concerned that a white roof would cause the house to stand out in comparison to the surroundings. This issue was eventually outweighed by the functionality of the new roofing, and the occupant came to the conclusion that the roof's effectiveness was the priority. Their decision to have a cool roof installed was motivated by the desire to have a more comfortable living space and hopefully to reduce their energy bills as well.

The occupants are very pleased with their choice to have the roof painted, stating that "it certainly has made a difference to the temperature inside the house". The change is particularly noticeable when they return home after the house has been closed up, and it now "feels very different in comparison to how hot and sweaty it used to be". Not only has the roof made the house more comfortable but they also believe it has helped improved the efficiency of some appliances. The resident noted that previously they have six air conditioners throughout the house, which they previously had to set at around 22°C in order to reach a reasonable temperature. Following the application of the cool roof product they report that they now only have to set the air-conditioner at 25°C to maintain comfort; providing the same amount of cooling benefit but with reduced energy use. Despite the reduced need for air-conditioning the primary participant reflected that very often other family members operate the air conditioning out of habit rather than out of necessity even if it requires sleeping with extra bedding to stay warm. They have encouraged their family to adopt new behaviours, thus far with limited effectiveness. The occupant feels that there has only been a marginal decrease in their energy bills, however the data indicates that there has actually been a significant reduction in their energy use since the roof was painted. It is also possible that the cooling effect may have been enhanced with the installation of their new solar system, which has added partial shading to the roof.

Although the occupant feels that the roof treatment has made the roof itself look neat and new, they still felt that the high contrast between the dark walls and white roof is 'a bit distracting'. They are considering having the external walls rendered in a lighter colour, which would make the roof appear less obvious and may also assist in reducing internal temperatures. The resident could not recall if any friends or neighbours had commented on the visual appearance of the roof, but several have commented about the reduction in temperature. They would recommend cool roofs to others, advocating that not only has it improved comfort but it has also extended the life of the current surface, and is significantly cheaper than replacing the entire roof. They would consider getting a cool roof if they moved to a new address that didn't have one, particularly if the roof required maintenance.

Participant Testimonial

"The main thing is that it has certainly decreased the temperature inside the house. The coating has made the roof look new and it has likely extended the life of the roof as well".

Dwelling B (two level 1950s Queenslander in North Ward)

Background Information

Dwelling B is a two level 1950s Queenslander style house located in North Ward. The original roof was unpainted corrugated iron with negligible shading. The house has a flat-pitched roof with no roof cavity and no insulation. Temperature data logging began on 22/11/2011 and the cool roof coating was applied on 29/11/2011 and 30/11/2011. A summary of the dwelling characteristics is presented in the Table 5 below.

Table 5: Building and roof profile for Dwelling B

Dwelling B - House and roof characteristics	
Type	House (Queenslander)
Suburb	North Ward
Roof materials	Corrugated iron
Original roof colour	Unpainted corrugated iron
Roof pitch	Close to flat (no attic)
Insulation	No insulation
Extent of shade	Morning – partially shaded, Midday - no shade, Afternoon – partially shaded.
Levels	Two
Air-conditioned	Yes

Temperature Performance Outcome

Figure 6 shows a comparison of temperature data before and after the application of the cool roof coating. Dwelling B has a flat-pitched roof with no roof cavity, and as such, both sensors were installed in separate internal non air-conditioned spaces. One was in a bathroom alcove, and the other in a separate, internal non air-conditioned room.

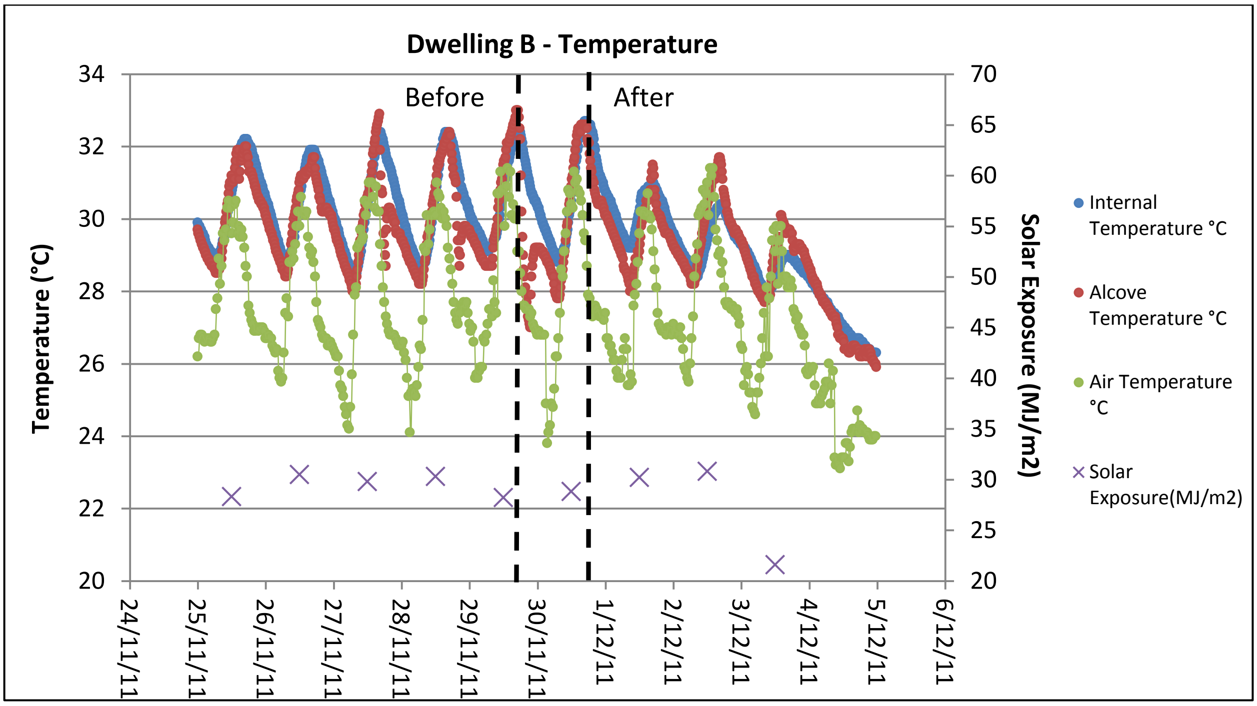


Figure 6: Dwelling B – Temperature readings before and after application of cool roof coating

Comparing two similar days with similar ambient temperature, solar insolation, wind speed and precipitation, the cool roof coating has reduced maximum internal temperatures by 1.2 - 2.0°C and average daytime internal temperatures by 0.2 - 1.3°C (see Table 6 below). Note that the date used for comparison after application of cool roof (02/12/2011) had a maximum temperature 0.4°C warmer than the baseline date (27/11/11), and this may have reduced the measured cooling effect. However, despite the 'after' date being 0.4°C warmer, internal temperatures were still significantly cooler than previously.

Table 6: Dwelling B summary of cool roof performance, comparing two similar days

Comparison of two similar days			
	Before	After	Difference
	27/11/2011	02/12/2011	
Maximum internal temperature; ˚C	32.4	30.4	-2.0
Average internal temperature; ˚C, (9am-9pm)	31.1	29.8	-1.3
Maximum alcove temperature; ˚C	32.9	31.7	-1.2
Average alcove temperature; ˚C (9am-9pm)	30.7	30.5	-0.2
Daily solar exposure; MJ/m2	29.8	30.8	1.0
Maximum ambient temperature; ˚C	31.0	31.4	0.4
Precipitation (mm)	0.0	0.0	0.0
Average wind speed (km/h)	40.6	21.1	-19.5

The cool roof has significantly reduced internal temperatures. Comparing temperature data in the dwelling with ambient temperature data before and after application of the cool roof coating it can be seen that maximum internal temperatures were previously on average 1.5˚C hotter than ambient conditions (see Figure 7). Maximum internal temperatures after the cool roof were reduced to an average 0.3˚C cooler than ambient temperatures. This has resulted in average maximum temperature reductions of 1.8˚C relative to ambient temperatures. The anomaly on 04/12/11 appears to be due to a large amount of rain in Townsville and low solar exposure values on that day.

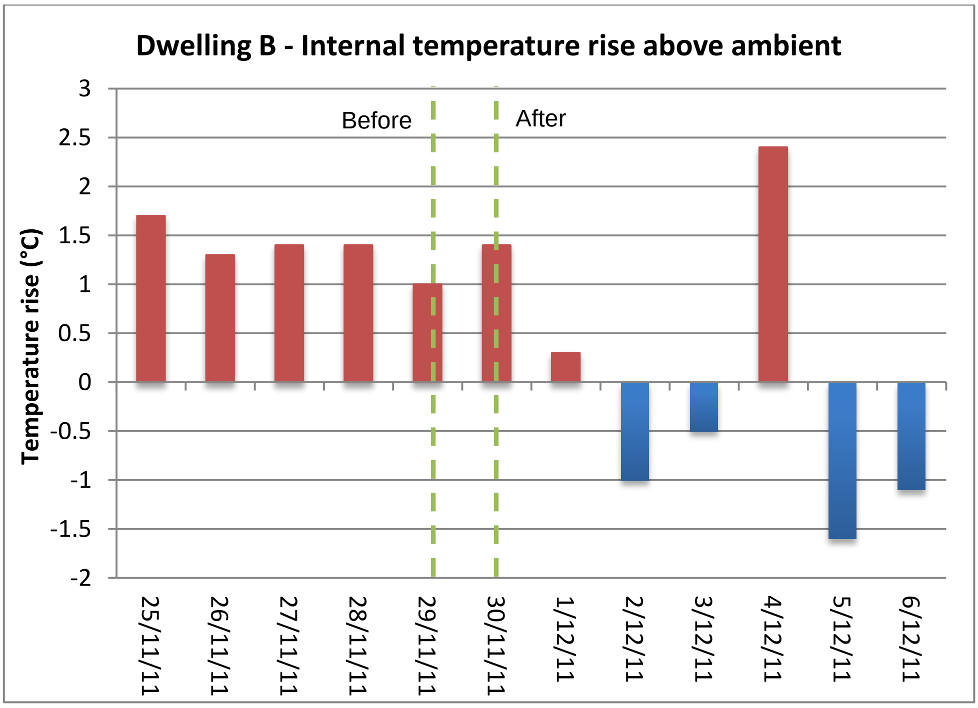


Figure 7: Dwelling B - Internal temperature rise above ambient conditions

Electricity Consumption

The cool roof coating was applied during Q1 2012. In order to compare electricity consumption before and after the application of the cool roof product, Q1 and Q2 were chosen for analysis as these two quarters are most representative of the summer cooling-demand period for this dwelling. Q1 covers the period mid-October to mid-January; Q2 covers the period mid-January to mid-April. An average kWh/day figure was determined by averaging the total energy consumption over the total number of days in these two quarters. At the time of writing, Q2 2013 data was not available and therefore only Q1 2013 data was used for this summer period.

Average daily electricity demand prior to application of the cool roof product was 23.2 kWh/day in 2009/2010 summer period, and 23.7 kWh/day in the 2010/2011 summer period. Following the application of the cool roof product, average daily electricity consumption has fallen to 10 kWh/day in Q1 2013 (see Figure 8). The 2011/2012 summer period data, which averaged 12.7 kWh/day has not been considered as the cool roof was applied during this period.

For the purposes of this analysis, the 2010-11 summer period has been chosen as the baseline period for comparison. Comparing electricity consumption data after application of the cool roof product with the 2010-11 baseline, this dwelling has achieved a reduction in average daily energy consumption of approximately 57 per cent.

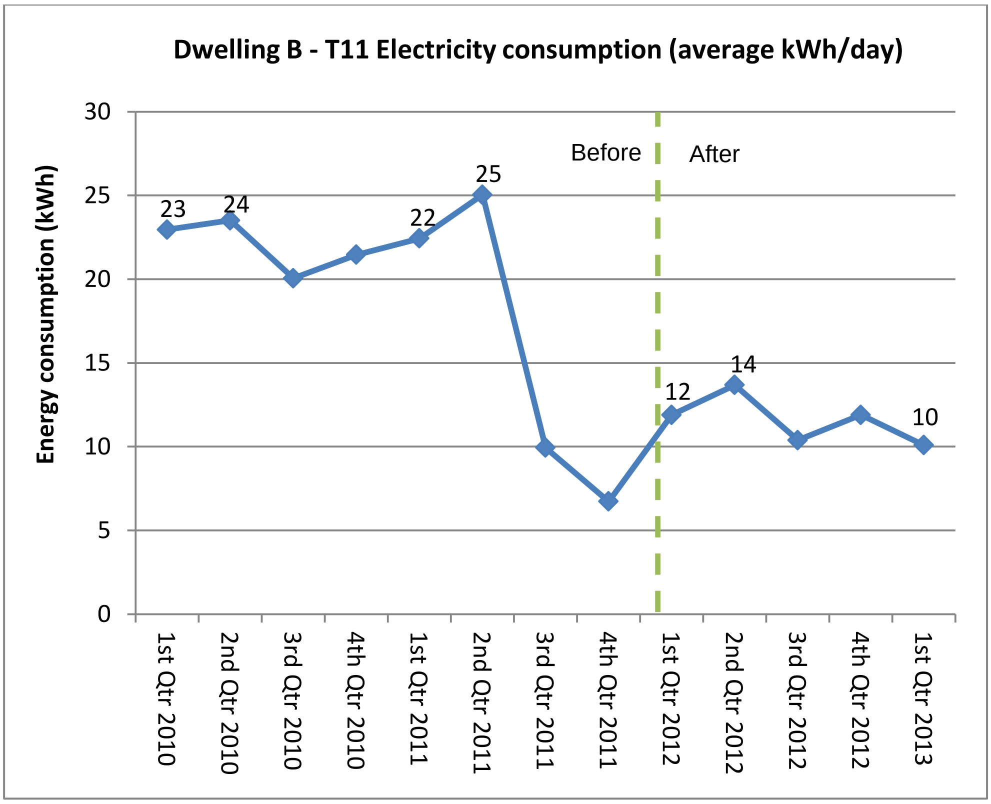


Figure 8: Dwelling B - Average daily T11 electricity consumption

Comparing the 2012/13 summer period against the 2011/12 summer period, it appears that since application of the cool roof product, energy use reductions have been maintained and reduced further. Note that the cool roof was applied approximately one-third of the way through Q1 2012. Analysing Q1 2012 against Q1 2013, it can be seen that average daily electricity use has fallen from 12 kWh/day in 2012 down to 10 kWh/day in 2013, equivalent to a further reduction on approximately 16 per cent.

Note: Since Q3 2011, the residents of this dwelling have been undertaking extensive energy efficiency upgrades, such as the installation of a more efficient pool pump and more efficient kitchen appliances. It should therefore be noted that a wide range of factors in addition to the cool roof have influenced energy consumption in this dwelling.

Occupant Experience of the Cool Roof

An interview was conducted with the resident to obtain feedback about the pilot program and about their experience with their new cool roof. The resident is very pleased with the new cool roof and stated that it had exceeded their expectations. The resident reported that it had effectively cooled the house, estimating that the internal temperature felt approximately 5°C cooler over summer.

The resident also stated that she felt like the cool roof had reduced her use of air conditioning. Previously the resident used a total of 5 air-conditioners throughout the house to maintain a comfortable temperature, and this had resulted in quarterly energy bills typically exceeding $700 during the summer period. The resident stated that since the cool roof the house has been much more comfortable and it has drastically reduced her reliance on air-conditioning, reducing her energy bill to approximately $285 over the most recent summer period (including other energy saving activities).

For this dwelling, installing a cool roof has been part of a series of actions taken by the residents to reduce their power bills. They had received a home audit under the previous State Government sponsored service, which had drawn attention to their use of stand-by power and recommended that they upgrade some of their appliances. Initially, the resident noticed a reduction in their bill simply by turning devices off at the wall. They had a new kitchen installed prior to the cool roof, and new efficient appliances made a significant impact on their next bill. Since the cool roof was completed they not only use their air conditioners less often, but they also felt that the both the air conditioner and the fridge were operating more efficiently given the cooler ambient temperature inside the house.

A substantial decrease in electricity use has resulted from having their pool upgraded. The previous pool pump was not only inefficient but also attached to a high-cost tariff. The pool was still under construction at the time of the most recent interview, and the resident expects that their bills may increase slightly when the new pump is online. Overall, their electricity bills have dropped from approximately $700 to $285 per quarter. They have shared this information with others, which has sparked interest in cool roofs from their friends and colleagues.

Another member of the household expressed concern about the cost of installing a cool-roof, stating that they felt it was an expensive undertaking. Despite this the primary participant (who initiated the installation process) remarked that they were very pleased with the result, which had exceeded their expectations. The primary participant commented that the difference it has made is significant, for both their own comfort and for the efficiency of their appliances.

Cost had been an initial barrier for the resident, who later stated that they had heard enough evidence and that the roof needed repainting and repair anyway. The main motivators for having the treatment done were the desire to reduce both the internal temperature and overall power use, especially the use of air-conditioning, and to improve the state of the roof.

The resident decided to get a cool roof after her daughter had a cool roof installed. The main reasons for deciding to get a cool roof were to reduce internal temperatures and reduce air-conditioning energy use. The resident has been actively telling friends and family about the benefits of cool roofs and stated that she believes they are essential from a sustainability perspective in Townsville. The participant stated that they would have one installed if they were to move to a new house.

Participant Testimonial

"I'm very happy with the new roof - it did what I wanted it to do. It's cooled the house down by about five degrees, which makes a difference for the appliances and for me. Combined with my new appliances my electricity bills have come down substantially. It was a good investment; when you see what it puts back in your pocket it is definitely worth the upfront cost".

Dwelling C (a single story masonry block house in Annandale)

Background Information

Dwelling C is a single story masonry block house located in Annandale. The original roof was a dark red terracotta tiled roof with negligible shading. The cool roof coating was applied on 25/02/2012. A summary of the dwelling characteristics is presented in Table 7.

Table 7: Building and roof profile for Dwelling C

Dwelling C - House and roof characteristics	
Type	House (Masonry block)
Suburb	Annandale
Roof materials	Terracotta tiled
Original roof colour	Unpainted, red tile
Roof pitch	Cathedral ceiling
Insulation	n/a
Extent of shade	Not shaded
Levels	One
Air-conditioned	Yes

Temperature Performance Outcome

Figure 9 below shows a comparison of temperature data before and after the application of the cool roof coating. Dwelling C was being renovated during the pilot program, and the sensor was accidently removed during the renovation process and was not returned. Hence, no internal data is currently available for Dwelling C. Temperature data logging began on 19/02/2012 and the cool roof coating was applied on 25/02/2012.

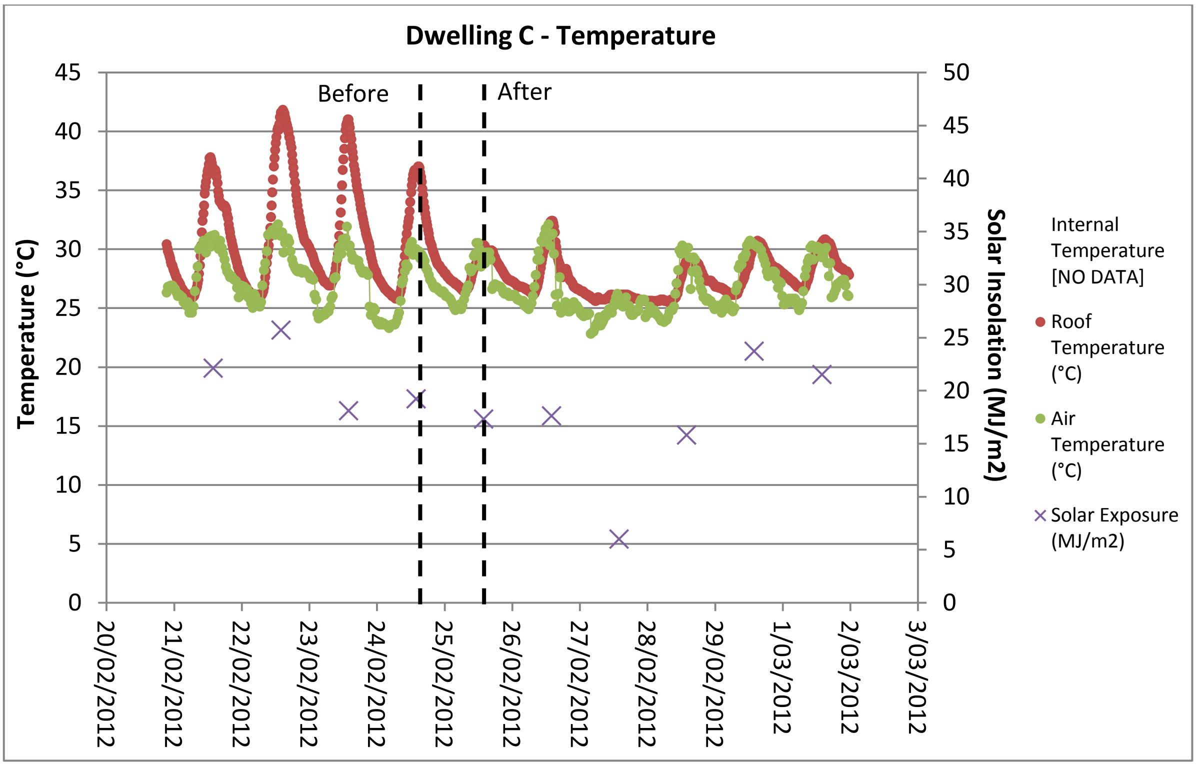


Figure 9: Dwelling C: Temperature readings before and after application of cool roof coating

There was an extended period of rain and overcast conditions in Townsville between 21/02/12 and 03/03/12, making comparison more difficult. However, comparing two similar days with similar ambient temperature, solar insolation, and precipitation, the cool roof coating has reduced maximum roof cavity temperatures by approximately 11.1°C (see Table 8 below). Average daytime roof cavity temperatures were reduced by 7.8°C. No internal temperature data was recorded for this property. Note that the ambient temperature on the date used for comparison after application of cool roof (29/02/2012) had a maximum temperature 1.4°C cooler than the baseline date (22/02/2012), and this may have contributed to the measured cooling effect.

