

Cooling Communities Final Report

August 2017

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Executive summary

This report has been produced by Moreland Energy Foundation (MEFL) and Moreland City Council to improve understanding of the actions required to mitigate the Urban Heat Island Effect (UHIE) impacts for vulnerable social housing residents. The UHIE refers to the way built up areas trap heat, especially at night, creating pockets of warmer areas.

Global warming is leading to longer, hotter and more frequent heatwaves across Victoria. These conditions are compounded in dense built up areas through the UHIE. Moreland's suburbs have been identified as particularly vulnerable to the UHIE (with temperatures in residential areas in excess of 50 degrees Celsius in peak summer periods) due to a lack of green infrastructure and large impervious areas. This extreme heat can cause and exacerbate a range of serious health issues.

Social housing residents are particularly at risk from heat stress as they are more likely to live in poorly designed or maintained properties and have chronic health conditions. They also may spend more time in their properties than residents renting privately or owner occupiers.

This project retrofitted ten social housing properties in Moreland to improve their resilience to the UHIE. The study explored measures to reduce UHIE impacts, resident perception of works, the barriers to wider roll-out and the role local councils and other stakeholders can play to support this.

The study found that **whilst no heatwaves were experienced in Melbourne during the study period, in January 2017 heatwave conditions were recorded inside one of the properties**. For several properties in a recently constructed apartment block, internal temperatures failed to drop below 27 degrees Celsius over a five-day period.

Failure to provide adequate protection from heat was not limited to the apartments, with residents in single-storey homes also experiencing discomfort. These properties however had more retrofit options than the apartments.

Key barriers to wider roll out of retrofits are a lack of funding and limited understanding of UHIE and its impacts on residents' health.

Prior to upgrades several of the properties in the study posed real threats to residents' health and wellbeing during extended hot spells. With heatwaves set to become more common, occupant exposure to heat stress is likely to be exacerbated in the future unless urgent action is taken to deliver large scale retrofit programs and improve building regulations and building design.

Key recommendations

State government, local government and social housing providers:

- Ensure new homes provide adequate protection from UHIE without reliance on air-conditioning.

Social housing providers:

- Assess thermal performance of their portfolio and prioritise properties for retrofitting.
- Prioritise building fabric upgrades and natural cooling retrofit options.

State Government:

- Develop an agreed metric to evaluate heat risk reflecting the absence of air-conditioning during blackouts for inclusion in building and planning policies.
- Provide funding options for social housing providers to deliver retrofits.
- Undertake detailed thermal image mapping of urban areas to identify UHIE hotspots.

Local councils:

- Publish data on UHIE hot spots and work with stakeholders to target resources in priority areas.

Frank is in his 60s and has lived in his Hadfield home with his brother for 33 years. He lives with a cardiovascular medical condition after suffering a heart attack 20 years ago.

He had been looking for ways to cool his property down, reporting that "*it's been a hotbox since 1983. It's unbearable here*."

Upgrades to Frank's property included draught-proofing and insulation, 12 trees and 30 shrubs, a 2,000lt rainwater tank to offset the costs of additional watering, a ceiling fan, a split system air-conditioner and a 2.08kW solar array to help offset the cost of the additional cooling.

Frank is now a happy man "*Now I can sleep at night. Before I was tossing and turning all night*."

Whilst he finds the air conditioning has made the biggest difference to his health he is "*amazed how much difference simple things [like draught-proofing] make*." He's also looking forward to when the trees grow and he can sit out in the garden during summer again.





Julia is in her 60s and has lived in her Pascoe Vale home for 2 years. Whilst she loves her home she has struggled with the heat over summer. The apartment does not have any opportunities for natural ventilation as the windows do not open and the concrete and metal construction retains the heat long after external temperatures drop.

The hot nights exacerbate her existing cardiovascular and renal health issues. Prior to the retrofit she slept in the lounge or moved out to live with her son and his family during hot periods. She had purchased a portable evaporative cooling unit but found this to be ineffective to reduce humidity.

Upgrade options for Julia's property were limited due to the apartment design and included a ceiling fan and split system air-conditioning.