Table 8: Dwelling C summary of cool roof performance, comparing two similar days

Comparison of two similar days			
	Before	After	Difference
	22/02/2012	29/02/2012	
Maximum roof cavity temperature; ˚C	41.8	30.7	-11.1
Average roof cavity temperature; ˚C (9am -	37.0	29.2	-7.8
Maximum internal temperature; ˚C	n/a	n/a	n/a
Average internal temperature; ˚C, (9am - 9pm)	n/a	n/a	n/a
Daily solar exposure; MJ/m^2	25.7	23.7	-2.0
Maximum ambient temperature; ˚C	32.1	30.7	-1.4
Precipitation (mm)	0.0	0.2	0.2
Average wind speed (km/h)	18.1	26.2	8.2

The cool roof has significantly reduced roof cavity temperatures. Comparing temperature data in the dwelling with ambient temperature data before and after application of the cool roof coating it can be seen that maximum roof cavity temperatures were previously on average 7.95˚C hotter than ambient conditions (see Figure 10). Maximum roof cavity temperatures after the cool roof were reduced to an average of only 0.35˚C hotter than ambient temperatures. This has resulted in average maximum temperature reductions of 7.6˚C relative to ambient temperatures.

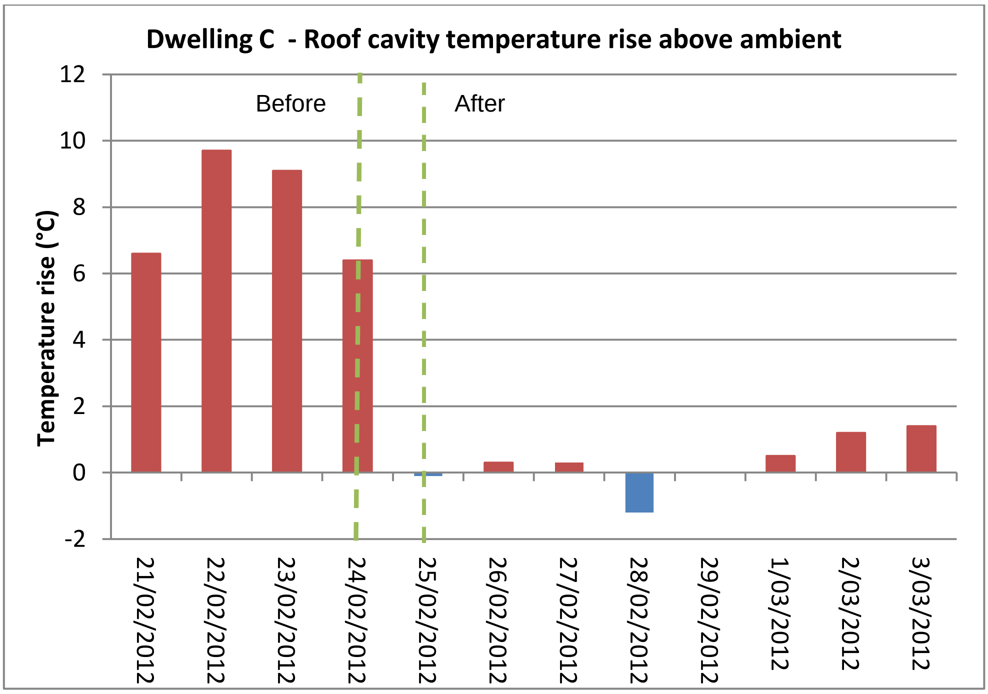


Figure 10: Dwelling C - Roof cavity temperature rise above ambient conditions

Electricity Consumption

The cool roof coating was applied during Q1 2012. In order to compare electricity consumption before and after the application of the cool roof product, Q4 and Q1 were chosen for analysis as these two quarters are most representative of the summer cooling-demand period for this dwelling. Q4 covers the period end-August to end-November; Q1 covers the period end-November to early-March. An average kWh/day figure was determined by averaging the total energy consumption over the total number of days in these two quarters. At the time of writing, Q1 2013 data was not available and therefore only Q4 2012 data was used for this summer period.

Average daily electricity demand prior to application of the cool roof product was 11.6 kWh/day in the 2009/2010 summer period, and 12.2 kWh/day in the 2010/2011 summer period. Following the application of the cool roof product, average daily electricity consumption has fallen to 7.0 kWh/day in Q4 2012 (see Figure 32). The 2011/2012 summer period data, which averaged 12.8 kWh/day has not been considered as the roof was painted during this summer period.

For the purposes of this analysis, the 2010-11 summer period has been chosen as the baseline period for comparison. Comparing electricity consumption data after application of the cool roof product with the 2010-11 baseline, this dwelling has achieved a reduction in average daily energy consumption of approximately 40 per cent.

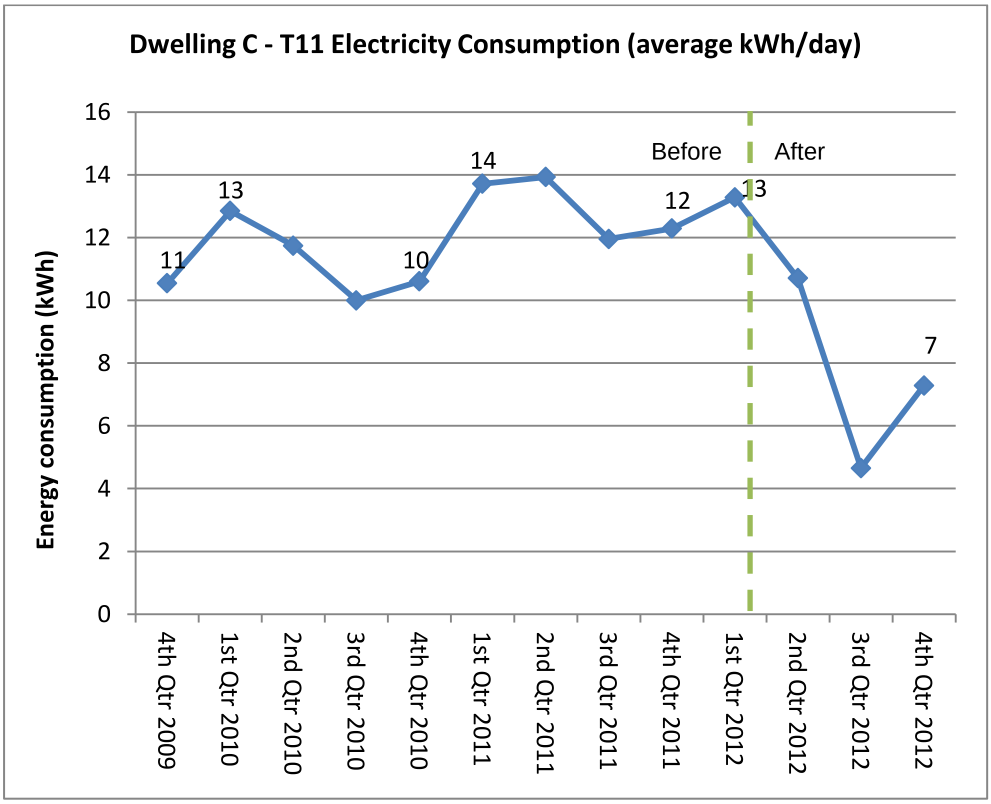


Figure 11: Dwelling C – Average daily T11 electricity consumption

Occupant Experience of the Cool Roof

An interview was conducted with the resident to obtain feedback about the pilot program and about their experience with their new cool roof. As the occupant was renovating their house at the time of installation several months had elapsed before they were living at home and able to fully experience their new roof. When contacted in February the resident reported being surprised by how effective the cool roof has been, stating that it has surpassed all expectations. The resident feels that the roof is 'amazing' and that 'the house used to be absolutely stifling, but there is a definite difference and the family can really feel it'.

The resident has two single split system air conditioners, which they reported using less than in previous summers. Despite this they were unsure if their energy usage has reduced owing to other confounding factors and difficulties with a pool pump. Although they were initially wary of the colour (which was originally a dark red), they have gotten used to it now and don't mind the look. They would definitely recommend it to others, and would certainly have a cool roof installed if they move into a new house in the future. They strongly recommended a cool roof to a family member who is planning their own renovation in the near future.

The resident is a strong and positive supporter of the pilot program, describing it as 'excellent' and hoping that it will be further expanded to more areas and to involve educational material on the difference between a cool roof product and regular white paint. The resident believes that cool roofs are a sensible choice for the climate, and that similar products should be promoted and encouraged in the Northern regions.

Testimonial

"Prior to my cool roof the temperature in my house was unbearable but there has been an amazing difference. I would like cool roofs to be promoted so that other people can benefit."

Dwelling D (a single story 1980s era low-set bessa-block house in Condon)

Background Information

Dwelling D is a single story 1980s era low-set bessa block house in Condon. The original roof was an olive/light green corrugated iron roof in poor condition. The cool roof coating was applied on 07/11/2011 and 08/11/2011. A summary of the dwelling characteristics will be presented in Table 9.

Table 9: Building and roof profile for Dwelling D

Dwelling D - House and roof characteristics	
Type	House (Low-set bessa block)
Suburb	Condon
Roof materials	Corrugated iron
Original roof colour	Light green/olive
Roof pitch	Steep
Insulation	Yes
Extent of shade	None
Levels	One
Air-conditioned	Yes

Temperature Performance Outcome

Figure 12 below shows a comparison of temperature data before and after the application of the cool roof coating. No internal non air-conditioned space was available for a sensor so no data is available. The graph below displays data recorded from two locations within the roof. Temperature data logging began on 04/10/11 and the cool roof coating was applied on 07/11/2012 and 08/11/2012. The sensors were removed by the painter on 09/11/12 and 10/11/12.

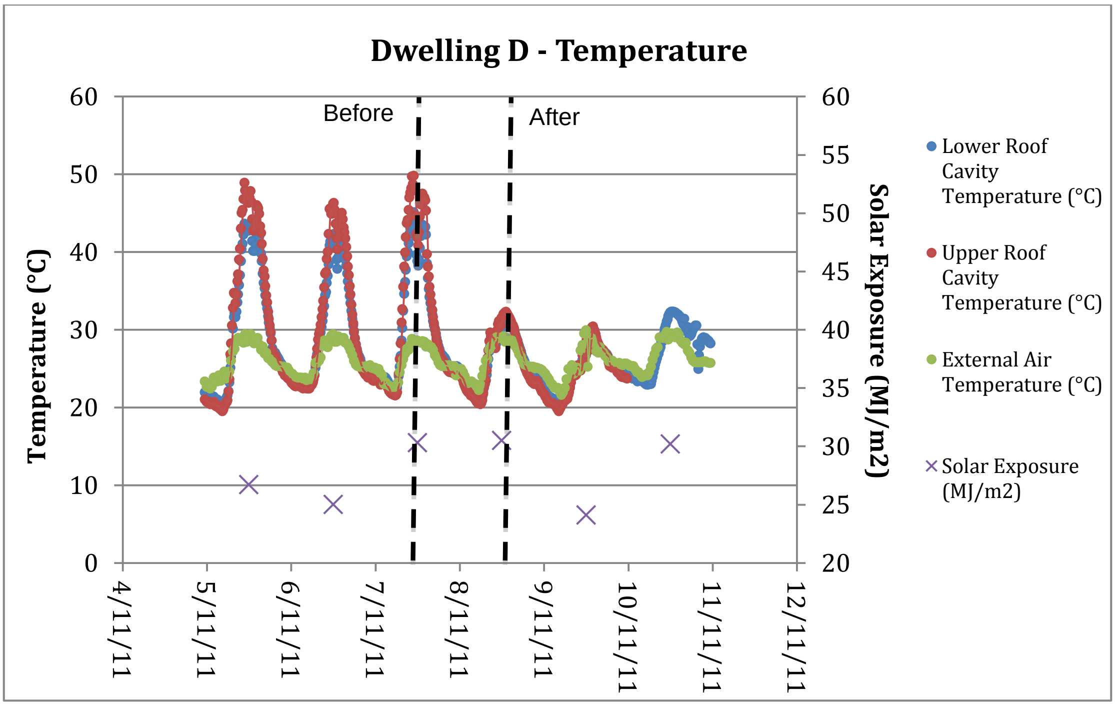


Figure 12: Dwelling D: Change in Temperature Before and After Roof Painting

Comparing two similar days with similar ambient temperature, solar insolation, and precipitation, the cool roof coating has reduced maximum roof cavity temperatures by 12.7 - 15.9°C and average daytime roof cavity temperatures by 7.1 – 8.8°C (see Table 10 below). Note that the ambient temperature on the date used for comparison after application of cool roof (09/11/2011) had a maximum temperature 0.5°C warmer than the baseline date (06/01/2011), and this may have reduced the measured cooling effect. However, despite the 'after' date being 0.5°C warmer, internal house temperatures were still significantly cooler than previously.

Table 10: Dwelling D summary of cool roof performance, comparing two similar days

Comparison of two similar days			
	Before	**After**	**Difference**
	06/01/2011	09/11/2011	
Maximum roof cavity temperature; ˚C	42.3	29.6	-12.7
Average daytime roof cavity temperature; ˚C (6am-9pm)	33.1	26.0	-7.1
Maximum upper roof cavity temperature; ˚C	46.3	30.4	-15.9
Average daytime upper roof cavity temperature; ˚C, (6am-9pm)	34.8	26.0	-8.8
Daily solar exposure; MJ/m^2	25	24.1	-0.9
Maximum ambient temperature; ˚C	29.4	29.9	+0.5
Precipitation (mm)	0	0.4	+0.4
Average wind speed (km/h)	21.9	18.4	-3.5

The cool roof has significantly reduced roof cavity temperatures. Comparing temperature data in the dwelling with ambient temperature data before and after application of the cool roof coating it can be seen that maximum roof cavity temperatures were previously on average 21.8˚C hotter than ambient conditions (see Figure 13). Maximum roof cavity temperatures after the cool roof were reduced to an average of only 1.9˚C hotter than ambient temperatures. This has resulted in average maximum roof cavity temperature reductions of 19.9˚C relative to ambient temperatures.

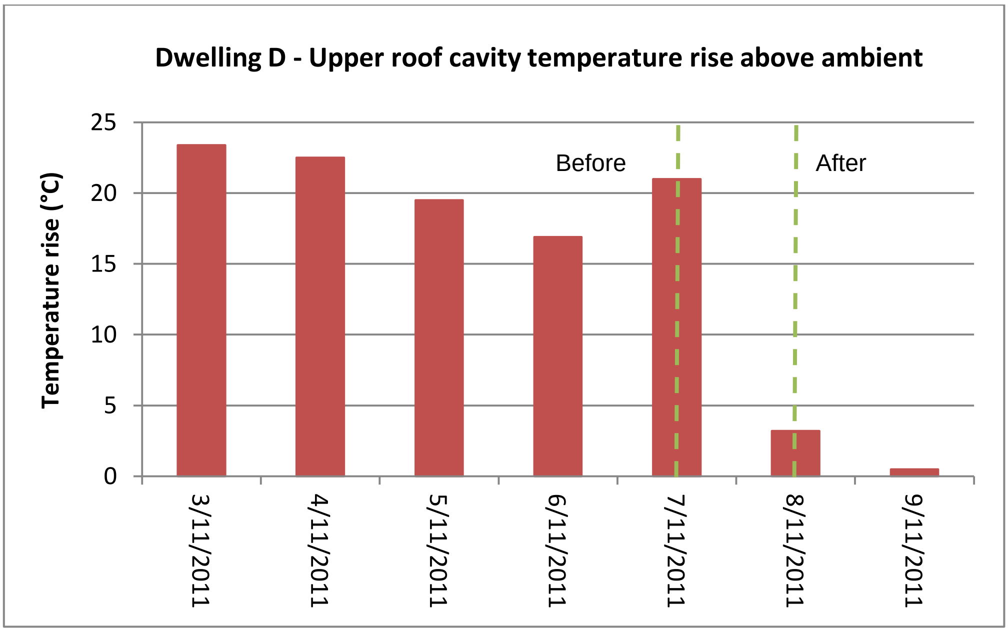


Figure 13: Dwelling D - Upper roof cavity temperature rise above ambient conditions

Energy Consumption

The cool roof coating was applied during Q4 2011. In order to compare electricity consumption before and after the application of the cool roof product, Q4 and Q1 were chosen for analysis and comparison year on year as these two quarters are most representative of the summer cooling-demand period for this dwelling. Q4 covers the period mid-October to mid-January (with the exception of Q4 2012 where the data period is mid-September to mid-December as result of an adjustment in dates in the Q3 period prior); Q1 covers the period mid-January to mid-April. An average kWh/day figure was determined by averaging the total energy consumption over the total number of days in these two quarters. At the time of writing, Q1 2013 data was not available and therefore only Q4 2012 data was used for this summer period.

Average daily electricity demand prior to application of the cool roof product was 21.7 kWh/day in the 2009/2010 summer period, and 17.1 kWh/day in the 2010/2011 summer period. Following the application of the cool roof product, average daily electricity consumption has fallen to 11.3 kWh/day in Q4 2012 (see Figure 5). The 2011/2012 summer period data, which averaged 16.2 kWh/day has not been considered as the cool roof was applied during this period.

For the purposes of this analysis, the 2010-11 summer period has been chosen as the baseline period for comparison. Comparing electricity consumption data after application of the cool roof product with the 2010-11 baseline, this dwelling has achieved a reduction in average daily energy consumption of approximately 34 per cent.

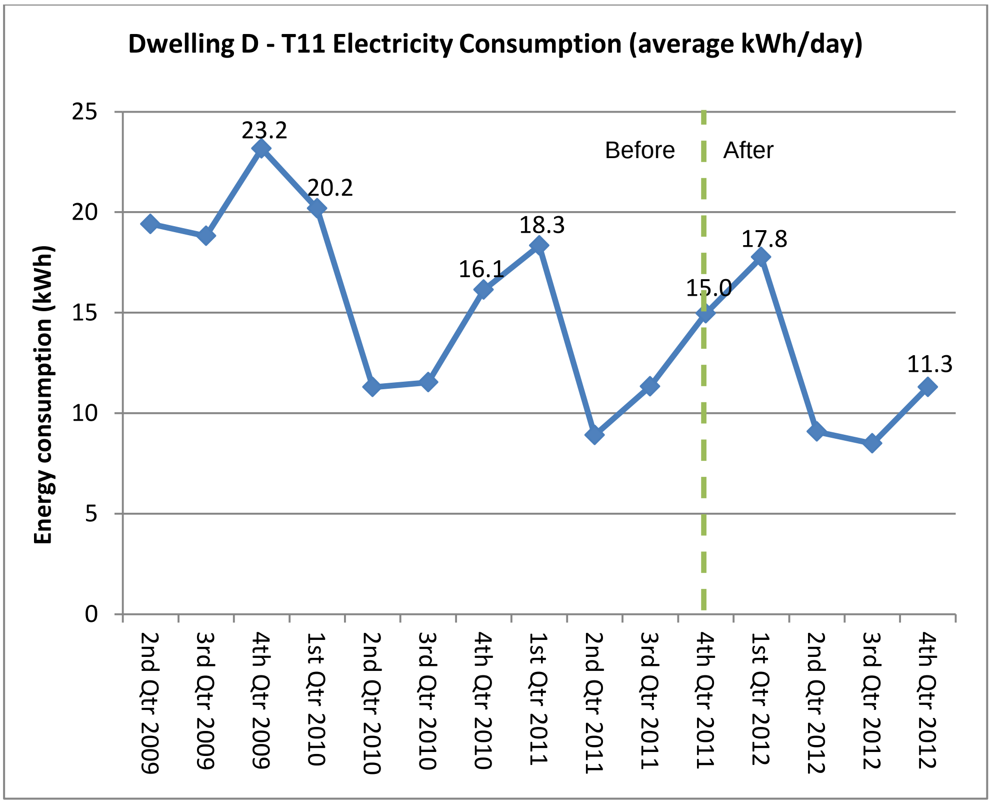


Figure 14: Dwelling D – Average daily T11 electricity consumption

Occupant Experience of the Cool Roof

An interview was conducted with the resident to obtain feedback about the pilot program and about their experience with their new cool roof. House D is a typical Townsville Bessa Brick house with a corrugated iron roof, which originally had a light green or olive-coloured roof. The owner was motivated to have a cool roof installed largely because the original paintwork was deteriorating, but later reported being pleasantly surprised by how effective the new roof was at reducing the internal temperature of the house. Booth the roof and the garage door were painted with a cool roof product by the contractors.

The owner had previously taken steps to cool the house by installing insulation, which the resident felt had made less of an impact than expected. In contrast, the performance of the cool roof has exceeded their expectations. The owner reported that "the house is normally all locked up during the day and use to be quite hot when we got home in the afternoon. After the [cool roof] painting, the house was cool to walk into at the end of the day." They were particularly pleased with the difference it made over the Christmas and New Year period, stating that they 'can't believe the change it's made'. The participant felt certain that they had reduced their use of the air conditioner, and stated that they felt it was now "only needed on the really hot, humid days" rather than on a regular basis.

The participant decided to get a cool roof in order to make the house more comfortable, and because the original roof paint was deteriorating and needed repainting anyway. The resident reported that they would recommend to friends and family that they get a cool roof and reports that several have since had their roofs painted. The participant also reported that one of their neighbours had their roof re-painted in a dark colour. The participant expressed concern that perhaps darker colours should not be allowed in Townsville as they are unsuitable for the climate.

Participant Testimonial

"We had the roof painted in November when the weather was starting to warm up. We could not believe how much cooler the house was the day after it was painted. The house is normally all locked up during the day and used to be quite hot when we got home in the afternoon. After the painting, the house was cool to walk into at the end of the day. Our carport and patio are just the bare metal colorbond roof. You can put your hand on the underside of the colorbond in the middle of a hot day and the metal is not hot at all, where before it would have burnt you. We found that when home we did not put the fans on until later in the day and there was reduced use of airconditioning during the day, as it was only needed on the really hot, humid days. I have certainly passed the word onto friends and know of a couple that have had their roofs painted."

Dwelling E (a 1950s era raised timber house in West End)

Background Information

Dwelling E is a 1950s era single-level timer house located in West End. The original roof was a silver corrugated iron roof approximately 30 years old. The cool roof coating was applied on 9/11/2011 and 10/11/2011. A summary of the dwelling characteristics is presented in Table 11.

Table 11: Building and roof profile for Dwelling E

Dwelling E - House and roof characteristics	
Type	House (1950s Timber house)
Suburb	West End
Roof materials	Corrugated iron
Original roof colour	Silver (painted)
Roof pitch	Steep
Insulation	Yes
Extent of shade	None
Levels	One
Air-conditioned	Yes, 2 in total

Temperature Performance Outcome

Figure 15 below shows a comparison of temperature data before and after the application of the cool roof coating. No internal non air-conditioned space was available for a sensor so no data is available. The graph below displays data recorded from two locations within the roof. Temperature data logging began on 04/11/11 and the cool roof coating was applied on 09/11/2012 and 10/11/2012.

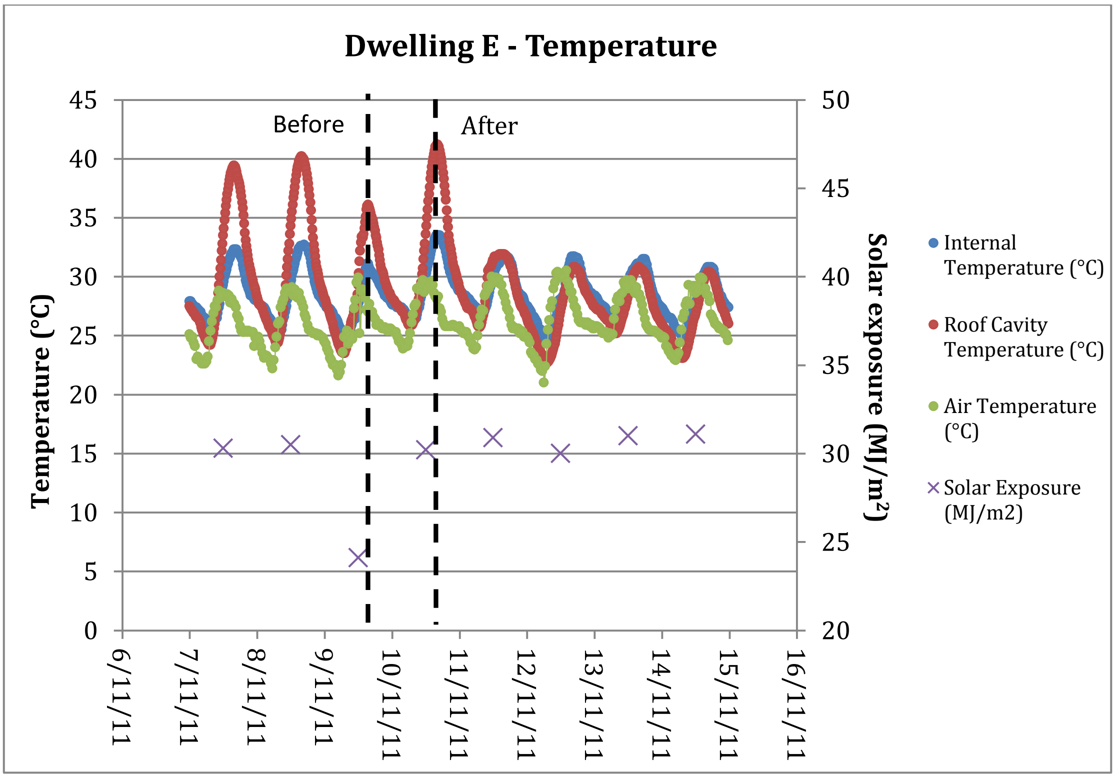


Figure 15: Dwelling E -Change in Temperature Before and After Roof Painting

Comparing two similar days with similar ambient temperature, solar insolation, and precipitation, the cool roof coating has reduced maximum roof cavity temperatures by 9.4˚C and maximum internal daytime temperatures by approximately 1.2°C (see Table 12 below). Average daytime roof cavity temperatures were reduced by 6.4°C and average internal daytime temperatures were reduced by 0.6°C. Note that the ambient temperature on the date used for comparison after application of cool roof (13/11/2011) had a maximum temperature 0.6°C warmer than the baseline date (08/11/2011), and this may have reduced the measured cooling effect. However, despite the 'after' date being 0.6°C warmer, internal temperatures were still significantly cooler than previously.

Table 12: Dwelling E: Summary of cool roof performance, comparing two similar days

Comparison of two similar days			
	Before	**After**	**Difference**
	08/11/2011	13/11/2011	
Maximum roof cavity temperature; ˚C	40.2	30.8	-9.4
Average daytime roof cavity temperature; ˚C (9am-9pm)	35.4	29.0	-6.4
Maximum internal temperature; ˚C	32.7	31.5	-1.2
Average daytime internal temperature; ˚C, (9am-9pm)	30.5	29.9	-0.6
Daily solar exposure; MJ/m^2	30.5	31.0	0.5
Maximum ambient temperature; ˚C	29.1	29.7	0.6
Precipitation (mm)	0.0	0.0	0.0
Average wind speed (km/h)	21.9	22.4	0.6

The cool roof has significantly reduced roof cavity temperatures. Comparing temperature data in the dwelling with ambient temperature data before and after application of the cool roof coating it can be seen that maximum roof cavity temperatures were previously on average 8.7˚C hotter than ambient conditions (see Figure 16). Maximum roof cavity temperatures after the cool roof were reduced to an average of only 0.8˚C hotter than ambient temperatures. This has resulted in average maximum temperature reductions of 7.9˚C relative to ambient temperatures.

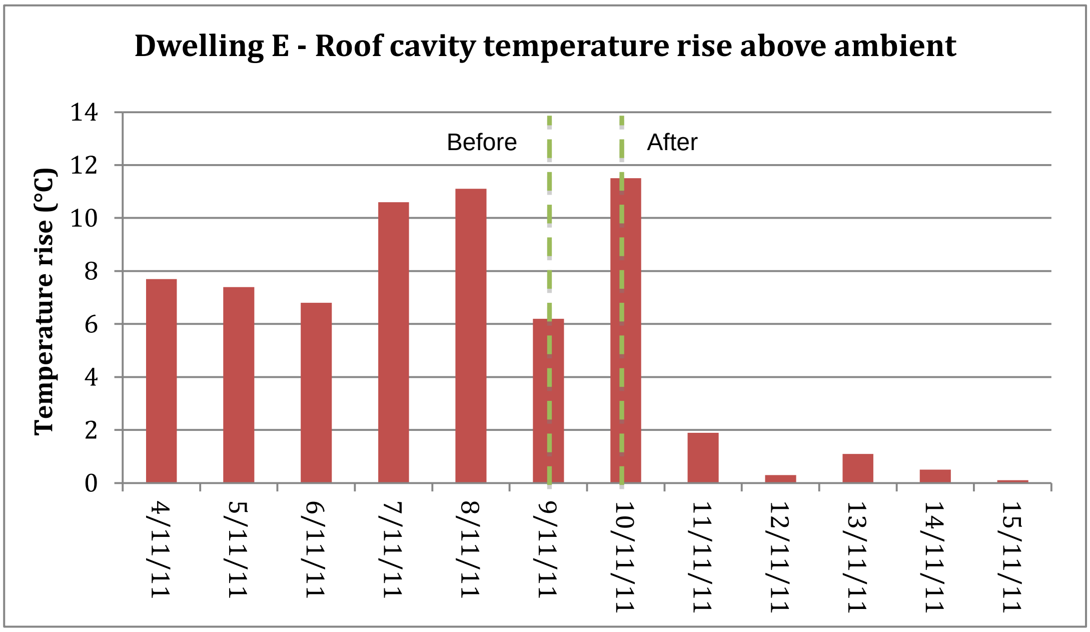


Figure 16: Dwelling E - Roof cavity temperature rise above ambient conditions

Similarly, internal maximum internal temperatures rises have been reduced from 2.8˚C hotter than ambient temperatures down to 1.3˚C hotter than ambient temperatures (see Figure 17). This has resulted in average maximum temperature reductions of 1.5˚C.

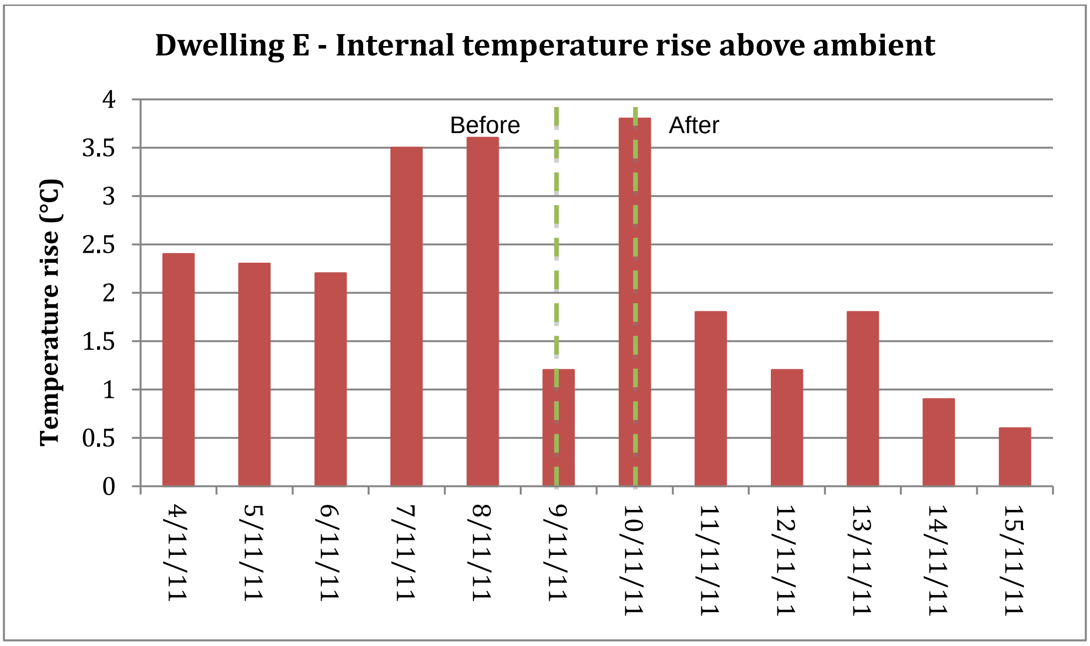


Figure 17: Dwelling E - Internal temperature rise above ambient conditions

Energy Consumption

The cool roof coating was applied during Q1 2012. Q1 and Q2 were chosen for analysis as these two quarters are most representative of the summer cooling-demand period for this dwelling. Q1 covers the period mid-October to mid-January; Q2 covers the period mid-January to mid-April. An average kWh/day figure was determined by averaging the total energy consumption over the total number of days in these two quarters. At the time of writing, however, Q2 2013 data was not available and therefore only Q1 2013 data was used for this summer period.

Average daily electricity demand prior to application of the cool roof product was 8.8 kWh/day in the 2009/2010 summer period, and 4.9 kWh/day in the 2010/2011 summer period. Following the application of the cool roof product, average daily electricity consumption has fallen to 4.7 kWh/day in the in Q1 2013 (see Figure 18). The 2011/2012 summer period data, which averaged 4.6 kWh/day has not been considered as the cool roof was applied within these months.

For the purposes of this analysis, the 2010-11 summer period has been chosen as the baseline period for comparison. Comparing electricity consumption data after application of the cool roof product with the 2010-11 baseline, this dwelling has achieved a reduction in average daily energy consumption of approximately 3.8 per cent. It should be noted that this household is already extremely efficient, using on average only around 5 kWh/day.

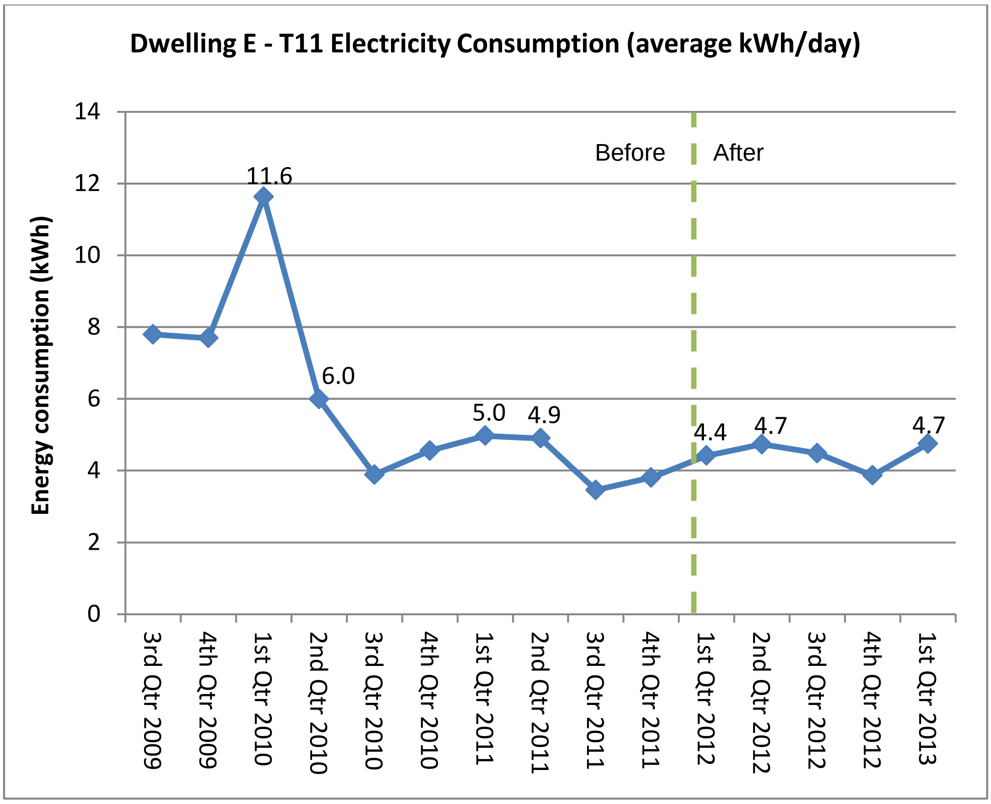


Figure 18: Dwelling E – Average daily T11 electricity consumption

Occupant Experience of the Cool Roof

An interview was conducted with the resident to obtain feedback about the pilot program and about their experience with their new cool roof. The resident reported being very happy with the cool roof and they estimate that the internal house temperature is about 5 degrees cooler on a summer's day.

The residents reported that they were somewhat skeptical about that cool roofing prior to installation but are now pleasantly surprised by the result. The new roof is performing as expected, and has reduced the internal temperature by 5-6 degrees. Although this difference was noticeable in winter as well as summer the resident did not feel that this made the house uncomfortably cold, remarking that Townsville winters were pleasantly mild anyhow. In summer they noticed the difference particularly when they return to the house after being out – it is no longer as terribly hot as it used to be when closed up for a period of time. The residents rely on a combination of ceiling fans and a single air-conditioning unit to cool the house on hot days, and even though the house is noticeably more comfortable than before they still feel that the system struggles to keep up and mostly 'work overtime', seldom managing to get the temperature down to 25 degrees. Because of this they are doubtful that there will be much change to their energy use. The resident attributes this as the result of a particularly hot summer, and is interested to see how the roof will perform over the long term.

The residents decided to get a cool roof partly because they hoped it would cool the house, and partly in order to prepare it for the installation of their new solar panels. The original roof was silver corrugated iron and hadn't been updated for about 30 years, so the residents felt that it needed maintenance and repair. They believe that the cool roof has improved the look of their house, although they hardly notice the colour anymore which they feel blends in well with the streetscape of their suburb. The resident has recommended cool roofs to friends/family and stated that they would install a cool roof if they moved to a new address.

Participant Testimonial

"I'd thoroughly recommend it if people can afford it – it's surprising what it can do. So as long as it's properly installed by a trustworthy contractor it's very effective. It's more effective than insulation. It's well worth having." [Verbal confirmation received. Awaiting written confirmation]

Dwelling F (a single storey concrete block house in Alice River)

Background Information

Dwelling F is a single storey house originally with a white Colorbond roof in Alice River. The cool roof coating was applied on 28/05/2012 and 29/05/2012. A summary of the dwelling characteristics is presented in Table 13.

Table 13: Building and roof profile for Dwelling F

Dwelling F - House and roof characteristics	
Type	House (Concrete block)
Suburb	Alice River
Roof materials	Colorbond
Original roof colour	White
Roof pitch	Mixed (cathedral ceilings and moderate pitch)
Insulation	Partial
Extent of shade	None
Levels	One
Air-conditioned	Yes, 4 in total

Temperature Performance Outcome

Error! Reference source not found.below shows a comparison of temperature data before and fter the application of the cool roof coating. During the period 30/06/2012 to 03/06/2012 Townsville experienced several days of rain (the impact of which can be seen on the temperature and insolation graph below), and as such, the two days selected for comparison are 27/05/12 and 04/06/12.

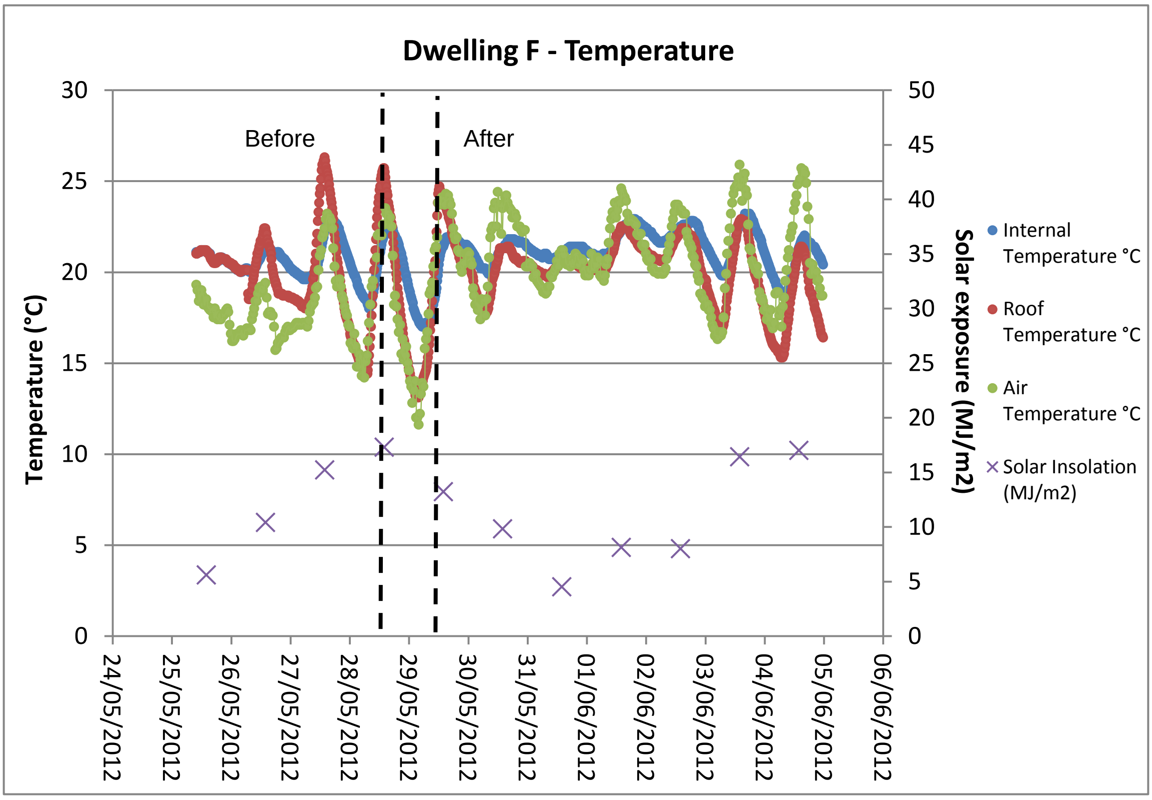


Figure 19: Dwelling F - Temperature readings before and after cool roof painting

Comparing two similar days with similar ambient temperature, solar insolation, and precipitation, the cool roof coating has reduced maximum roof cavity temperatures by 4.9°C and maximum internal temperatures by 0.8°C (see Table 14 below). Average daytime roof cavity temperatures were reduced by 3.2°C and average daytime internal temperatures were reduced by 0.9°C. Since the dwelling originally had a white roof coating, and also considering the study was conducted during winter, the effect is not as drastic compared to other dwellings analysed in the study. Additionally, it should be noted that that the ambient temperature on the date used for comparison after application of cool roof (04/06/2012) had a maximum temperature 2.5°C warmer than the baseline date (27/05/2012), and this may have reduced the measured cooling effect. However, despite the 'after' date being 2.5°C warmer, internal temperatures were still significantly cooler than previously.

Table 14: Dwelling F - Summary of cool roof performance, comparing two similar days

Comparison of two similar days			
	Before	**After**	**Difference**
	27/05/12	4/06/12	
Maximum roof cavity temperature; ˚C	26.3	21.4	-4.9
Average daytime roof cavity temperature; ˚C (9am-9pm)	22.8	19.6	-3.2
Maximum internal temperature; ˚C	22.8	22.0	-0.8
Average daytime internal temperature; ˚C, (9am-9pm)	21.8	20.9	-0.9
Daily solar exposure; MJ/m^2	15.2	17.0	1.8
Maximum ambient temperature; ˚C	23.2	25.7	2.5
Precipitation (mm)	0.0	0.0	0.0
Average wind speed (km/h)	20.0	16.4	-3.6

The cool roof has significantly reduced roof cavity temperatures. It can be seen that prior to the cool roof application both internal and roof cavity maximum temperatures were typically higher than ambient temperatures, however after the cool roof application, both internal and roof cavity maximum temperatures are typically lower than ambient temperatures.

Comparing temperature data in the dwelling with ambient temperature data before and after application of the cool roof coating it can be seen that maximum roof cavity temperatures were previously on average 2,7˚C hotter than ambient conditions (see Figure 20). Maximum roof cavity temperatures after the cool roof were reduced to an average of 2.4˚C cooler than ambient temperatures. This has resulted in average maximum temperature reductions of 5.1˚C relative to ambient temperatures.