She had been looking for an affordable private rental with air-conditioning because the heat was so unbearable for her. Now she wants to stay in the apartment forever and that "*the rest of her life is happy."*

Julia reports that since the upgrades she is "*happy for everything, but first of all my health. Thank you, thank you."*

Introduction

This project investigates the negative impacts of the UHIE on Moreland's social housing residents and explores how these impacts can be minimised through a range of property upgrades. It considers implications for future development, the role councils can take and actions required by stakeholders.

The project was funded by the Department of Environment, Land, Water and Planning's Victorian Climate Change Grants 2015.This project has been undertaken by Moreland Energy Foundation (MEFL) in partnership with Moreland City Council.

MEFL is a not-for-profit dedicated to tackling climate change. As well as leading Moreland Council's Zero Carbon Evolution strategy to reduce carbon emissions in Moreland, MEFL have delivered many consultancy and research projects for clients such as local, state and federal government, property developers and community and industry organisations. MEFL have undertaken multiple projects focused on improving the comfort of our existing public and private housing stock and supported the Department of Health and Human Services (DHHS) to design climate-adapted housing able to withstand temperature extremes. MEFL are currently delivering upgrades to 1,500 DHHS properties.

Moreland is a municipality in the inner north of Melbourne. The City of Moreland covers 50.9 square kilometres and is one of Melbourne's most populous municipalities with more than 160,000 people. The City of Moreland lies between 4 and 14 kilometres north of central Melbourne. It is bordered by the Moonee Ponds Creek to the west, Merri Creek to the east, Park Street to the south and the Western Ring Road to the north. The council's vision is for a sustainable Moreland that supports a resilient community who live in an attractive, accessible and safe environment, with a strong local economy and services that meet their diverse needs.

In alignment with the values of both Moreland City Council and MEFL the project was undertaken with a community centred approach, involving residents throughout the decision making process.

This project focuses on not-for-profit community housing organisations (which we have termed 'social housing providers'). Social Housing is however an umbrella term for homes provided through both the state government (public housing) and not-for -profit community housing organisations (CHOs). CHOs are in a period of major change and growth, driven by a new common Housing Register, significant funding for new buildings, and public housing stock transfer initiatives under the state government's Homes for Victorians strategy.

Background

The health impacts of climate change are already being felt.[1] Heatwaves kill more Australians than other natural disasters. In 2009 in Victoria 179 people died as a result of the Black Saturday fires however more than 370 Victorians died from extreme heat that same week. Despite its temperate climate, Melbourne currently experiences more heat related deaths than other Australian cities[2].

In Australia, we are seeing more very hot days, and longer, hotter and more frequent heatwaves. This trend is set to increase[3]. Although more people die in Victoria from cold related health issues than heat, as our climate warms the risk of exposure to severe and extreme heat increases.