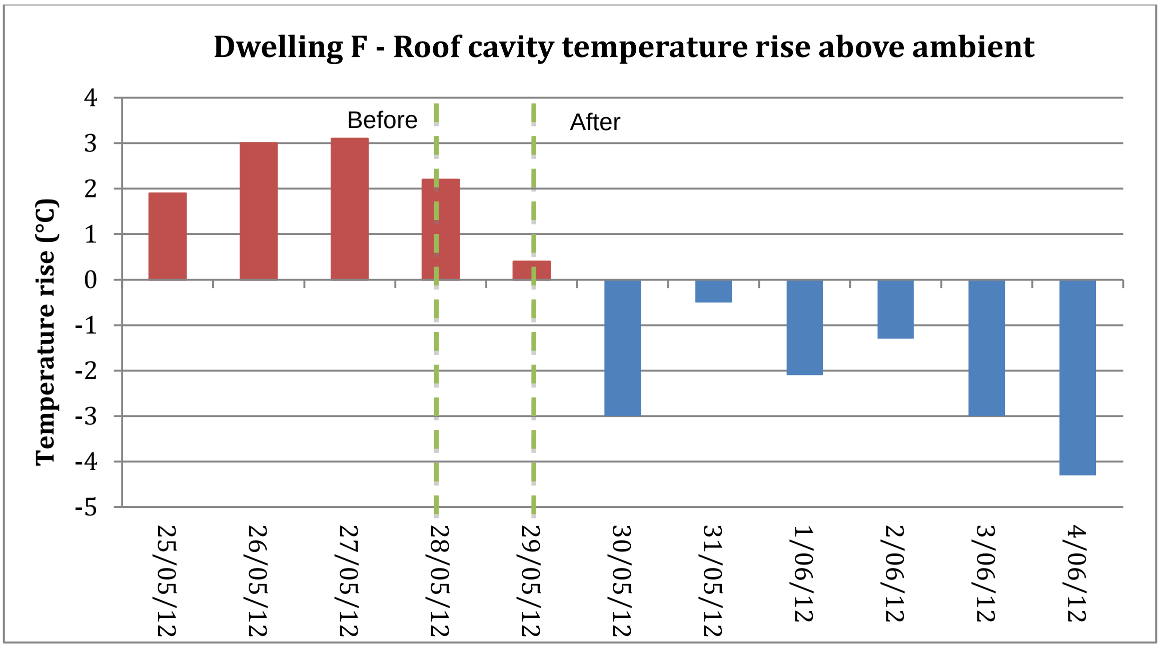


Figure 20: Dwelling F - Roof cavity temperature rise above ambient conditions

The cool roof has also significantly reduced maximum internal temperatures from an average of 1.1˚C warmer than ambient down to 1.9˚C cooler than ambient after the cool roof application (see Figure 21) for an average relative difference of 3˚C.

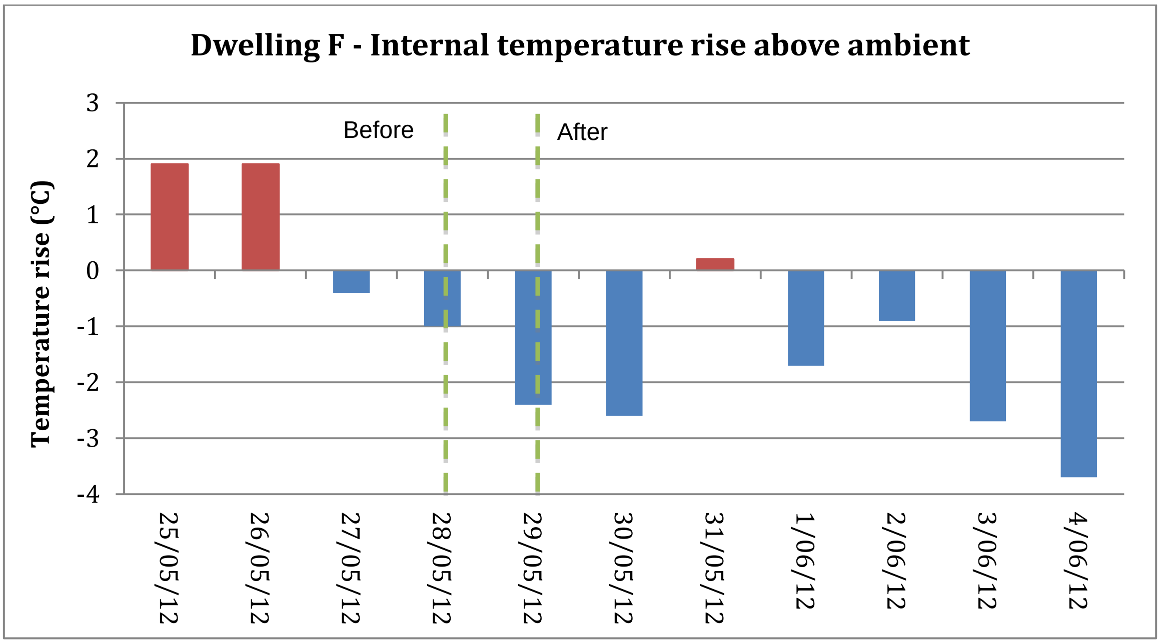


Figure 21: Dwelling F - Internal temperature rise above ambient conditions

Energy Consumption

The cool roof coating was applied during Q3 2012. Q1 and Q2 were chosen for analysis as these two quarters are most representative of the summer cooling-demand period for this dwelling. Q1 covers the period late-October to late-January; Q2 covers the period late-January to late-April. An average kWh/day figure was determined by averaging the total energy consumption over the total number of days in these two quarters. At the time of writing, however, Q2 2013 data was not available and therefore only Q1 2013 data was used for this summer period.

Average daily electricity demand prior to application of the cool roof product was 16.6 kWh/day in the 2009/2010 summer period, 15.2 kWh/day in the 2010/2011 summer period, and 15.2 kWh/day in the 2011/2012 summer period. Following the application of the cool roof product, average daily electricity consumption rose slightly to 15.8 kWh/day in Q1 2013 (see Figure 22).

For the purposes of this analysis, the 2011-12 summer period has been chosen as the baseline period for comparison. Comparing electricity consumption data after application of the cool roof product with the 2010/11 baseline, this dwelling has increased energy consumption by 3.8 per cent.

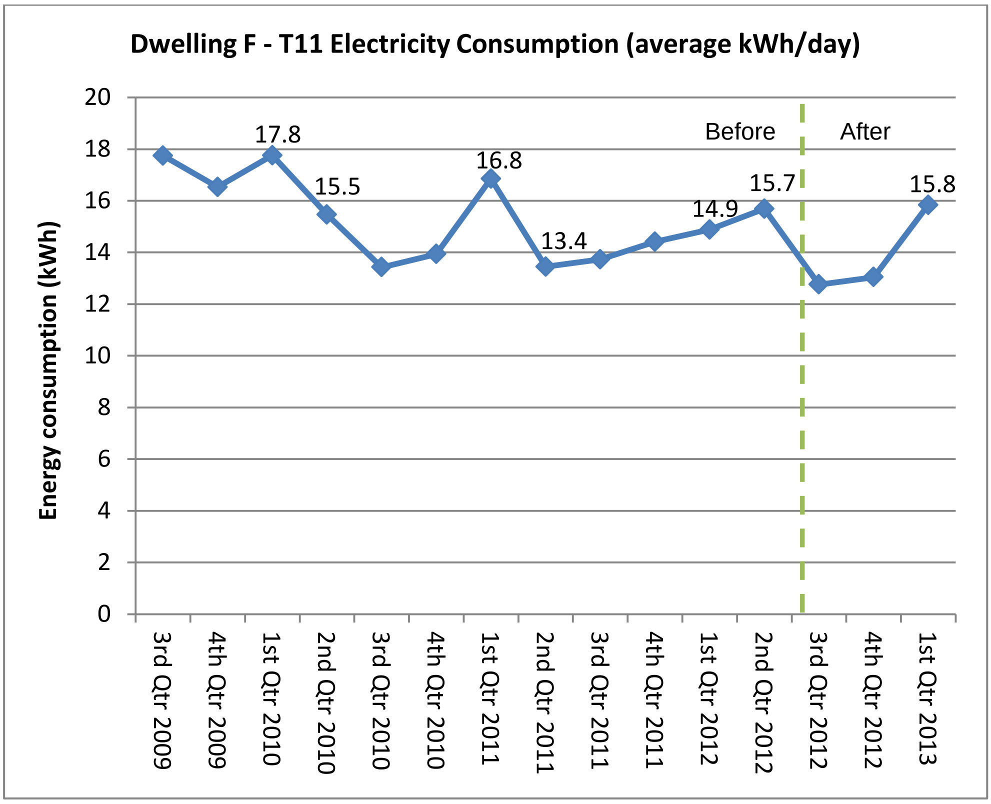


Figure 22: Dwelling F – Average daily T11 electricity consumption

Occupant Experience of the Cool Roof

An interview was conducted with the resident to obtain feedback about the pilot program and about their experience with their new cool roof. The resident stated that they had noticed a difference in the comfort of their house since last summer. They observed that the house was much slower to heat up during the day provided the windows were closed to prevent the hot breeze from blowing in. If they left the house in the morning and returned at lunchtime it was much cooler than it was prior to roof installation. The resident reported that their most recent energy bill was on average $4 a day less than what it had been during the same period last year.

The resident also decided to get his shed painted at the same time as the house roof was painted. The resident reported that the temperature difference was particularly apparent in the shed. The resident uses the shed to house a model railway set and spends many hours there during the day, despite the fact that the shed was very hot and un-airconditioned. They were certain that it was now much cooler and more comfortable thanks to the cool roof, and many of the resident's friends had commented on the difference.

The resident decided to get a cool roof because the original (white) roof was deteriorating and the resident reported that that they felt the internal temperature of the house was increasing over time as the surface gradually deteriorated. They had previously considered getting a cool roof prior to hearing about the pilot program but found the initial quotes unaffordable. The discounted price was therefore a major factor that influenced their decision to participate in the program.

The resident stated that the new roof has definitely improved the look of their house. They were happy with the professionalism of the contractor and would recommend cool roofs to their family and friends.

Participant Testimonial

The participant declined to provide a testimonial

Dwelling G (a raised timber house in Rasmussen)

Background Information

Dwelling G is a raised timber Queenslander originally with white Colorbond roof in Rasmussen. The cool roof coating was applied on 20/02/2012 and 21/02/2012. A summary of the dwelling characteristics is presented in Table 15 below.

Table 15: Building and roof profile for Dwelling G

Dwelling G - House and roof characteristics	
Type	House (Queenslander)
Suburb	Rasmussen
Roof materials	Colorbond
Original roof colour	White, poor condition
Roof pitch	n/a
Insulation	n/a
Extent of shade	n/a
Levels	One
Air-conditioned	Yes, 4 in total

Temperature Performance Outcome

Figure 23 below shows a comparison of temperature data before and after the application of the cool roof coating. Two sensors were installed in the dwelling; one in the roof cavity and one in an internal un-conditioned space. Temperature data logging began on 10/02/2012 and the cool roof coating was applied on 20/02/2012 and 21/02/2012.

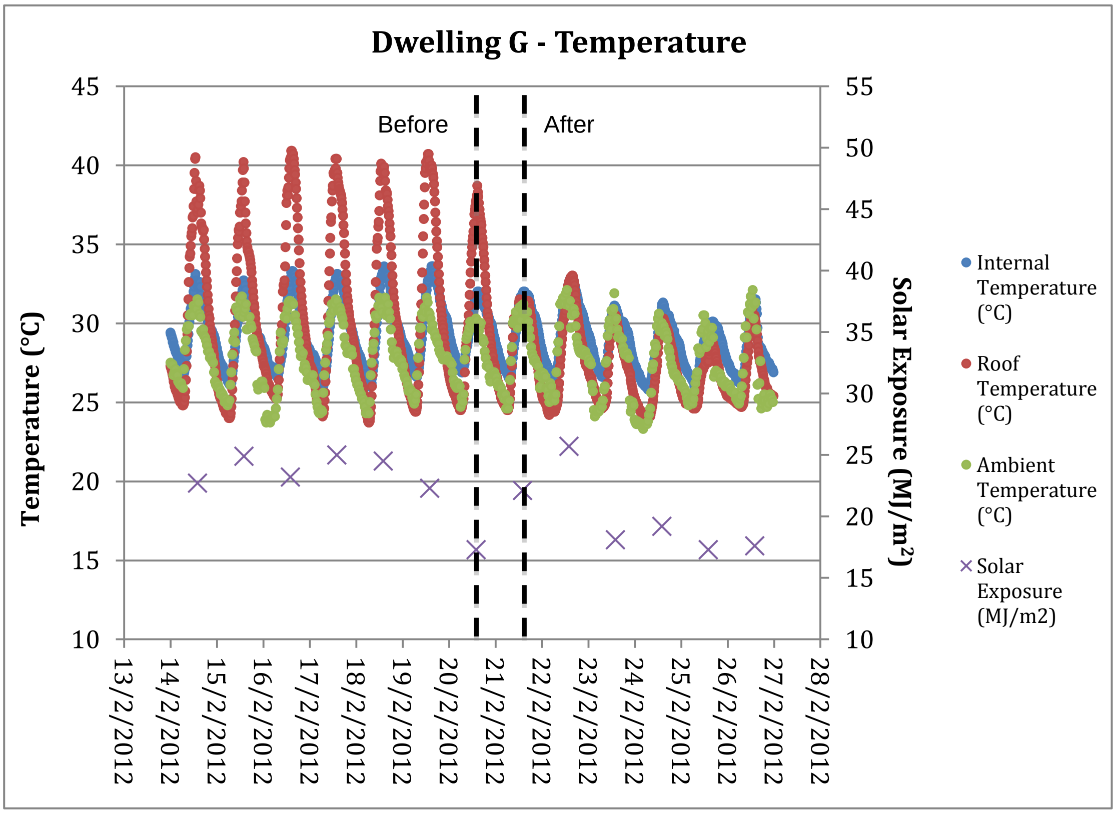


Figure 23: Dwelling G - Temperature readings before and after cool roof painting

Comparing two similar days with similar ambient temperature, solar insolation, and precipitation, the cool roof coating has reduced maximum roof cavity temperatures by 9.5°C and maximum internal temperatures by 2.5°C (see Table 16 below). Average daytime roof cavity temperatures were reduced by 6.8°C and average daytime internal temperatures by 1.5°C. Note that the ambient temperature on the date used for comparison after application of cool roof (23/02/2012) had a maximum temperature 0.3°C warmer than the baseline date (18/02/2012), and this may have reduced the measured cooling effect. However, despite the 'after' date being 0.3°C warmer, internal temperatures were still significantly cooler than previously.

Table 16: Dwelling G – Summary of cool roof performance, comparing two similar days

Comparison of two similar days			
	Before	After	Difference
	18/02/12	23/02/12	
Maximum roof cavity temperature; ˚C	40.1	30.6	-9.5
Average daytime roof cavity temperature; ˚C (9am-9pm)	35.3	28.5	-6.8
Maximum internal temperature; ˚C	33.6	31.1	-2.5
Average daytime internal temperature; ˚C, (9am-9pm)	31.3	29.8	-1.5
Daily solar exposure; MJ/m^2	24.5	18.1	-6.4
Maximum ambient temperature; ˚C	31.6	31.9	0.3
Precipitation (mm)	0.0	0.0	0
Average wind speed (km/h)	23.5	14.8	-8.68

The cool roof has significantly reduced roof cavity and internal house temperatures. Comparing temperature data in the dwelling with ambient temperature data before and after application of the cool roof coating it can be seen that roof cavity temperatures were previously on average 8.8 ˚C hotter than ambient conditions. Roof cavity temperatures after the cool roof were reduced significantly, averaging 1.1˚C cooler than ambient temperatures (see Figure 24), resulting in an average temperature reduction of approximately 9.9˚C.

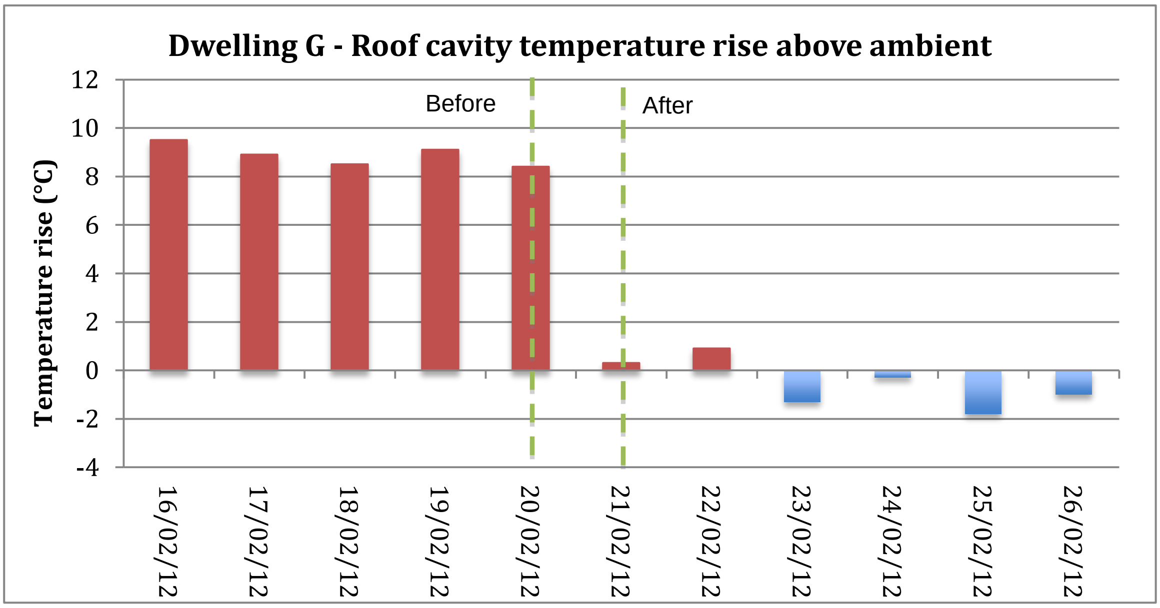


Figure 24: Dwelling G - Roof cavity temperature rise above ambient conditions

Similarly, the cool roof has had a significant impact on maximum internal temperatures. Internal house temperatures previously averaged 1.84˚C hotter than ambient conditions prior to the cool roof, but were reduced to an average of 0.28˚C cooler than ambient conditions (see Figure 25), resulting in an average maximum temperature reduction of approximately 2.1˚C relative to ambient temperatures.

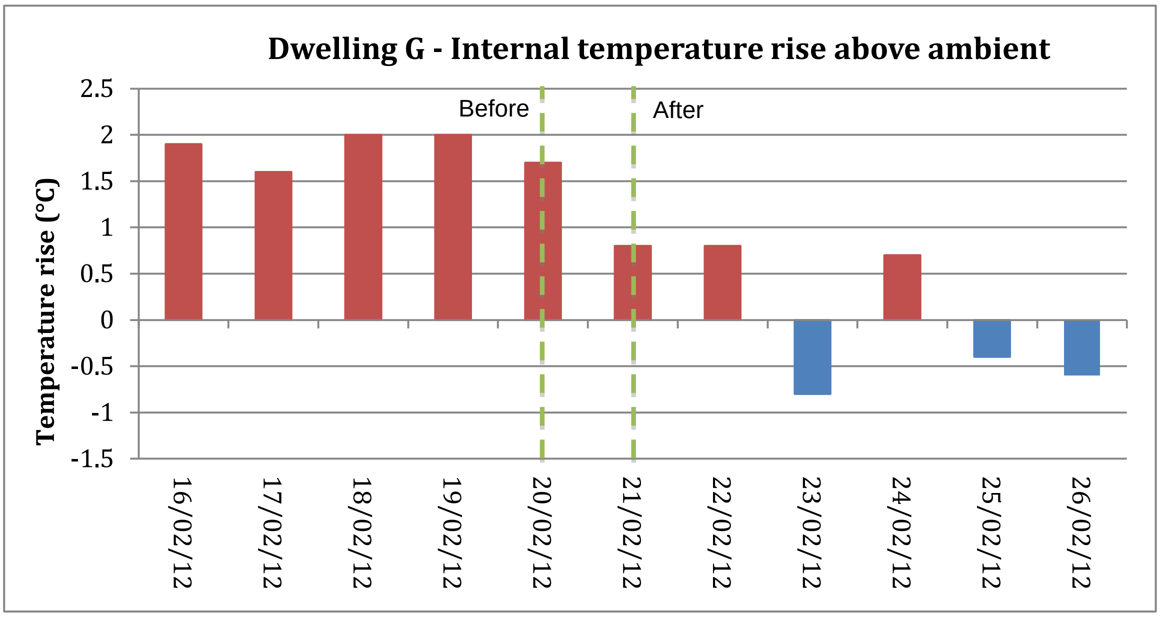


Figure 25: Dwelling G - Internal temperature rise above ambient conditions

Energy Consumption

The cool roof coating was applied during Q2 2012. Q1 and Q2 were chosen for analysis as these two quarters are most representative of the summer cooling-demand period for this dwelling. Q1 covers the period mid-October to mid-January (with the exception of Q1 2013 where the billing period was mid-September to mid-December); Q2 covers the period mid-January to mid-April. An average kWh/day figure was determined by averaging the total energy consumption over the total number of days in these two quarters. At the time of writing Q2 2013 data was not available and therefore only Q1 2013 data was used for this summer period.

Average daily electricity demand prior to application of the cool roof product was 31.2 kWh/day in the 2009/2010 summer period, and 30.6 kWh/day in the 2010/2011 summer period. Following the application of the cool roof product, average daily electricity consumption has fallen to 12.5 kWh/day in Q1 2013 (see Figure 26). The 2011/2012 summer period data, which averaged 33.8 kWh/day has not been considered as the cool roof was applied within these months.

For the purposes of this analysis, the 2010-11 summer period has been chosen as the baseline period for comparison. Comparing electricity consumption data after application of the cool roof product with the 2010-11 baseline, this dwelling has achieved a reduction in average daily energy consumption of approximately 59 per cent.