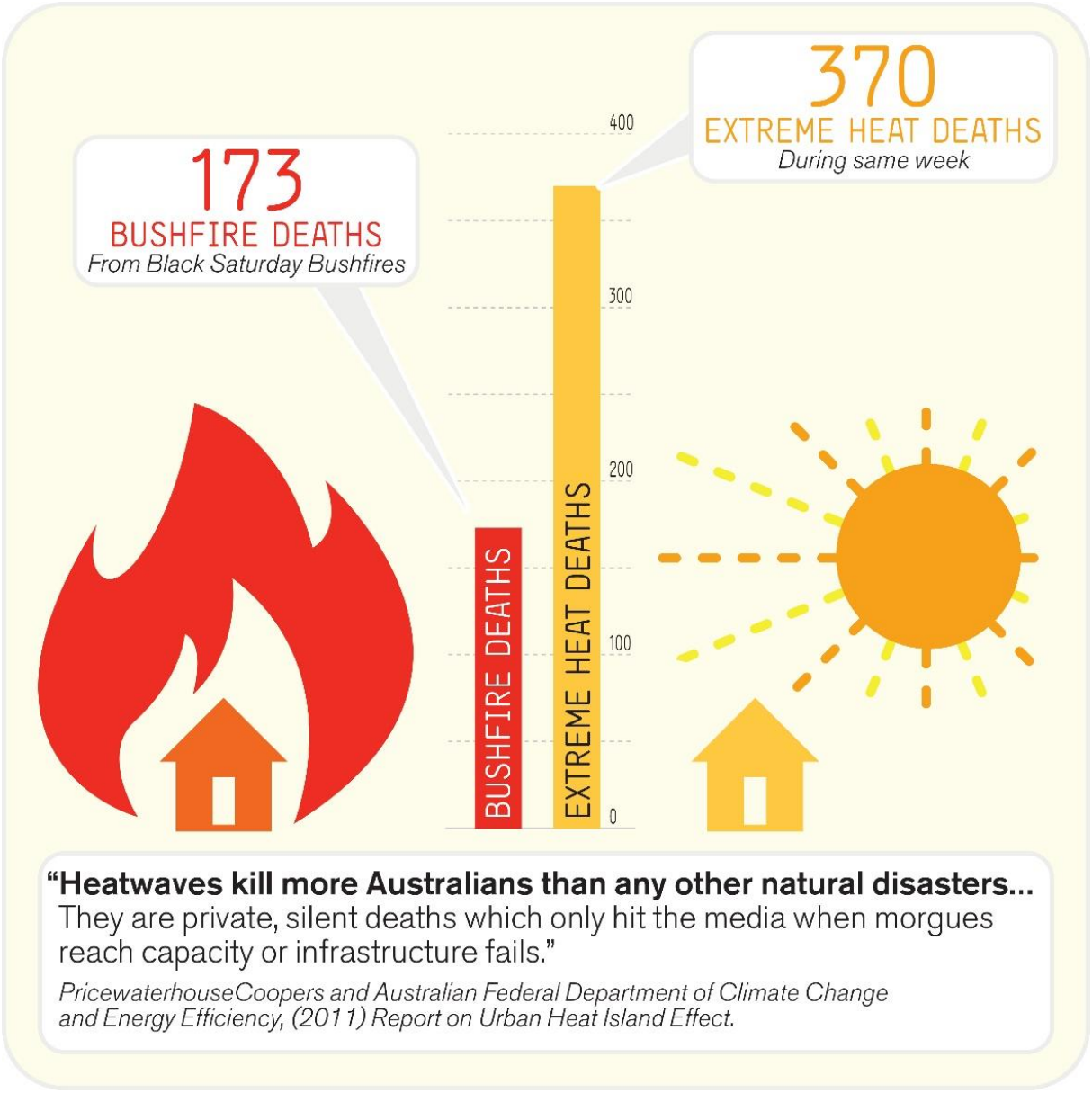
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[1] Sarfaty, Gould, Malbach and Burness (2017) 'Medical Alert! Climate Change is harming our health', The Medical Society Consortium on Climate and Health - https://medsocietiesforclimatehealth.org/wp-content/uploads/2017/03/medical_alert.pdf

[2] PricewaterhouseCoopers and Australian Federal Department of Climate Change and Energy Efficiency (2011), Report on Urban Heat Island Effect.

[3] BOM, State of the Climate (2016)

Figure 1: Deaths from extreme heat during 2009 heatwave

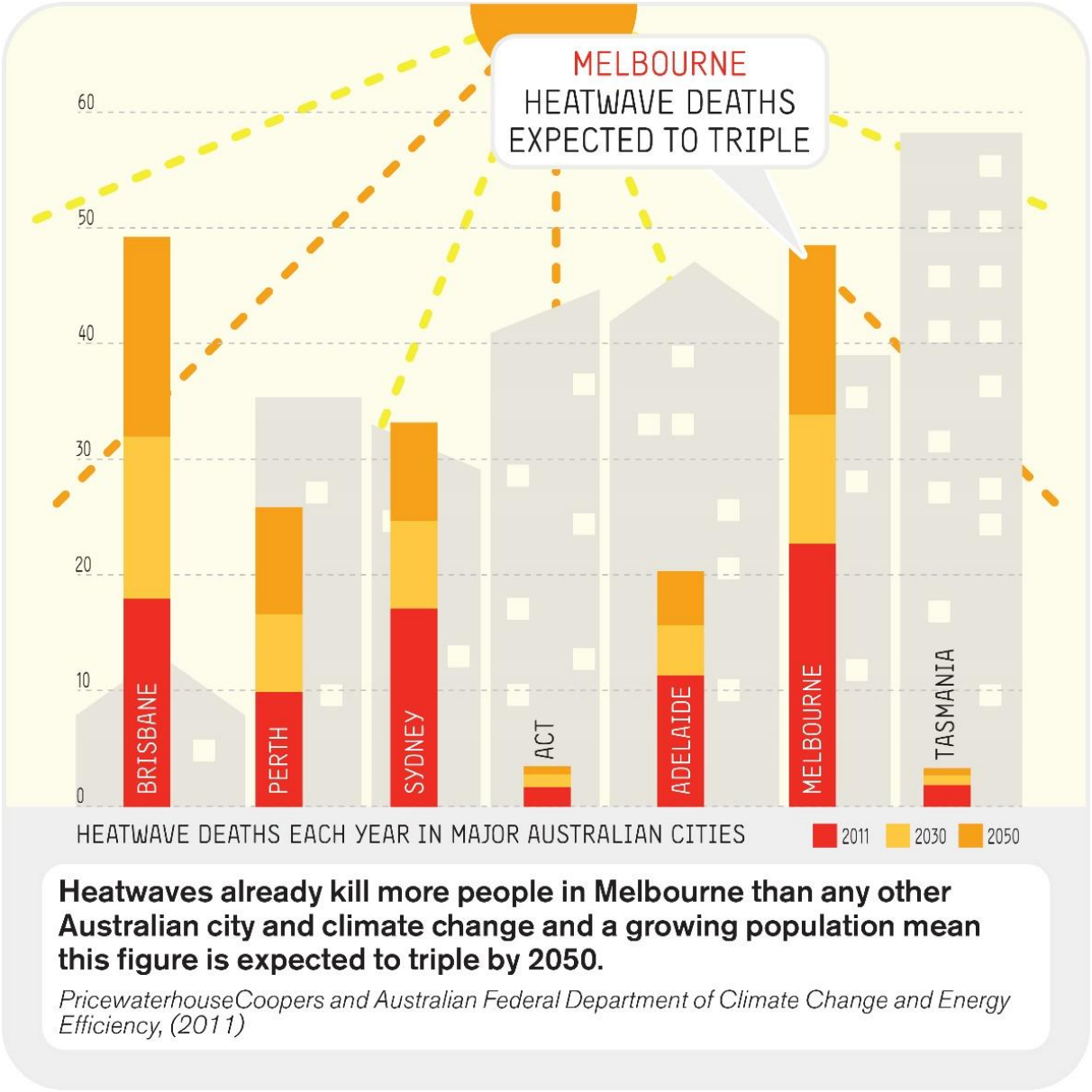


Extreme heat can lead to heat-related illness and death from heat stroke and dehydration. Heat stress can also worsen many chronic conditions, especially cardiovascular, respiratory, kidney and cerebrovascular diseases as well as metabolic disorders[4]. Heat stress can also exacerbate existing mental and behavioural disorders[5]. Research finds that excessive heat and humidity compounded by factors of lethargy, lack of sleep, and the inability to function normally may affect mood and behaviour, increasing mental stress, depression, and suicide, and triggering irritability and risky behaviours such as excessive alcohol consumption, violence, and aggression[6].

[4] D'Ippoliti et al., 2010, 'The impact of heat waves on mortality in 9 European cities: results from the EUROheat project.' Environmental Health, 9(37).
[5] Hansen, A, Bi, P, Nitschke, M, Ryan, P, Pisaniello, D & Tucker, G 2008, 'The Effect of Heat Waves on Mental Health in a Temperate Australian City', Environmental Health Perspectives, vol. 116, no. 10, pp. 1369-75
[6] Hansen A, Bi P, Nitschke M, Ryan P, Pisaniello D, Tucker G. The effect of heat waves on mental health in a temperate Australian city. Environ Health Perspect. 2008;116:1369–75.

It is predicted that by 2050 an extreme heat event in Melbourne could kill more than a thousand people in a few days[7].

Figure 2: Predicted deaths from extreme heat across Australia by city to 2050



In urban areas, extreme heat events are intensified by the UHIE. This results in temperatures 3.5 – 4.5 °C warmer in inner-urban areas than surrounding rural areas. The UHIE is driven by factors including a proliferation of dense, dark and solid surfaces which absorb, trap and retain heat, limited vegetation and water bodies and heat production from human activity (such as vehicles and split system air conditioners). The UHIE traps heat in the built form, providing little relief overnight during heatwaves. Higher overnight temperatures have been seen to increase the mortality risk from extreme heat[8][9]. UHIE

[7] PricewaterhouseCoopers and Australian Federal Department of Climate Change and Energy Efficiency (2011), Report on Urban Heat Island Effect.