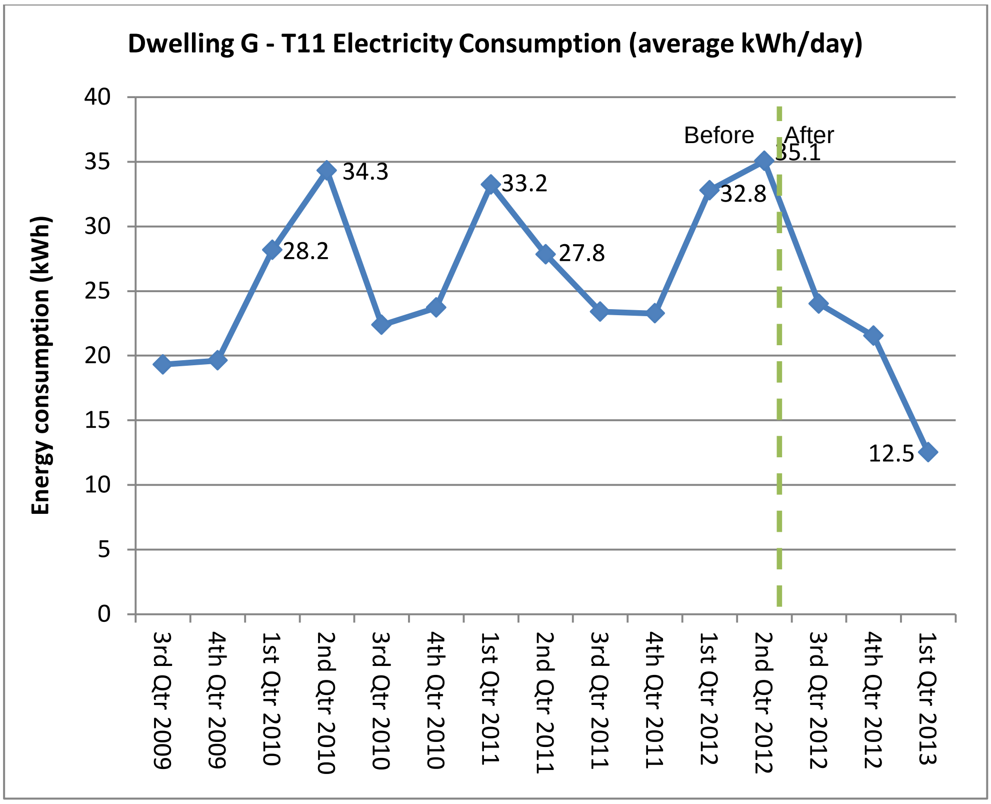


Figure 26: Dwelling G – Average daily T11 electricity consumption

Occupant Experience of the Cool Roof

An interview was conducted with the resident to obtain feedback about the pilot program and about their experience with their new cool roof. The residents initially chose to live in a house with a white roof because they believed it would be cooler, based on their experiences of other houses and display homes with dark roofs. Part of their motivation for adopting a new roof was that the original white colourbond (ordinary, non-reflective paint) was flaking and in poor condition. They wanted to use Dulux as they thought it was a good product: finding a Dulux painter had initially been a barrier that had stopped them from having the work done sooner.

This resident was contacted in August 2012 but requested that they be contacted again in the new year once they had had a chance to experience the performance of their new roof during the summer period. Although the resident had initially reported that they were unsure if the cool roof had made much difference at all, by February they were certain that the roof had made a significant difference to the internal temperature of their house. They also reported that they now use their air conditioner less often, and that they felt the refrigerator has been working more efficiently since installation.

The resident bought extra product from the contractor and used it to paint two sheds on their property as they thought that this would be better for the equipment being stored within the shed (such as bicycles). Since the installation many of their friends have made comments about how comfortable the house is. A neighbour has also painted their roof white, but the resident was unsure if this was an ordinary or reflective paint. The resident feels that it is very important that educational material is provided on the difference between ordinary paint and reflective 'cool roof' paint in a way that helps people to understand the cost difference. They have had to explain to several friends that ordinary white paint is not the same as solar reflective paint.

The resident would recommend cool roofs to friends/family and stated they would consider installing a cool roof if they moved to a new house. The resident believes that cool roofs make a lot of sense in Townsville, and were hopeful that council might encourage the uptake of cool roofs in the future and to make it a mandatory requirement for new houses to have a cool roof.

Participant Testimonial

"It definitely works! When you walk in the door when you get home it no longer feels like walking into an oven – the wall of hot air has gone. It was worth the money. I hope more people get a cool roof!" [Verbal confirmation received. Awaiting written confirmation]

Dwelling H (a low-set brick house in Kelso)

Background Information

Dwelling H is a low-set brick house with a brown tin roof in Kelso. The cool roof coating was applied on 09/11/2011 and 10/11/2011. A summary of the dwelling characteristics is presented in Table 17 below.

Table 17: Building and roof profile for Dwelling H

Dwelling H - House and roof characteristics	
Type	House (Low-set brick)
Suburb	Kelso
Roof materials	Tin
Original roof colour	Brown
Roof pitch	n/a
Insulation	Yes
Extent of shade	None
Levels	One
Air-conditioned	Yes

Temperature Performance Outcome

Temperature data for Dwelling H is not available. The resident was a private customer of one of the painters who was approached several months after their roof was painted to ask if they would be willing to contribute to the pilot program by granting access to energy consumption data and providing feedback on their experience with their new cool roof.

Energy Consumption

The cool roof coating was applied during Q1 2012. Q1 and Q2 were chosen for analysis as these two quarters are most representative of the summer cooling-demand period for this dwelling. Q1 covers the period mid-October to mid-January; Q2 covers the period mid-January to mid-April. An average kWh/day figure was determined by averaging the total energy consumption over the total number of days in these two quarters. At the time of writing, however, Q2 2013 data was not available and therefore only Q1 2013 data was used for this summer period.

Average daily electricity demand prior to application of the cool roof product was 18.1 kWh/day in the 2009/2010 summer period, and 16.6 kWh/day in the 2010/2011 summer period. Following the application of the cool roof product, average daily electricity consumption has fallen to 13.3 kWh/day in Q1 2013 (see Figure 27). The 2011/2012 summer period data, which averaged 16.2 kWh/day has not been considered as the cool roof was applied within these months.

For the purposes of this analysis, the 2010-11 summer period has been chosen as the baseline period for comparison. Comparing electricity consumption data after application of the cool roof product with the 2010-11 baseline, this dwelling has achieved a reduction in average daily energy consumption of approximately 19 per cent.

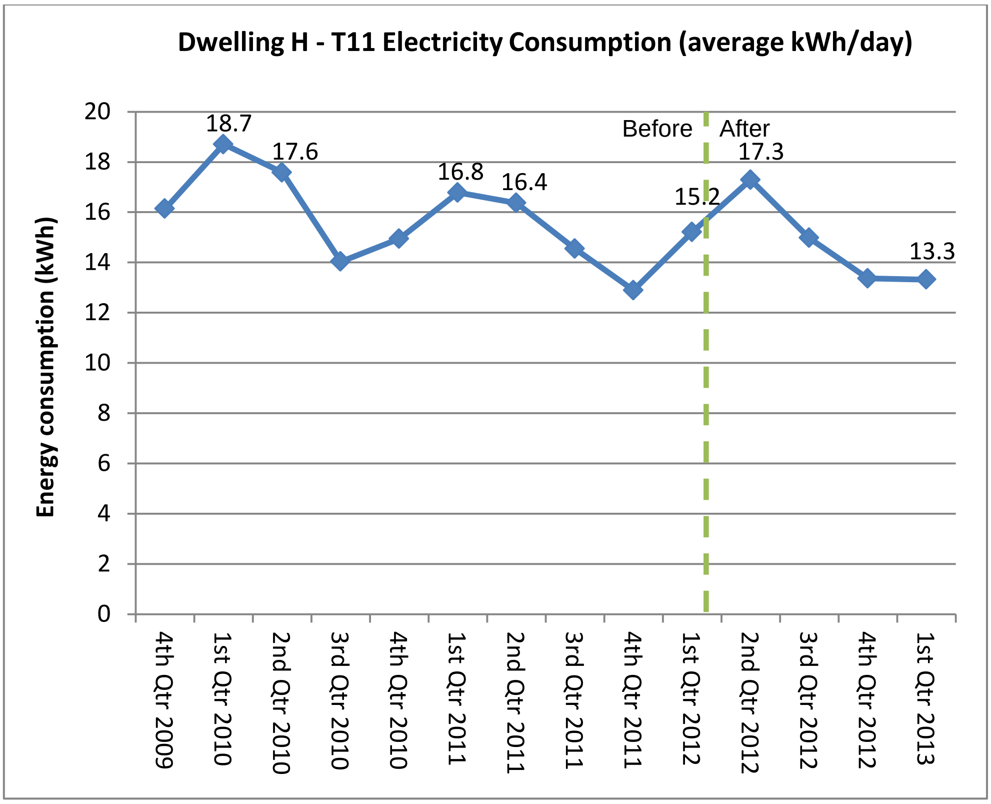


Figure 27: Dwelling H – Average daily T11 electricity consumption

Occupant Experience of the Cool Roof

An interview was conducted with the resident to obtain feedback about the pilot program and about their experience with their new cool roof. The resident reported that the temperature has dropped noticeably since application of the cool roof coating. The resident stated that the house has five air-conditioning units and that they believe their use of air-conditioning has reduced since the application of the cool roof.

The new roof has exceeded the occupant's expectations and they feel that it has made a big difference to the comfort of their home. The temperature has dropped noticeably, and now it is possible for them 'to go for a walk in the morning and find that the house is still nice and cool when we get back – without the air conditioning'. The resident has noticed that the cat has taken to sleeping on the roof of the entertaining area, which they take as an indication that the product is working. They have also noticed the difference in the garage when they work on the cars. Overall, they are certain that it has made a huge difference to the temperature in their home.

As a result the occupants reported that their use of air conditioning has also reduced. They have not needed to use the units in the bedrooms, finding that the ceiling fans are now sufficient. The unit in the lounge area is used from time to time but not as often as previously. The effect of the cool roof has been also been enhanced by the addition of tinted windows. These changes have contributed to a reduction in their energy bills.

The occupants had heard about cool roofs before being introduced to the pilot program. When their neighbours opted to have one installed the resident was curious, and requested a quote from the same contractors on-site. The price was initially a barrier to having their own roof painted, and the discount offered by the pilot program was a big factor in their decision to go ahead with installation. The resident wanted to install solar panels and decided to get the roof painted before installing the panels. The residents were hopeful that the product would lower the temperatures inside their home but they were also mindful about roof repairs: it was important to them that the roof was properly maintained and inspected prior to cyclone season for insurance purposes. They also wanted to install solar panels and thought that this should be done after the roof was painted. The occupants are satisfied with this decision as they have since heard that the cool roof may contribute to making their solar system more efficient. They eventually opted to have three surfaces painted: the main roof of the house, the garage roof, and the outdoor entertaining area.

The occupants feel that the new roof has improved the look of their house. They were initially concerned that it might cause a glare problem for their neighbour, who's two storey dwelling looks out over the roof. The neighbours did comment on the roof, although this may have been prompted by the visual change from brown to white rather than because of a specific issue with glare. The occupants no longer believe that this is an issue of concern, stating that they 'Feel like the roof is less reflective now than when it was first treated, but perhaps that is just everyone getting used to it'. They have also commented that 'white is probably a more acceptable colour choice these days'.

The residents have stated that they 'would definitely recommend it to anyone, if they could afford it'. They feel that it has increased the life of their roofing and been a worthwhile investment. They would also consider having one installed if they moved to a new address, particularly if the roof needed repairs. The residents were positive about the pilot program however they did have some concerns with the work done by the contractors arising from overspray. They raised their concerns with the tradespeople who re-visited the house to remedy the problem.

Participant Testimonial

"We would recommend it to everyone. If you can afford to have the work done then it's well worth the investment – it cuts down on electricity costs, makes a difference to cooling, and it's also a good chance for people to have their roof checked out and make sure it's properly maintained".

Dwelling I (a concrete block house in Kirwan)

Background Information

Dwelling I is a single level concrete block house with a brown/red corrugated iron roof in Kirwan. The cool roof coating was applied on 26/10/2011. A summary of the dwelling characteristics is presented in Table 18 below.

Table 18: Building and roof profile for Dwelling I

Dwelling I - House and roof characteristics	
Type	House (Concrete block)
Suburb	Kirwan
Roof materials	Corrugated iron
Original roof colour	Brown/red
Roof pitch	n/a
Insulation	n/a
Extent of shade	None
Levels	One
Air-conditioned	Yes

Temperature Performance Outcome

Temperature data for Dwelling I is not available. The resident was a private customer of one of the painters who was approached several months after their roof was painted to ask if they would be willing to contribute to the pilot program by granting access to energy consumption data and providing feedback on their experience with their new cool roof.

Energy Consumption

The cool roof coating was applied during Q4 2011. Q1 was chosen for analysis as this quarter is most representative of the summer cooling-demand period for this dwelling. Q1 covers the period late-November to early-March. An average kWh/day figure was determined by averaging the total energy consumption over the total number of days in this quarter. At the time of writing, Q1 2013 data was not available.

Average daily electricity demand prior to application of the cool roof product was 56.5 kWh/day in the 2009/2010 summer period, and 47.9 kWh/day in the 2010/2011 summer period. Following the application of the cool roof product, average daily electricity consumption has fallen to 35.0 kWh/day (see Figure 28).

For the purposes of this analysis, the 2010-11 summer period has been chosen as the baseline period for comparison. Comparing electricity consumption data after application of the cool roof product with the 2010-11 baseline, this dwelling has achieved a reduction in average daily energy consumption of approximately 27 per cent.

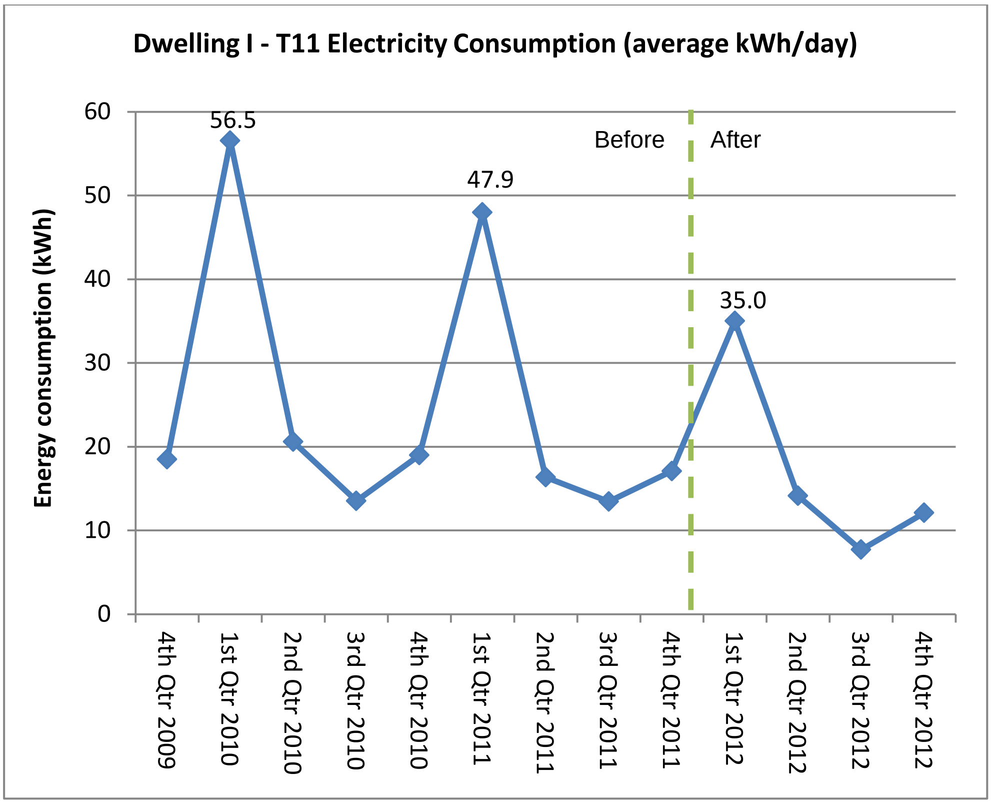


Figure 28: Dwelling I – Average daily T11 electricity consumption

Note: The residents of this dwelling reported making a conscious decision to reduce their use of air-conditioning after noticing the large impact it was having on their energy bill. The resident also reported replacing their electric storage hot water system with an instantaneous system at approximately the same time as the cool roof application, however as hot water systems are typically on an off-peak tariff (such as Tariff 33) this would not be reflected in the above energy consumption figures, which consider only Tariff 11 electricity consumption.

Occupant Experience of the Cool Roof

An interview was conducted with the resident to obtain feedback about the pilot program and about their experience with their new cool roof. The resident reported that the cool roof is performing better than expected and has substantially reduced internal temperatures, making the house much more comfortable to live in. The house has four air conditioning units, which the residents now report using on fewer days throughout the week however this is partly because they made a conscious decision to reduce air-conditioning use after noting the large impact it was having on their energy bill. Improvements were made to the hot water system roughly around the time that the roof was treated which also contributed to a reduction in their energy use (however the electricity data analysis above accounts for this by considering only Tariff 11 consumption).

The resident decided to get a cool roof to reduce the temperature inside the house. A cyclone knocked down a shade tree that previously provided shade and cooling to the house, and the resident reported noticing that the house had become much hotter since the tree was gone. Furthermore the original roof colour was a dark mission brown; a poorly performing colour in Townsville. The house has no ceiling insulation, owing to lack of space in the roof cavity. The combination of these factors meant that a cool roof had the potential to make a substantial improvement for this dwelling.

The resident feels that the new roof has improved the look of the house now that they have become accustomed to the colour. They would recommend a cool roof to friends and family, and some have since gone on to get a cool roof themselves. One of their neighbors asked about the roof after installation. They reported that they would consider getting a cool roof if they moved to a new address, and were 'very happy' both with the effectiveness of the roofing and with the service provided by the contractors.

Participant Testimonial

The participant declined to provide a testimonial

Dwelling J (a timber house in North Ward)

Background Information

Dwelling J is a single storey timber Queenslander style house located in North Ward. It is low set at the back and high set at the front. The original roof was unpainted corrugated iron with partial shading at different times of day, and also was shaded by photovoltaic panels and a solar hot water system. The house has a roof with many angles, and minimal, patchy insulation. The cool roof coating was applied on 02/07/2012 and 3/07/2012. A summary of the dwelling characteristics is presented in Table 19 below.

Table 19: Building and roof profile for Dwelling J

Dwelling J - House and roof characteristics	
Type	House (Queenslander)
Suburb	Kirwan
Roof materials	Corrugated iron
Original roof colour	Unpainted
Roof pitch	Steep
Insulation	Partial (poor quality)
Extent of shade	Partial
Levels	One
Air-conditioned	Yes

Temperature Performance Outcome

Figure 29 below shows a comparison of temperature data before and after the application of the cool roof coating. Two sensors were installed in the dwelling; one in the roof cavity and one in an internal un-conditioned space. Temperature data logging began on 05/06/2012 and the cool roof coating was applied on 03/07/2012. The full series of ambient temperature data was not available so maximum and minimum temperature data from the Bureau of Meteorology website has been used for the period.

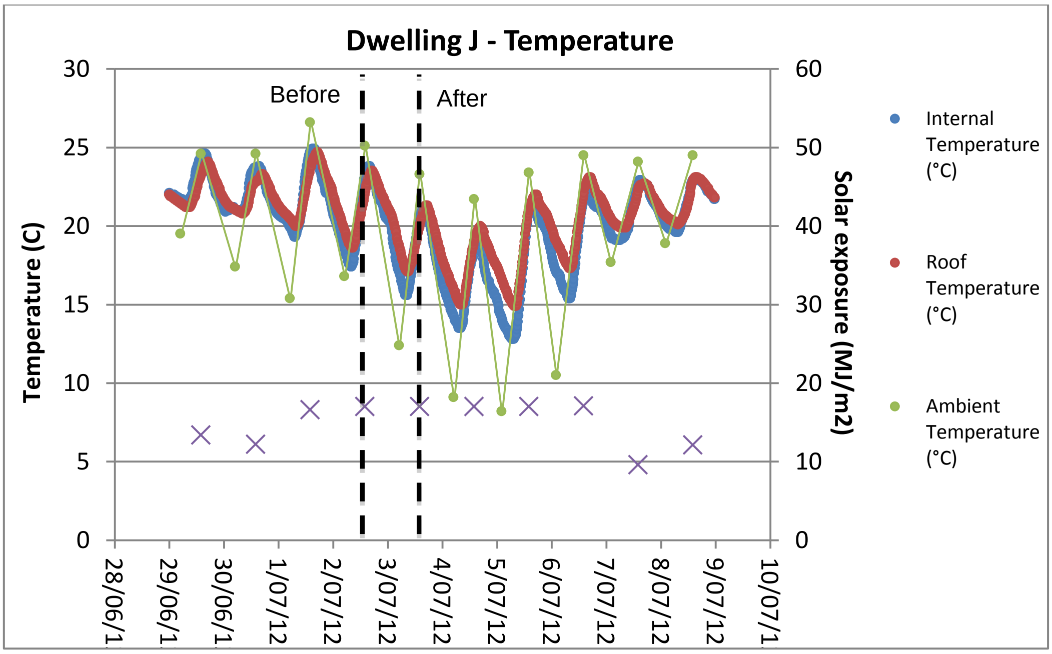


Figure 29: Dwelling J - Temperate readings before and after cool roof painting

Comparing two similar days with similar ambient temperature, solar insolation, and precipitation, the cool roof coating has reduced maximum roof cavity temperatures by 0.6˚C and maximum internal daytime temperatures by approximately 0.9°C (see Table 20 below). Average daytime roof cavity temperatures were reduced by 0.7°C and average internal daytime temperatures were reduced by 0.9°C. Note that the ambient temperature on the date used for comparison after application of cool roof (07/07/2012) had a maximum temperature 0.5°C cooler than the baseline date (30/06/2012), and this may have contributed to the measured cooling effect.

Table 20: Dwelling J - Summary of cool roof performance, comparing two similar days

Comparison of two similar days			
	Before	After	Difference
	30/06/2012	7/07/2012	
Maximum roof cavity temperature; ˚C	23.3	22.7	-0.6
Average daytime roof cavity temperature; ˚C (9am-9pm)	22.4	21.8	-0.7
Maximum internal temperature; ˚C	23.8	22.9	-0.9
Average daytime internal temperature; ˚C, (9am-9pm)	22.8	21.8	-0.9
Daily solar exposure; MJ/m^2	12.2	9.6	-2.6
Maximum ambient temperature; ˚C	24.6	24.1	-0.5
Precipitation (mm)	0.0	0.0	0.0
Average wind speed (km/h)	n/a	n/a	n/a

As the roof was painted in winter, the temperature data is unlikely to show the full temperature reduction benefit that could potentially be achieved during the summer cooling-demand period. However, this data provides an indication of the performance of cool roofs in winter months. Comparing temperature data in the dwelling with ambient temperature data before and after application of the cool roof coating it can be seen that roof cavity temperatures were previously on average 0.3˚C cooler than ambient conditions. Roof cavity temperatures after the cool roof were reduced, averaging 1.5˚C cooler than ambient temperatures (see Figure 30), resulting in an average temperature reduction of approximately 1.2˚C.

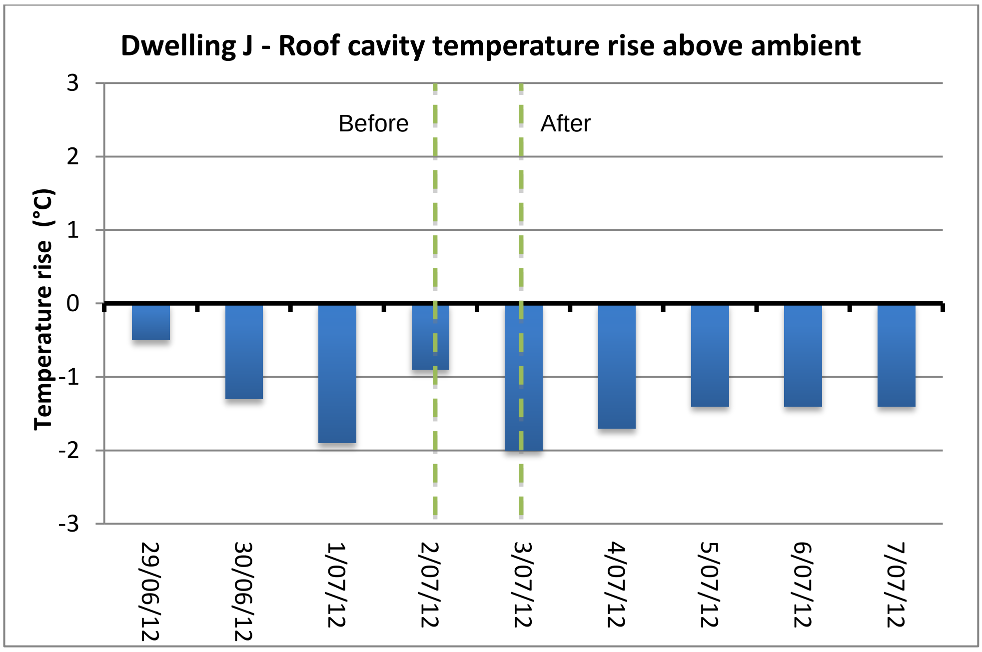


Figure 30: Dwelling J - Roof cavity temperature rise above ambient conditions

Similarly, the cool roof has had an impact on maximum internal temperatures. Maximum internal house temperatures previously averaged 0.1˚C warmer than ambient conditions prior to the cool roof, but were reduced to an average of 2.1˚C cooler than ambient conditions (see Figure 31), resulting in an average maximum temperature reduction of approximately 2.2˚C.

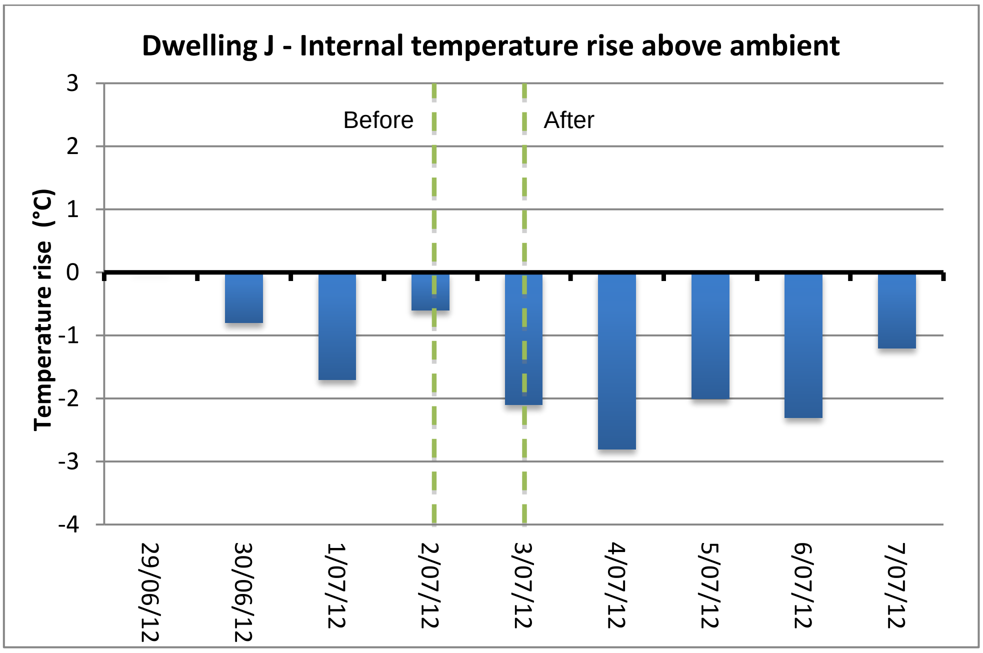


Figure 31: Dwelling J - Internal temperature rise above ambient conditions

Energy Consumption

The cool roof coating was applied during Q3 2012. Q1 and Q2 were chosen for analysis as these two quarters are most representative of the summer cooling-demand period for this dwelling. Q1 covers the period mid-October to mid-January; Q2 covers the period mid-January to mid-April. An average kWh/day figure was determined by averaging the total energy consumption over the total number of days in these two quarters. At the time of writing, however, Q1 2010 and Q2 2013 data was not available and therefore only Q2 2010 and Q1 2013 data was used for these respective summer periods.

Average daily electricity demand prior to application of the cool roof product was 7.1 kWh/day in the 2009/2010 summer period, 7.8 kWh/day in the 2010/2011 summer period, and 6.9 kWh/day in the 2011/2012 summer period. Following the application of the cool roof product, average daily electricity consumption has fallen to 4.8 kWh/day in Q1 2013 (see Figure 32).

For the purposes of this analysis, the 2011-12 summer period has been chosen as the baseline period for comparison. Comparing electricity consumption data after application of the cool roof product with the 2011-12 baseline, this dwelling has achieved a reduction in average daily energy consumption of approximately 31 per cent.

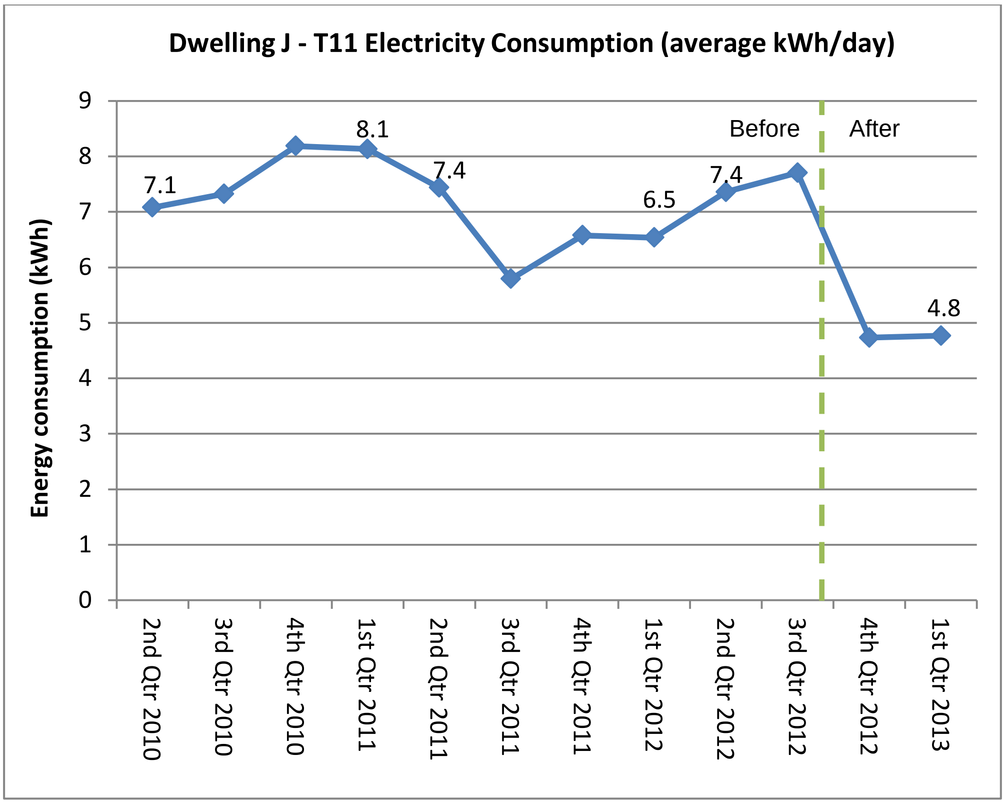


Figure 32: Dwelling J – Average daily T11 electricity consumption

Occupant Experience of the Cool Roof

An interview was conducted with the resident to obtain feedback about the pilot program and about their experience with their new cool roof. The occupant reported that the effectiveness of their cool roof has been hard to judge. They are frequently away from the house, and when at home they tend to spend a large portion of time on their recently renovated deck rather than inside where the effect of the roof might be more apparent. Both the house and portions of the roof are shaded by a leafy garden, which further cools the building. They were not large users of energy to begin with and were conservative with their use of air-conditioning, hence they have not noticed a significant difference with their energy bills. Nevertheless, the fact that the occupant reported that their house has been just as comfortable as usual during a particularly hot summer may be due to the moderating effects of the cool roof.

The roof of this dwelling had some rust and according to the resident was due for repair. They had heard about cool roofs through personal contacts at council and had also visited a display home that featured a cool roof product, however they needed time to think about the expense involved before opting for treatment. They stated that the information they received at the EcoFiesta was a factor in their eventual decision to have their own roof painted. For this participant, the main motivations were both the maintenance of the roof and the heat. They had noticed the temperatures increasing over a few years and preferred to leave the windows open for fresh air rather than relying on air conditioning for cooling.

The occupant had some reservations about the choice of colour, stating that 'white doesn't really match our colour scheme'. They felt they would have been more hesitant to proceed if their roof was more visible to the street, however they have not found it particularly noticeable in the months since installation. Despite their reservations about aesthetics, they stated that they would certainly consider having a cool roof installed if they were to move to a new address. They felt that this would be an excellent option if the roof needed repairs, and that they would be likely to incorporate a cool roof into a new building if they were starting from scratch. Overall, they would consider a cool roof as one option amongst a suite of sustainability and energy efficiency measures. They would also recommend it to their family and friends particularly if their roof needed maintenance, and they "admire that it gives an opportunity for retrofitting which is more affordable than installing an entirely new roof". They were also very positive about the pilot program, stating that they think it is 'a great initiative', and that receiving additional information and a discount was a powerful motivator for Townsville residents to install a cool roof.

Participant Testimonial

"We were considering the options for insulation and maintenance on our roof when we were attracted to the Townsville Solar City Cool Roof Program display at the annual Ecofiesta.

We decided that it was a good, cost-effective option, enabling us to 'retrofit' rather than replace the roof entirely. We believe that the pre-treatment of the roofing iron plus the protective/reflective coating has extended the life of our roof and will give us additional benefits of cooling.

Our house is slightly elevated, well ventilated and surrounded by a shady garden, so it has always been reasonably comfortable in hot weather. We extended and roofed the deck just prior to painting the roof, enabling us to enjoy the benefits of outdoor living, more shade to the interior and heat reflection from the roof.

Since painting the roof we haven't noticed a significant difference in the temperature on a daily basis, but we have observed that the house does not heat up so much when locked up during our absence, particularly in the hot summer. When opened up, it appears to cool down relatively quickly.

We are very happy with the decision we made to sign on to the Townsville Solar City Cool Roof Program, as one more step towards sustainable living. We commend the council for its leadership with the Solar Cities program and the opportunities, education and encouragement if provides to residents to promote sustainability."

Dwelling K (a single storey brick house in Deeragun)

Background Information

Dwelling K is a single storey brick house in Deeragun. The original roof was unpainted corrugated iron. The cool roof coating was applied on 14/10/2011. A summary of the dwelling characteristics is presented in Table 21 below.

Table 21: Building and roof profile for Dwelling K

Dwelling K - House and roof characteristics	
Type	House (Single storey brick)
Suburb	Deeragun
Roof materials	Corrugated iron
Original roof colour	Unpainted
Roof pitch	Steep
Insulation	n/a
Extent of shade	Negligible
Levels	n/a
Air-conditioned	n/a

Temperature Performance Outcome

Temperature data for Dwelling K is not available. The resident was a private customer of one of the painters who was approached several months after their roof was painted to ask if they would be willing to contribute to the pilot program by granting access to energy consumption data and providing feedback on their experience with their new cool roof.

Energy Consumption

The cool roof coating was applied during Q4 2011. Q1 and Q2 were chosen for analysis as these two quarters are most representative of the summer cooling-demand period for this dwelling. Q1 covers the period mid-October to mid-January; Q2 covers the period mid-January to mid-April. An average kWh/day figure was determined by averaging the total energy consumption over the total number of days in these two quarters. At the time of writing, Q2 2013 data was not available and therefore only Q1 2013 data was used for this summer period.

Average daily electricity demand prior to application of the cool roof product was 10.4 kWh/day in the 2009/2010 summer period, and 6.3 kWh/day in the 2010/2011 summer period. Following the application of the cool roof product, average daily electricity consumption has fallen to 5.8 kWh/day in the 2011/2012 summer period, and 5.8 kWh/day in Q1 2013 (see Figure 33).

For the purposes of this analysis, the 2010-11 summer period has been chosen as the baseline period for comparison. Comparing electricity consumption data after application of the cool roof product with the 2010-11 baseline, this dwelling has achieved a reduction in average daily energy consumption of approximately 7.9 per cent.

Analysing the 2012/13 summer period, it appears that the energy consumption reductions have been approximately maintained. Comparing only Q1 figures after application of the cool roof, average daily electricity consumption has increased very slightly from 5.6 kWh/day in Q1 2012 to 5.8 kWh/day in Q1 2013, representing an increase of 3.6 per cent. As this is a small increase of only 0.2 kWh/day, energy use could be considered to have been approximately maintained.

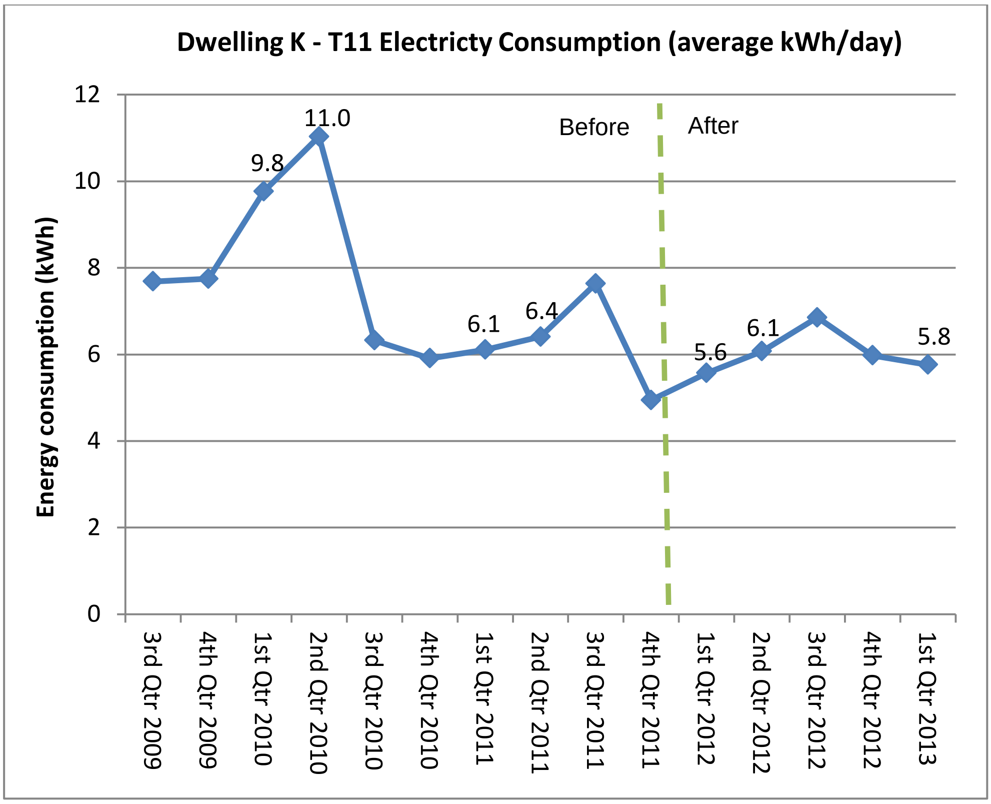


Figure 33: Dwelling K – Average daily T11 electricity consumption

Occupant Experience of the Cool Roof

The resident of dwelling K requested not to be contacted for an interview.

Dwelling L (a single storey masonry block house in Kirwan)

Background Information

Dwelling L is a one-level masonry block house located in Kirwan. The original roof was an off-white Colourbond corrugated metal. It receives minimal afternoon shading and had recently had solar panels installed, which shade approximately one fifth of the total roof surface. The cool roof coating was applied on 08/06/12. A summary of the dwelling characteristics is presented in Table 22.

Table 22: Dwelling L - Building and roof profile

Dwelling L - House and roof characteristics	
Type	House (Masonry block)
Suburb	Kirwan
Roof materials	Corrugated iron
Original roof colour	Off-white
Roof pitch	Steep
Insulation	Yes (reflective only)
Extent of shade	Negligible
Levels	One
Air-conditioned	Yes

Temperature Performance Outcome

Figure 34 shows a comparison of temperature data before and after the application of the cool roof coating. Two sensors were installed in the dwelling; one in the roof cavity and one in an internal un-conditioned space. Temperature data logging began on 28/05/2012 and the cool roof coating was applied on 08/06/2012. The cool roof coating was applied during winter on this dwelling and the data provides some indication of the performance of cool roofs in winter conditions.

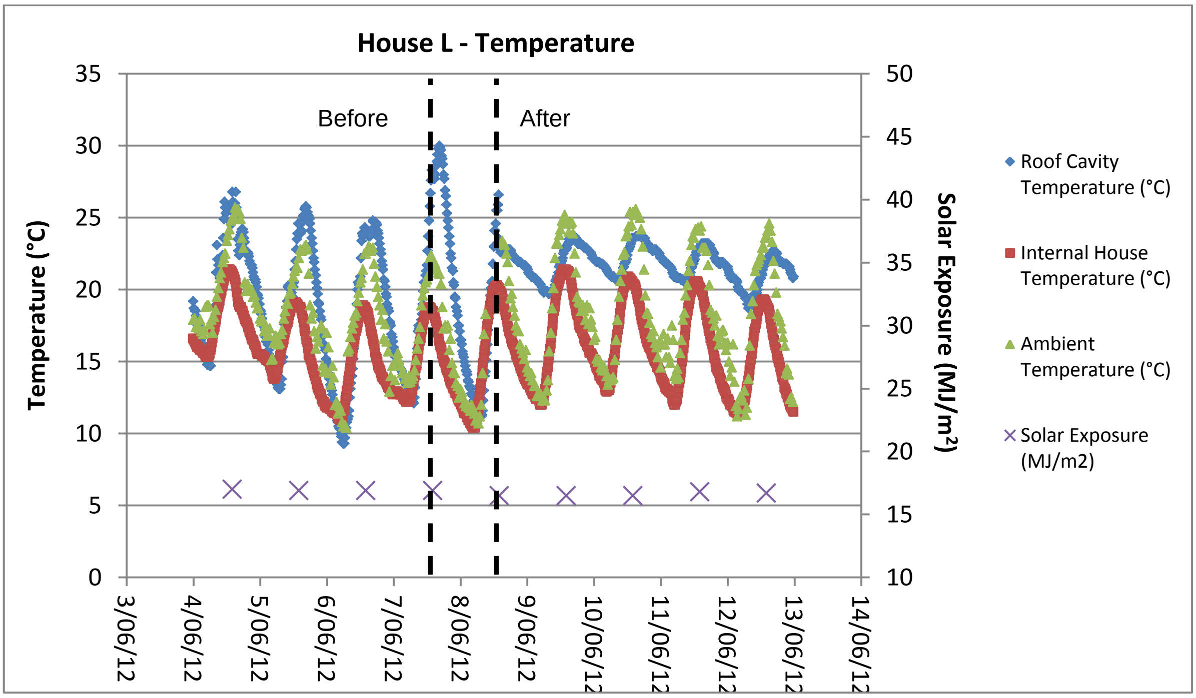


Figure 34: A Dwelling L - Temperate readings before and after cool roof painting

Comparing two similar days with similar ambient temperature, solar insolation, and precipitation, the cool roof coating has reduced maximum roof cavity temperatures by 2.6°C, however maximum internal temperatures actually increased by 1.5°C (see Table 23 below). Average daytime roof cavity temperatures decreased by 0.1°C and average daytime internal temperatures increased by 1.3°C. Note that the date used for comparison after application of cool roof (11/06/2012) had a maximum temperature 1.3°C warmer than the baseline date (05/06/2012) which may partially account for the internal temperatures being 1.5°C after the cool roof was applied.

Table 23: Dwelling L – Summary of cool roof performance, comparing two similar days

Comparison of two similar days			
	Before	After	Difference
	05/06/12	11/06/12	
Maximum roof cavity temperature; ˚C	25.8	23.2	-2.6
Average roof cavity temperature; ˚C, (9am-9pm)	22.4	22.3	-0.1
Maximum internal temperature; ˚C	19.1	20.6	1.5
Average internal temperature; ˚C, (9am-9pm)	17.0	18.3	1.3
Daily solar exposure; MJ/m^2	16.9	16.8	-0.1
Maximum ambient temperature; ˚C	23.1	24.4	1.3
Precipitation (mm)	0.0	0.0	0.0
Average wind speed (km/h)	19.2	9.6	-9.5

The cool roof has reduced roof cavity temperatures. Comparing temperature data in the dwelling with ambient temperature data before and after application of the cool roof coating it can be seen that roof cavity temperatures were previously on average 1.87˚C warmer than ambient conditions. Roof cavity temperatures after the cool roof were reduced, averaging 1.65˚C cooler than ambient temperatures (see Figure 35), resulting in an average temperature reduction of approximately 3.5˚C.