[8] Kovats, R.S., and Hajat, S. (2008). Heat stress and public health: A critical review. Annual Review of Public Health, 29, 41-55.

[9] Nicholls, N., Skinner, C., Loughnan, M. and Tapper, N. (2008). A simple heat alert system for Melbourne, Australia. International Journal of Biometeorology, 52(5), 375-384

warming is predicted to rise by approximately 1°C per decade, over and above that caused by global warming[10].

The UHIE is a key issue for Moreland as a 2014 UHIE vulnerability map for Melbourne produced by Monash University[11] identified Glenroy and Coburg as the Melbourne suburbs (including Sunshine, St Albans, Preston, Reservoir, Clayton and Dandenong) most at risk due to a combination of extreme heat and social vulnerability. Further mapping work undertaken for Moreland in 2015 found there were very few cool places in the municipality and a significant number of extremely hot places, with surface temperatures commonly exceed 50 degrees Celsius.

Moreland's population is set to increase almost 35% in the next 20 years, which will further increase developed areas and human activity. There is also likely to be a significant increase in the number of apartments. The UHIE is therefore a significant and growing issue for Moreland. This is why Moreland City Council has developed an Urban Heat Island Action Plan which sets out a number of recommendations and projects to perform until the period of 2025/2026 in order to make Moreland a cooler, greener, more liveable city.

Moreland City Council is also in the process of creating an Urban Forest Strategy which aims to increase tree coverage in both the public and private realm, which has direct UHIE benefits.

Why target social housing?

Not every person is equally at risk from heat stress. People on low incomes are twice as likely to have heat related health impacts when compared to people on higher incomes, particularly low-income elderly people, and people who are living with health issues[12].

Social housing residents are amongst the most vulnerable in our society. They often experience a myriad of socio-economic, physiological and psychological disadvantages. The quality of their homes can therefore play a critical role in improving or impeding their life prospects and wellbeing.

Social housing residents are highly sensitive to the effects of extreme weather and other climate change impacts. They often spend more time in their properties than those renting from private landlords or owner occupiers and face a range of barriers to improving their homes. These include the requirement for approval from their housing provider to undertake works, limited access to money, poor health, limited knowledge of effective measures to prevent heat stress and limited/no English. The affluent will be able to buy their way out of the heat stress caused by UHIE by upgrading their homes and installing air conditioners, however choices for social housing residents are limited.

Whilst a significant portion of social housing in Victoria tends to be old, inefficiently designed or built or poorly maintained there are proven measures that can be taken to improve the protection they offer residents from extreme weather. Research has identified significant opportunities to reduce severe heat-related health risk within Australia's social housing portfolio through building upgrades (such as insulation, external shading and draught-proofing) and urban greening[13].

Many of these upgrades can provide additional co-benefits such as lower energy costs and improved social and wellbeing outcomes for residents, reduction in carbon emissions and decreasing the UHIE.

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[10] Voogt (2002), 'Urban heat island', in I Douglas (ed.), Encyclopaedia of global environmental change, John Wiley and Sons, New York, pp. 660-6.

[11] http://www.mappingvulnerabilityindex.com/home/melbournevi

[12] CSIRO 2013: Pathways to climate adapted and healthy low income housing, Final Report: CSIRO, National Climate Change Adaptation Research Facility, 2013.

[13] CSIRO 2013: Pathways to climate adapted and healthy low income housing, Final Report: CSIRO, National Climate Change Adaptation Research Facility, 2013.

What other work have Victoria's councils undertaken to address this?

There have been several notable projects in Victoria where local councils explored ways to support low income households improve the thermal performance of their homes through a range of measures. These include Hume City Councils' 'Heatwave Help for Homecare Clients' which used Council's Home Care services to retrofit 100 properties with draught-proofing, insulation and external shading and SECCA's 'Low Income Energy Saver Direct Care and Motivators Project'[14] which also worked with Council Home and Community Care (HACC) departments to investigate the most effective ways to support low income households improve their energy efficiency.

This project seeks to widen this area of knowledge by specifically exploring the experiences of those living in social housing. It considers how councils can support social housing providers to ensure the impacts of the UHIE are minimised for their vulnerable residents.