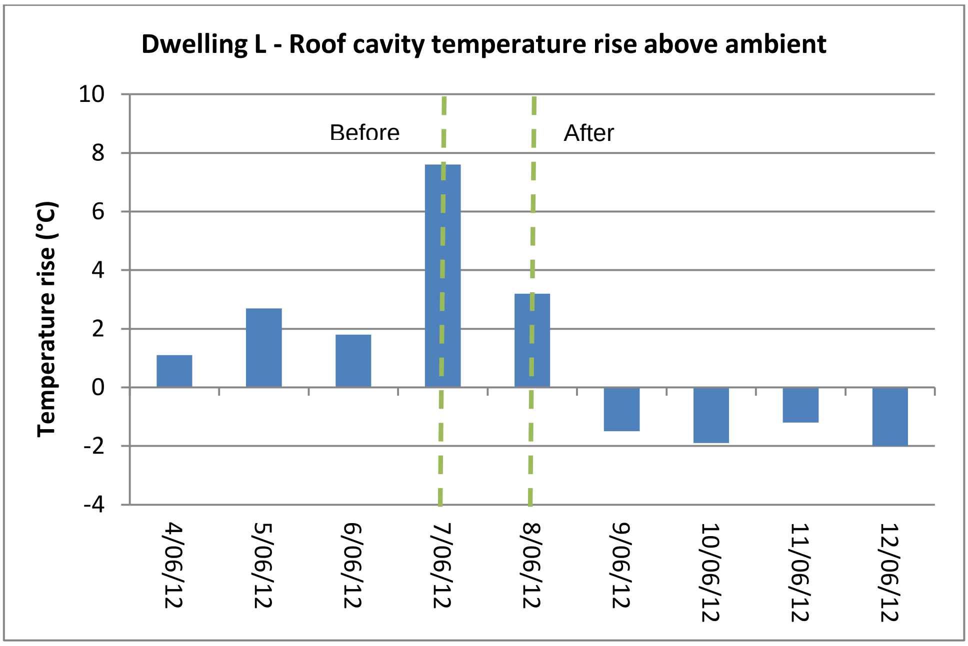


Figure 35: Dwelling L - Roof cavity temperature rise above ambient conditions

The cool roof has had a minimal impact on maximum internal temperatures. Maximum internal house temperatures previously averaged 4.13˚C cooler than ambient conditions prior to the cool roof, and were reduced slightly to an average of 4.4˚C cooler than ambient conditions (see Figure 36), resulting in an average maximum temperature reduction of approximately 0.3˚C.

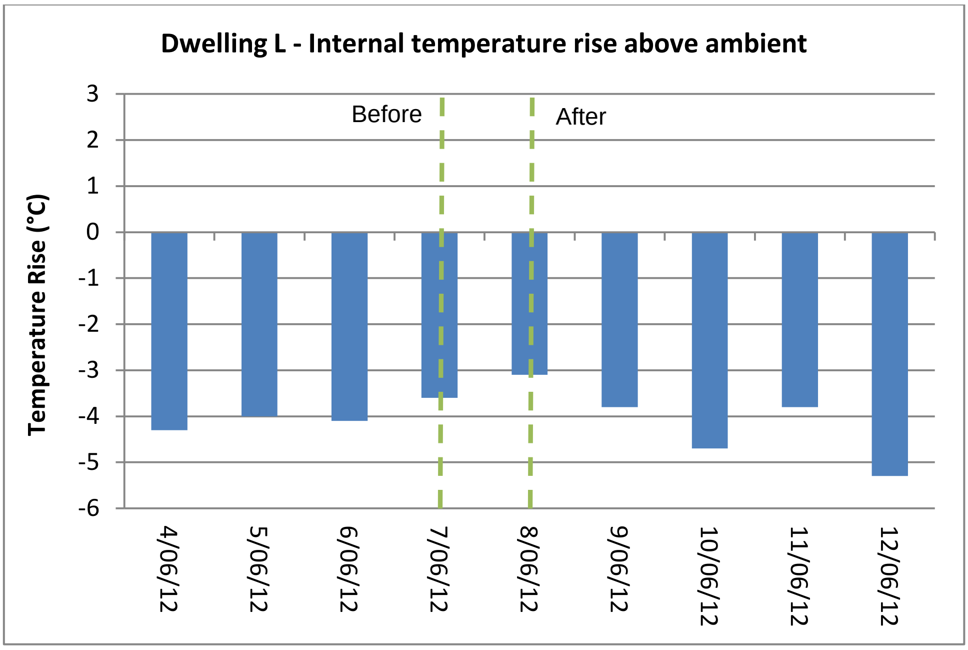


Figure 36: Dwelling L - Internal temperature rise above ambient conditions

Electricity Consumption

The cool roof coating was applied during Q3 2012. Q4 and Q1 were chosen for analysis as these two quarters are most representative of the summer cooling-demand period for this dwelling. Q4 covers the period mid-August to mid-November; Q1 covers the period mid-November to mid-February. An average kWh/day figure was determined by averaging the total energy consumption over the total number of days in these two quarters.

Average daily electricity demand prior to application of the cool roof product was 22.3 kWh/day in the 2010/2011 summer period, and 18.3 kWh/day in the 2011/2012 summer period. Following the application of the cool roof product, average daily electricity consumption has fallen to 8.5 kWh/day in the 2012/2013 summer period (see Figure 37).

For the purposes of this analysis, the 2011-12 summer period has been chosen as the baseline period for comparison. Comparing electricity consumption data after application of the cool roof product with the 2011-12 baseline, this dwelling has achieved a reduction in average daily energy consumption of approximately 53 per cent.

Note: This dwelling had solar panels installed during Q4 2012, however the energy produced by the solar panels has been removed from the analysis to ensure only T11 electricity consumption is considered. The addition of solar panels has not therefore contributed to the electricity reduction figures presented here.

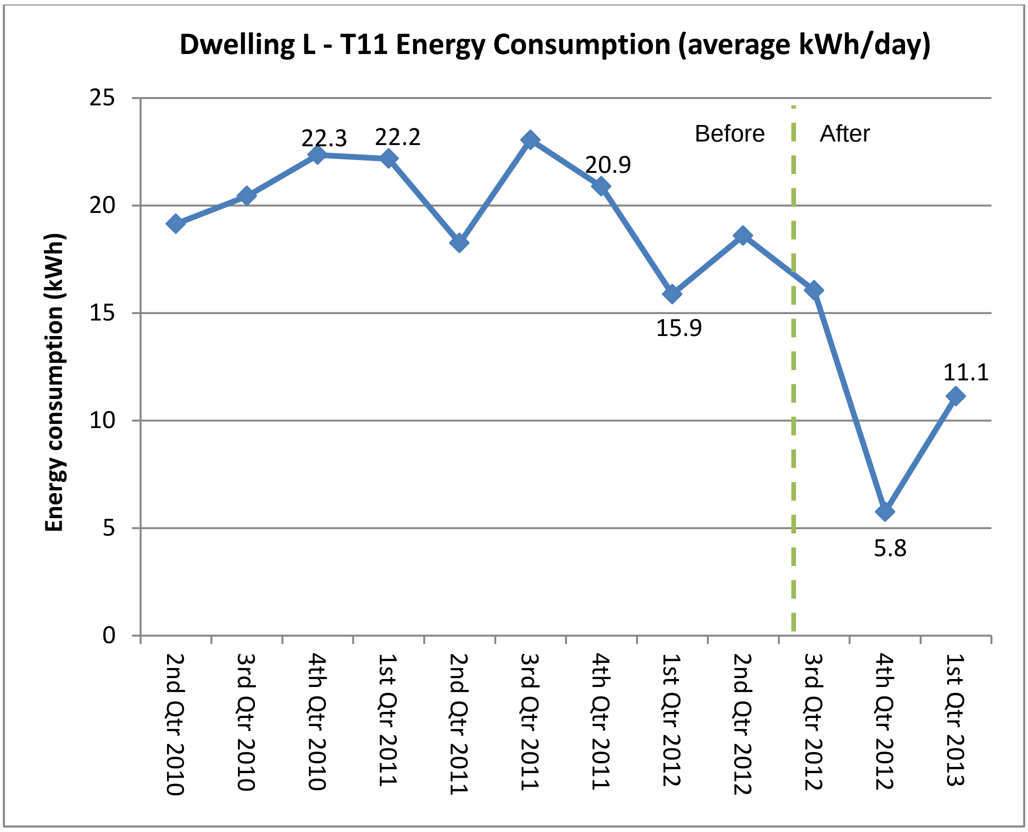


Figure 37: Dwelling L – Average daily T11 electricity consumption

Occupant Experience of the Cool Roof

An interview was conducted with the resident to obtain feedback about the pilot program and about their experience with their new cool roof. After summer, the occupant reported a noticeable difference in internal temperatures. The house was generally cooler, and much slower to heat up particularly when it has been closed during the day. On one 36 degree day the resident reported that it was only 28 degrees inside - without the air conditioning. They feel that the effectiveness of the cool roof may have been enhanced by the new solar panels, which provide partial shading. The occupant reported that the interior temperature felt cooler in winter than in previous years.

For this occupant the catalyst for having the roof treated was the decision to have solar panels installed, thus necessitating having the existing, worn coating repaired before the panels arrived. They also said that the previously prohibitive cost had been lowered, making it a more affordable option.

The neighbors, whose houses are in need of similar renovations, appreciated that the new paint did not reflect glare as the previous coating had. The resident said that they would definitely recommend cool roofs to them, and would definitely consider having one installed if they were to move in the future. The occupant was keen to note that there is an excellent opportunity for manufacturers to provide this kind of coating as an option for all new roofs. Furthermore, they felt that it should be mandated in building legislation and that all new buildings should be required to have this sort of coating on their roofs. They feel that cool roofs are particularly appropriate for Townsville, stating that *"it's a smart move for everybody to have (these systems) in place."*

Participant Testimonial – still needs confirmation

"I do think that it is a good thing; it all adds to the reduction of power use, as does solar; I honestly believe that there are marketing opportunities available for the future, especially in building new houses, and these could be included in regulation, such as making it mandatory for new houses to have this kind of paint used on the roof..." "...It's a smart move for everybody to have (these systems) in place." [Verbal confirmation received. Awaiting written confirmation]

Dwelling M (a high-set timber house in Kelso)

Background Information

Dwelling M is a high set timber house located in Kelso. The original roof was an unpainted, corrugated iron roof receiving no shade during the day. The cool roof coating was on 13/10/2011. A summary of the dwelling characteristics is presented in Table 24.

Table 24: Dwelling M - Building and roof profile

Dwelling M - House and roof characteristics	
Type	House (High set timber)
Suburb	Kelso
Roof materials	Corrugated iron
Original roof colour	Unpainted
Roof pitch	Moderate
Insulation	n/a
Extent of shade	None
Levels	One
Air-conditioned	Yes

Temperature Performance Outcome

Temperature data for Dwelling M is not available. The resident was a private customer of one of the painters who was approached several months after their roof was painted to ask if they would be willing to contribute to the pilot program by granting access to energy consumption data and providing feedback on their experience with their new cool roof.

Electricity Consumption

The cool roof coating was applied during Q4 2011. Q1 and Q2 were chosen for analysis as these two quarters are most representative of the summer cooling-demand period for this dwelling. Q1 covers the period mid-October to mid-January; Q2 covers the period mid-January to mid-April. An average kWh/day figure was determined by averaging the total energy consumption over the total number of days in these two quarters. At the time of writing, Q2 2013 data was not available and therefore only Q1 2013 data was used for this summer period.

Average daily electricity demand prior to application of the cool roof product was 68.7 kWh/day in the 2009/2010 summer period, and 55.0 kWh/day in the 2010/2011 summer period. Following the application of the cool roof product, average daily electricity consumption has fallen to 32.5 kWh/day in the 2011/2012 summer period, and 33.0 kWh/day in Q1 2013 (see Figure 38).

For the purposes of this analysis, the 2010-11 summer period has been chosen as the baseline period for comparison. Comparing electricity consumption data after application of the cool roof product with the 2010-11 baseline, this dwelling has achieved a reduction in average daily energy consumption of approximately 41 per cent (for the 2011/12 summer period).

Analysing the 2012/13 summer period, it appears that the energy consumption reductions have been maintained, and have potentially reduced further. Comparing only Q1 figures after application of the cool roof, average daily electricity consumption has fallen from 44.8 kWh/day in Q1 2012 to 33.0 kWh/day in Q1 2013, representing a reduction of a further 26 per cent.

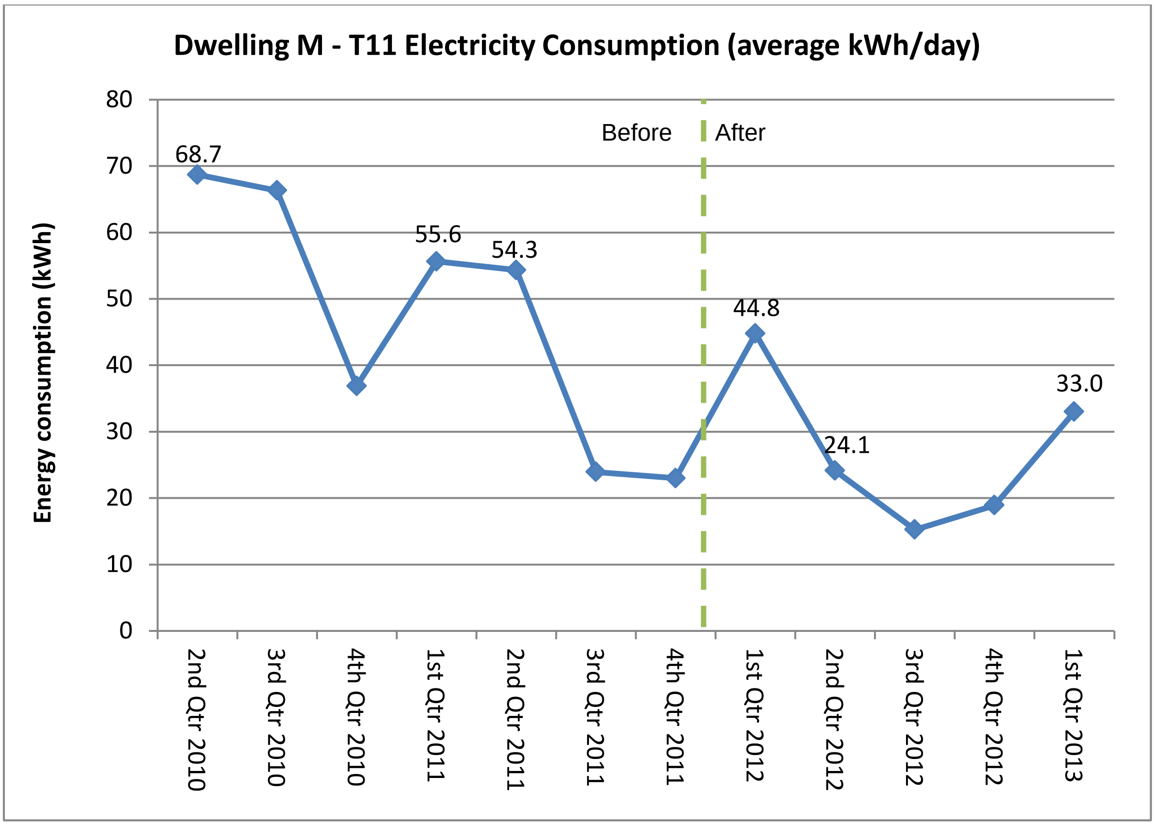


Figure 38: Dwelling M – Average daily T11 electricity consumption

Occupant Experience of the Cool Roof

An interview was conducted with the resident to obtain feedback about the pilot program and about their experience with their new cool roof. The occupant reported that the roofing has made a noticeable difference to the internal temperature. Since treatment the occupant has been impressed with the effectiveness of the new roof, remarking that 'it really works' and that 'it used to be a lot hotter'. During the initial interview the occupant estimated that the cool roof had cooled the house by around two or three degrees. The occupant reported that not only has it made a noticeable difference to the internal temperature – thereby making the house more comfortable – but they have also noted a reduction in their energy use. This is not an insignificant result, given that the occupant does not feel that their habits have changed or that they are being more mindful of their energy use.

The decision to install a cool roof was partly motivated by the fact that the roof already required maintenance. His aim was to not only improve the look of the roof and protect it, but also to help cool the house, which becomes very important during the hotter summer months.They found out about the program through personal contacts who said that it was well worth the cost, and the occupant felt that it sounded like 'a good idea'. They also wanted to make their house cooler for summer. They are also very pleased with the visual effect, stating that it has definitely improved the look of the house. No neighbours have commented on the change, possibly because the roof of the home is not particularly visible from street level. The resident has stated that they would definitely recommend a cool roof to their friends, and that they would definitely consider having another one installed if they were to move into a new address.

Participant Testimonial

"It works and it's made the roof and the house look good. I'd recommend it." [Verbal confirmation received. Awaiting written confirmation]

Dwelling N (a low-set brick house in Annandale)

Background Information

Dwelling N is a single level brick house in Annandale. The original roof was a brown decramastic tile roof in need of repainting. The cool roof coating was applied on 24/10/2011 and 25/10/11. A summary of the dwelling characteristics is presented in Table 25.

Table 25: Dwelling N - Building and roof profile

Dwelling N - House and roof characteristics	
Type	House (Low-set brick)
Suburb	Annandale
Roof materials	Decramastic tile
Original roof colour	Brown
Roof pitch	Moderate
Insulation	n/a
Extent of shade	None
Levels	One
Air-conditioned	Yes

Temperature Performance Outcome

Temperature data for Dwelling N is not available. The resident was a private customer one of the painters who was approached several months after their roof was painted to ask if they would be willing to contribute to the pilot program by granting access to energy consumption data and providing feedback on their experience with their new cool roof.

Electricity Consumption

The cool roof coating was applied during Q4 2011. Q1 was chosen for analysis as this quarter is most representative of the summer cooling-demand period for this dwelling. Q1 covers the period late-November to early-March. An average kWh/day figure was determined by averaging the total energy consumption over the total number of days in this quarter.

Average daily electricity demand prior to application of the cool roof product was 71.7 kWh/day in the 2009/2010 summer period, and 68.8 kWh/day in the 2010/2011 summer period. Following the application of the cool roof product, average daily electricity consumption has fallen to 29.2 kWh/day in Q1 2012 (see Figure 39).

For the purposes of this analysis, the 2010-11 summer period has been chosen as the baseline period for comparison. Comparing electricity consumption data after application of the cool roof product with the 2010-11 baseline, this dwelling has achieved a reduction in average daily energy consumption of approximately 57 per cent.

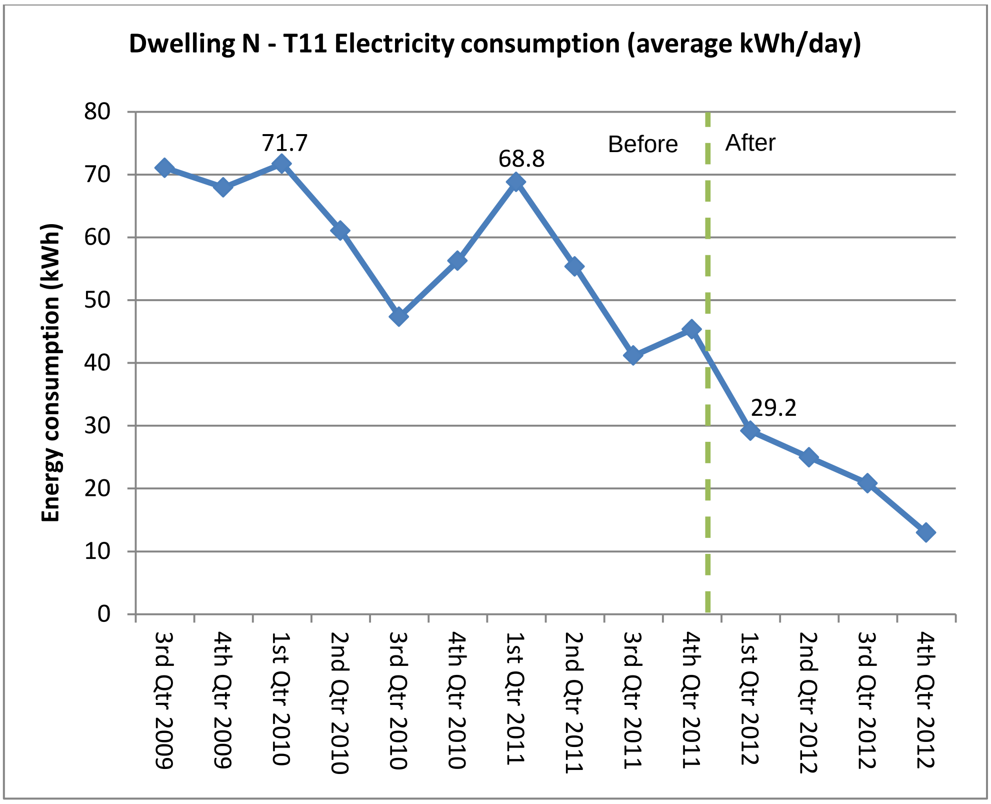


Figure 39: Dwelling N – Average daily T11 electricity consumption

Occupant Experience of the Cool Roof

An interview was conducted with the resident to obtain feedback about the pilot program and about their experience with their new cool roof. The resident reports being very happy with the result, stating that since the application of the cool roof paint "the house is noticeably cooler and the air-conditioners don't work as hard". The occupant had heard about the energy saving benefits of cool roof and decided to get one. The resident reported that cost was initially a barrier, but that the discount offer made it a more affordable option. The consideration of the energy saving and thermal comfort benefits also helped them overcome the cost barrier. The roof was also in poor condition and needed painting anyway, so this was also a consideration.

The resident reports noticing a reduction in their energy bill since getting the cool roof. They stated that they would recommend cool roofs to friends and family and that they would install a cool roof again if they moved to another address. The occupant reported that that they felt the new roof looks good, but also felt it didn't match the house, which is a dark colour with green gutters. Despite this, the resident reported being very pleased with the overall result, stating that the house is now 'much cooler'. The house has six split-system air conditioners that the residents do not need to use as often as they did prior to roof treatment, and when they do the units operate more efficiently. Previously these had to be set at 21°C in order for the house to stay comfortable, but are now set at 25°C. As a result their energy bills have also decreased. A neighbour commented on the roof and asked if it had really made a difference, and the occupant was happy to report that they would recommend it to others. This resident would get another cool roof if they were to move into a new house and is strongly supportive of their use, stating that cool roof products 'should be mandatory in Townsville'.

Participant Testimonial

The participant declined to provide a testimonial.

Key recommendations and considerations for the community wide program

Reductions in Temperature from a 'Cool Roof' in Townsville

The cool roof coatings were found to be effective in reducing internal temperatures in all of the participating dwellings, with significant temperature reductions achieved during the summer period, as shown in Table 26. Maximum roof cavity temperatures were reduced by up to 17°C, while maximum internal living area temperatures were reduced by up to 2.5°C. The average maximum temperature reduction in internal living areas was 1.83°C. These figures are in line with other national and international studies on cool roofs.

Table 26: Summary of summer temperature reductions across participating pilot program houses

Comparison of two similar days (average of houses; n=11)	Temperature change (°C)
Maximum roof cavity temperature reduction; ˚C	-9.5 to -17
Average daytime roof cavity temperature reduction; ˚C (9am-9pm)	-6.4 to -15.3
Maximum internal temperature reduction; ˚C	-1.2 to -2.5
Average daytime internal temperature reduction; ˚C, (9am-9pm)	-0.6 to -1.5

Three dwellings had cool roof products applied during winter, which provided an indication of the performance of the cool roof in cool conditions, as shown in Table 27. A sample size of three is too small to draw any firm conclusions from, however two houses experienced a reduction in roof cavity and internal temperature, while the other house unexpectedly experienced increased temperatures. The house that experienced increased temperatures during winter originally had a white roof prior to application of the new cool roof paint, and this may have influenced the results.

Table 27: Summary of winter temperature reductions across participating pilot program houses

Comparison of two similar days (average of houses; n=3)	Temperature change (°C)
Maximum roof cavity temperature reduction; ˚C	-0.6 to -4.9
Average daytime roof cavity temperature reduction; ˚C (9am-9pm)	-0.1 to -3.2
Maximum internal temperature reduction; ˚C	1.5 to -0.9
Average daytime internal temperature reduction; ˚C, (9am-9pm)	1.3 to -0.9

Key findings for future programs include:

- The temperature sensors used in the pilot program were found to be acceptable for the purpose of logging temperature data. The temperature sensors were readily available, reliable, un-obtrusive, easily installed, and cost-effective. These temperature sensors would be appropriate for use in a community-wide program. The painters suggested that consideration be given to having participants visited by TCC staff at the time of registration in the program to fill in paperwork and install the sensors ahead of time. This would provide a longer data set prior to the roof being painted as often the painters have only a day or two notice of the location of jobs.
- The use of two temperature sensors; one in the roof cavity and one in an internal unconditioned space, was found to be acceptable for the pilot program. The most relevant

and important dataset was from the sensors located in the living area, and thus a single temperature sensor in an appropriate internal non air-conditioned space would provide adequate data to evaluate the effectiveness of the cool roof coating. However, given the ease of installation and affordable price, two sensors would be still be considered to be appropriate for a community-wide program to allow temperatures in the roof cavity to be recorded.

- The use of Bureau of Meteorology climate data was found to be acceptable for the purpose of comparing temperature data from the pilot program. BOM data was readily available, reliable, and cost-effective. It provided an adequate and simple means of comparing similar days to help determine temperature reductions in the pilot program houses.

Reductions in Electricity Consumption from a 'Cool Roof' in Townsville

The pilot program sought to evaluate a cost-effective method for measuring changes in household electricity consumption in collaboration with the energy utility to see whether this would be a viable component of a community-wide program. Household electricity consumption data was provided by Ergon Energy in the form of aggregated quarterly data, with written permission received from residents and under Griffith University Ethics Clearance. The main benefits of the use of this data were ease of access to data and the low-cost involved in sourcing data directly from the utility without the need to fund and install additional energy monitoring technology. The data provided by the utility was for 3 month periods and it would be beneficial to have greater granulation in future programs to be able to investigate the period before and after the roof coating. In discussions with Ergon Energy, no other data is available that would provide a higher resolution. However, where dwellings have already installed a smart meter or other similar equipment that may provide high resolution energy data, this should be capitalized upon in any subsequent community-wide program.

For each participating dwelling Ergon Energy provided up to 2-3 years of electricity use data up to and including the most recent data available. This allowed a comparison of electricity use before and after application of the cool roof. For the purposes of this analysis, only tariff 11 electricity consumption has been considered. Tariff 11 is the tariff used for general residential electricity use 24 hours per day for all light and power used in dwellings. All other electricity consumption from other tariffs has been removed from the analysis, including tariff 31, tariff 33, and the solar feed-in tariff (SS). This has been done to remove the impact of off-peak equipment (such as hot water systems) and solar energy from the calculations.

The primary energy-related benefit expected to result from a cool roof is a reduction in energy used to cool a dwelling through the use of mechanical cooling equipment such as an air-conditioner. The predominant impact of this is assumed to be in the warmer summer months, when cooling demand is highest. Unfortunately, the period that comprises each dwelling's 3-month energy billing quarter has no relation to local climatic conditions or seasons. As such the 'summer period' was taken to be the one or two quarters that most aligned with the hottest months in Townsville. Baseline electricity consumption data was taken to be the summer period immediately prior to application of the cool roof. In most cases this baseline was during the 2010/2011 summer period. Where a cool roof was applied during a summer period, the previous year was used as the baseline. Summer electricity consumption data following application of the cool roof was comparing against the baseline to determine the change in electricity consumption.

Analyzing electricity consumption in the participating dwellings, it can be seen that the average reduction in summer tariff 11 electricity consumption was 32.3 per cent (see Table 28). The majority of dwellings experienced a significant reduction in electricity consumption of approximately 20-60 per cent. Two dwellings (Dwelling E and Dwelling K) experienced only a slight reduction in electricity use (4.1 per cent and 7.9 per cent respectively), however it should be noted that both of these dwellings were already extremely energy efficient to begin with, using only 5-6 kWh/day each prior to application of the cool roof. One dwelling (Dwelling F) experienced a slight increase in energy consumption (4.0 per cent).

As tariff 11 is the general tariff for household electricity consumption, it should be noted that other factors may also have contributed to the reduction in electricity use, including efficiency upgrades of other equipment and appliances (e.g. kitchen appliances, fridges, televisions) and more energy-efficient occupant behaviour (as noted in the sections above). During the interviews with participating households, residents were asked if they could think of any other factors that may have influenced their energy use, and these factors have been noted in the occupant experience sections.

Table 28: Tariff 11 Electricity Reduction in Pilot Program Houses

Dwelling	T11 Electricity Use Reduction (%)
Dwelling A	-20.6%
Dwelling B	-57.8%
Dwelling C	-42.6%
Dwelling D	-33.9%
Dwelling E	-4.1%
Dwelling F	+4.0%
Dwelling G	-59.2%
Dwelling H	-19.9%
Dwelling I	-26.9%
Dwelling J	-30.4%
Dwelling K	-7.9%
Dwelling L	-53.6%
Dwelling M	-40.9%
Dwelling N	-57.6%
Average	-32.3%

In order to compare the electricity use data with the local average, residential T11 electricity consumption for the entire Townsville and Lower-Burdekin region is provided in Figure 40 for comparison with the pilot program houses. For the purposes of this analysis, the period from the start of September to the end of December has been used to provide an indication of the summer cooling-demand period during 2010, 2011 and 2012. At the time of writing, no data was available beyond December 2012.

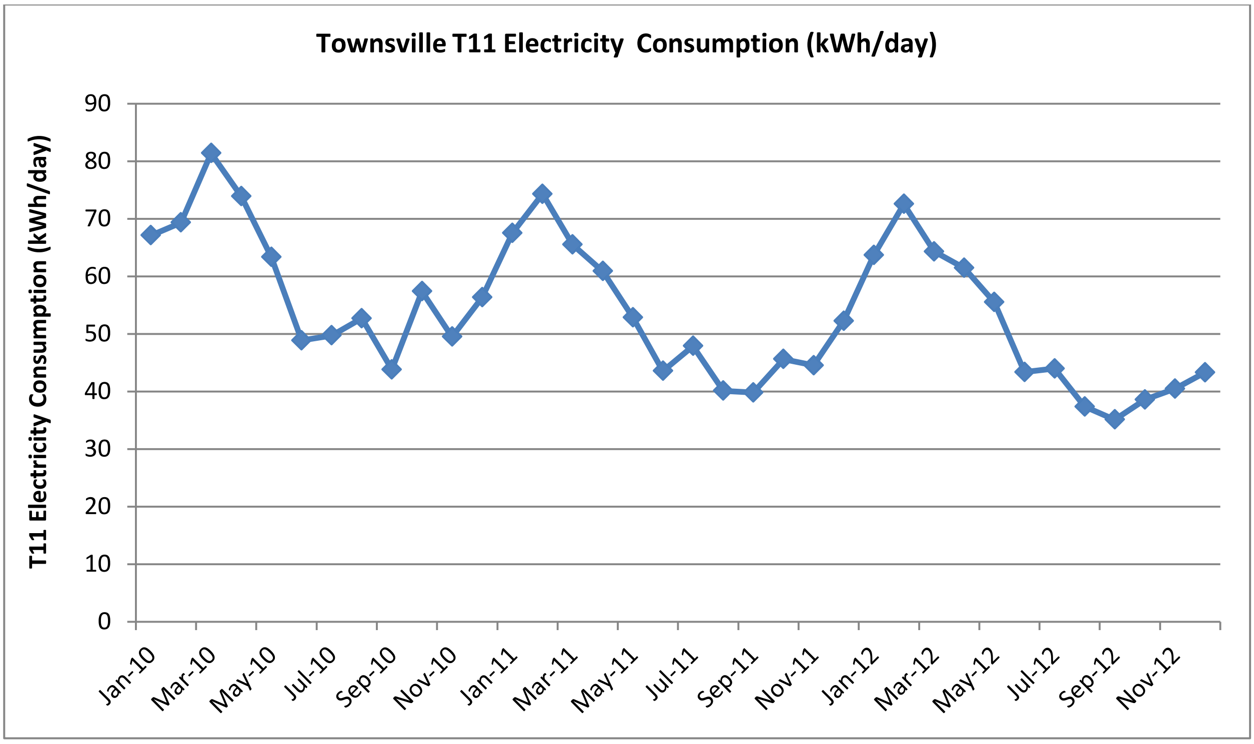


Figure 40: Townsville and Lower-Burdekin Region T11 Electricity Consumption

Analysing the change in electricity demand during the period Sept-Dec in 2010, 2011 and 2012, it can be seen that average daily T11 electricity consumption was approximately 52 kWh/day in 2010 and 46 kWh/day in 2011, falling to 39 kWh/day in 2012. Comparing 2012 against 2010, this represents a reduction in average electricity use of approximately 23.9 per cent. Comparing 2012 against 2011 this represents a reduction in average electricity use of 13.6 per cent. By comparison, the average T11 electricity reduction in the pilot program houses was 32.3 per cent.

Key findings for future programs include:

- Energy data for the dwellings that participated in the pilot program appear to show a decrease in energy consumption. However, the low resolution of available data has not allowed a thorough analysis of the impact of the cool roofs on energy consumption.
- The average reduction in energy use of 32.3 per cent is larger than the average reduction in residential electricity use seen across the Townsville and Lower-Burdekin region, however the small sample size of pilot program participants is too small to determine conclusively if this is a statistically significant result, especially given the low-resolution of the data.
- Dwellings that have already installed a 'smart meter' represent an opportunity to capture high resolution energy data that may allow a more precise analysis of the energy demand reduction potential of cool roofs. Any opportunity to collect data from such houses should be capitalised upon.
- If consent forms are needed for any aspect of a future program, it will be essential to ensure that these are given to, and collected from, the household at an opportune time, such as when any of the cool roof program team are physically with the household. This may include when the household is signing up to be part of the program, when they are having their roof painted, or during other program aspects.
- Discussions with Ergon Energy revealed that the process of extracting electricity data and generating reports for the research team was somewhat time consuming. The main reason for this was that data requests were initially made intermittently as pilot program participants

returned their ethics forms. In future, the research team should accumulate a large number of ethics forms and request all participant data at one time, preferably shortly after the end of the summer period. This will also ensure the most recent summer electricity data is included in the data.

- Electricity data supplied to the research team was often incomplete, requiring additional follow up. This may be due to the database software available. In order to further streamline the data collection and analysis process a template should be supplied to Ergon Energy for any future program.

Collecting roof characteristics and participant demographics

The painters participating in the pilot program were provided with checklists to complete for each participating house to gather information about the dwelling, including the original roof characteristics and details of the new cool roof coating.

Key findings for future programs include:

- The painters' checklists weren't completed for all dwellings as anticipated in the pilot program design, meaning information needed for comparing the impact of dwelling characteristics on temperature reduction had to be obtained from the householder in many cases. Reasons for painters not having completed the checklists are hypothesised to include:
- Lack of appreciation of the purpose of the checklists;
- Poor communication of the process for filling in the checklists to third-party contractors;
- Lack of time, and lack of prompts to fill these in.
- It will be important to include a monitoring element for future programs that ensures relevant forms and paperwork is filled in for each dwelling.

Understanding participant experience (Post program survey)

To investigate potential benefits of the cool roof experienced by participating households, as well as to gain further insights into the barriers and benefits to having a cool roof, a post program participant survey was conducted with pilot program participants. Participants were asked a series of questions regarding their experience with the 'Cool Roof' Pilot Program and their new cool roof (see Appendix B). Responses were overwhelmingly positive and the general consensus is that residents feel that the cool roof has reduced temperatures in their homes.

> *"We had the roof painted in November when the weather was starting to warm up. We could not believe how much cooler the house was the day after it was painted. The house is normally all locked up during the day and use to be quite hot when we got home in the afternoon. After the painting the house was cool to walk into at the end of the day. Our carport and patio are just the bare metal colorbond roof. You can put your hand on the underside of the colorbond in the middle of a hot day and the metal is not hot at all, where before it would have burnt you. We found that when home we did not put the fans on until later in the day and there was reduced use of air-conditioning during the day, as it was only needed on the really hot, humid days. I have certainly passed the word onto friends and know of a couple that have had their roofs painted."*

Pilot Program Participant with a single story

1980s era low-set bessa block house in Condon

Key findings for future programs include:

- Participants had a positive experience with the Pilot Program.
- Participants were pleased with the performance of their cool roofs. All participants responded that they felt the cool roof performed as expected and had noticeably cooled their house.
- On several occasions participants estimated that the internal temperature reductions achieved by their cool roof are larger than that shown by the data, estimating temperature reductions of five or more degrees. This may be due to the larger reduction in the perceived or apparent temperature, which takes into account factors such as humidity. Additionally, this suggests that that even small temperature reductions of a few degrees noticeably improve thermal comfort.
- The most common reasons for having their roof painted with a cool roof coating were for internal thermal comfort benefits, energy saving potential, and because the roof needed to be renovated anyway.
- Many program participants have recommended cool roofs to friends and family, commonly citing the thermal comfort and energy saving benefits of their cool roof.
- A telephone interview with the householder was an appropriate method of collecting feedback about the cool roofs. In some cases, particularly when participants had the cool roof product installed during winter, the participant was not initially able to provide feedback. In these cases, participants were advised that the research team would call back after the following summer period. This initial contact and follow up approach should be continued.

Understanding Painters experience (Post program survey)

Participating painters were interviewed to gain feedback on the pilot program and suggestions for improvement to consider for the community-wide program. Participating painters were two local licensed painters offering two different cool roof products.

- Roof Seal: Roof Seal is a local business specialising in roof restoration and painting. Roof Seal use a proprietary cool roof coating called Ellemex Reflect and all applicators are trained in the correct application of the coating. Ellemex Reflect is a durable acrylic coating sprayed directly onto a roof and can be used on a variety of surfaces including iron sheet and concrete tile.
- Roofguard: Roofguard is a locally owned business specialising in roof painting. Roofguard use Dulux Acra-Tex 962 Cool Roof White and Dulux Acra-Tex 962 Commercial White cool roof coatings and all applicators are licensed and registered Dulux Acra-Tex applicators. Dulux Acra-Tex is a durable high build acrylic coating that can be applied to a variety of surfaces including concrete and metal roofs.

Key findings for future programs include:

- The painters support the idea of the community program and are interested in supporting the Council to help increase the uptake of cool roofs in Townsville.
- There is a high level of interest from participants to see the results of the pilot program.
- Both painters emphasised the need to have a faster turn-around time between a participant registering their interest and the contact details being released. The painters stated that additional participants may have been achieved if this timeframe was shortened.
- Painters reflected that the timings of the program are very important to match seasons. The lead up to summer was felt to be the ideal time to roll out the program as houses are beginning to heat up and people are starting to think about summer. Painters suggested that

October to December was the ideal time to paint houses in Townsville. Additionally, many people are thinking of getting their roofs fixed before the cyclone season arrives and the ideal time to paint a roof is in conjunction with roof restoration.

- The painters felt that offering a discount based on the volume of customers in the pilot did not provide significant benefit due to the number of houses participating. Noting that the discount was offered as a form of promotion for the product and not based on this intended outcome. Noting also that one of the painters was offering 25% discount at the time of the pilot registration and the program asked for a commitment of 15%. Painters suggested that they already buy in large quantities so received little additional discount from the manufacturer.
- However, when asked if a more clustered program could offer greater savings to painters that could be passed onto residents (e.g. 'Cool Streets' - where a large number of houses in the one street all have the same product applied at the same time), they expressed that this could be an option. If potential participants are clustered closer together this would save on travel and set-up time and could potentially reduce costs, which may be able to be passed onto the participants.
- Due to often having a short turnaround time between providing a quote and painting the roof, the sensors were often not installed far enough in advance to provide pre-roof coating temperature records. An alternative option could be that temperature sensors are installed (preferably by a council representative) shortly after expression of interest to participate in the program. Where a resident does not go through with the cool roof painting, the sensor could be removed.

Appendix A: Painters Checklist

Cool Your Roof Pilot Program

Pilot Program Checklist

Completed by: ____________

Date: ____________

Householder Contact Details

Title: ______ Given name: ____________ Surname: ____________

Phone number: ____________ Email: ____________

Address: ____________

Suburb: ____________ Postcode: ____________

Current Characteristics

Roof material: ____________

Painted ☐ Unpainted ☐ Current roof colour: ____________

Ceiling insulation type / R-value: ____________

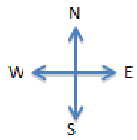
Roof insulation type / R-value: ____________

Approximate roof pitch: ____________ External house wall colour: ____________

Shading: none ☐ moderate ☐ extensive ☐ total ☐

General roof condition / notes: ____________

Orientation: provide rough sketch



Cool Roof Characteristics

Cool Roof product applied: ____________

Colour: ____________

Manufacturer-specified solar reflectance value: ____________

Manufacturer-specified thermal emittance value: ____________

Date applied: ____________ Applied by: ____________

Monitoring Equipment

Sensor installed in roof cavity ☐ yes

Sensor installed in internal un-conditioned area ☐ yes

Appendix B: Participant survey

PHONE CALL RUN SHEET: PILOT PROGRAM PARTICIPANTS [15 MINS]

1. Introduction (2 mins)

⇒ Good morning/afternoon, my name is ___________. I'm a researcher from Griffith University working with the Townsville City Council to investigate opportunities for reducing energy use as part of a program within the Townsville Solar Cities initiative.

⇒ You recently participated in the Cool Your Roof Pilot Program. We are interested in your feedback about the program and your experience with your cool roof. Any information you provide will be kept confidential amongst the research team, with any information given to Council being anonymous.

⇒ With this in mind, would you be prepared to talk for 10 minutes about your experiences? *(If YES, but not now, then ask when would be a good time. If NO, then thank them for considering)*

2. Property Details (2 min)

The purpose of the following questions is to gather basic data about your house, to cross-check with information provided by the painters.

⇒ [CHOOSE] What is your house type (Queenslander, Brick, Unit/Townhouse, Other)?

⇒ [CHOOSE] How many levels are there in your house? (1, 2, 3, more than 3)

⇒ [CHOOSE] Do you have an air-conditioner? (YES/ NO; if YES, central system/ individual units - how many?)

⇒ [CHOOSE] What is the roof material (metal – corrugated iron; metal – tin; tile; other; don't know)

⇒ [CHOOSE] What was the original roof colour? (silver, white, cream, terracotta, grey, brown, black, unpainted metal, other)

⇒ [CHOOSE] What is the new cool roof colour? (silver, white, cream, terracotta, grey, brown, black, other)

3. Discussion Items – Cool Your Roof Pilot Project Review (8 mins)

The following questions will help us to focus on getting feedback on the pilot program and your opinions on the new cool roof.

⇒ Had you considered getting a cool roof prior to hearing about the Cool Your Roof pilot program? (YES/ NO)

⇒ Is there anything that initially stopped you getting a cool roof? (YES/ NO; If YES, ask for brief details)

⇒ [OPEN] What helped you to overcome these barriers?

⇒ [OPEN] What are the two or three main reasons you decided to get a cool roof for your property?

⇒ Is your cool roof performing as you expected? (YES/ NO; Ask for brief details)

⇒ Do you think the cool roof has affected the temperature in your house? (YES/ NO)

⇒ (If YES to air-conditioner in Section 2) Has your use of the air-conditioner/s changed since getting the cool roof? (YES/NO; Ask for brief details)

⇒ Has there been a change in your energy bill since getting the cool roof? (YES/NO/UNSURE) *Are there any other factors that might have influenced your energy use, other than the cool roof? (e.g., more efficient appliances, downsizing to a single fridge instead of two…)*

⇒ Do you think the cool roof has improved the look of your house? (YES/NO/UNSURE)

⇒ Would you recommend to friends/family that they get a cool roof? (YES/NO/UNSURE; as Why/why not?)

⇒ Have your neighbours or friends commented on your cool roof? (YES/NO – if YES, details?)

⇒ Would you install a cool roof again if you moved to a new address? (YES/NO/UNSURE)

⇒ [OPEN] Do you have any comments about cool roofs that you would like to share?

⇒ [OPEN] Do you have any comments about the Cool Your Roof pilot program that you would like to share?

⇒ [OPEN] Do you have any comments about the painter/s that you would like to share?

4. Request for testimonial (1 min)

As part of the pilot program we are looking for testimonials from Townsville residents who have a cool roof for use in communication material to encourage the uptake of cool roofs. This testimonial would be used on the Townsville City Council website and in cool roof education material, such as posters and information brochures. Participation would be voluntary with no financial or other reward. Would you like to provide a testimonial?

(If YES, take quote verbally and follow up with emailed version for written confirmation. If NO, thank them for considering)

5. Request for photo (1 min)

As part of the pilot program we are looking for images of Townsville residents with their cool roof for use in communication material to encourage the uptake of cool roofs. These images would be used on the Townsville City Council website and in cool roof education material, such as posters and information brochures. Participation would be voluntary with no financial or other reward. Would you like to participate?

(If YES, record interest for future follow-up. If NO, thank them for considering)

6. Complete Phone Call (1 min)

Thank you for your time – if you have any questions or further queries please contact the project leader on (mobile +61 407 071 729).