[14] http://www.seccca.org.au/wp-content/uploads/2015/11/SECCCA-LIEEP-final-report-executive-summary.pdf

Objectives of this report

This work explores how the negative impacts of the UHIE on vulnerable social housing residents can be reduced by retrofitting a range of mitigation measures.

Key areas of focus are:

- Exploring the current experience of social housing residents in Moreland during periods of extreme heat
- Resident perception of the impact upgrades made to their health and wellbeing
- Barriers to implementing measures
- The role councils and state government can play to support vulnerable residents.

This project provides essential knowledge and learning to inform the maintenance, renewal and construction of new and existing social housing. It also improves local and state government's understanding of the role they can play in mitigating the impact of the UHIE for vulnerable social housing residents.

Ultimately, the project aims to reduce the susceptibility of vulnerable populations to the UHIE, measuring improvements in thermal comfort and health after the application of different retrofits. Literature on social housing retrofits and the UHIE validates the need for such an exploratory program, as it is clear there are few real-life studies or programs which have focused on helping vulnerable residents who live in non-state supplied social housing.

Key objectives of the report are to:

- Create a replicable model councils can utilise to identify social housing residents at most risk
- Identify key issues facing social housing residents during extreme heat
- Identify effective measures to reduce negative impacts of UHIE
- Identify barriers to implementing upgrades
- Identify resources and partnerships for wider delivery

Report structure

This report outlines the findings of the study and is presented as outlined below, and then supported by a consolidated discussion.

- **Introduction** – Background and study objectives
- **Section 1** – What did we do (overview of retrofits delivered)
- **Section 2** – Findings (impact on thermal comfort of dwellings, resident perception, implementation issues and barriers to delivery)
- **Section 3** – Discussion
- **Section 4** – Recommendations
- **Annexes** – Summary of works and methodologies (model to identify priority areas/properties, housing typologies and upgrade measures)

1 What did we do?

The budget for works was $45,000 ex GST (with contributions from DEWLP, Housing Choices Australia, Aboriginal Housing Victoria and Bunnings). These funds were used to perform retrofits on 10 dwellings.

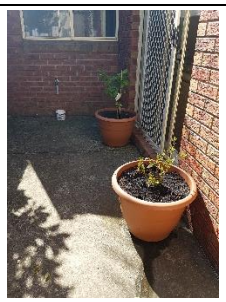
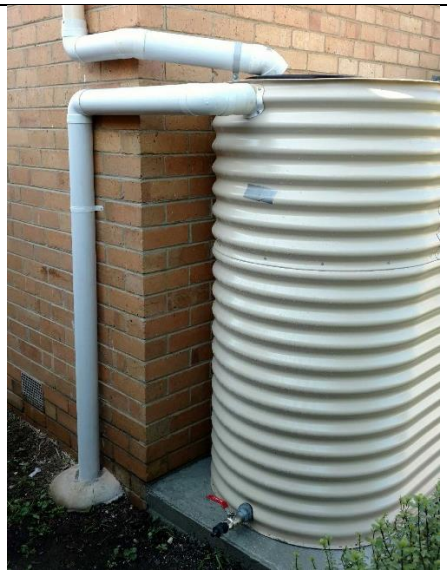
Types of dwellings were:

- 4 apartments (within 1 apartment building)
- 4 attached single storey houses
- 2 attached single storey houses

We performed the following range of retrofits:

Ceiling insulation – upgrade to R4	
Draught-proofing – internal and external doors	
Draught-proofing – wall vents	
Draught-proofing – exhaust fan	

Shade cloth – to provide external shading over exposed windows and prevent solar radiation from exposed concrete	
Retractable awnings – to provide external shading over exposed windows	
Trees – deciduous trees were planted to provide summer shade and winter solar warmth, prevent solar radiation from exposed concrete and provide evapotranspirative cooling	

Vegetation – to prevent solar radiation from exposed concrete and provide evapotranspirative cooling	 
Downpipe diverter and hose – to reduce cost impacts of maintaining additional trees and vegetation	
Rainwater tank – to reduce cost impacts of maintaining additional trees and vegetation	
Ceiling fans – in bedrooms and living areas	

Split system air-conditioner – in living areas	
Solar PV system – to offset additional energy costs of split system air-conditioner	

Full details of the measures installed at each property and the budget is included at Annex 1.

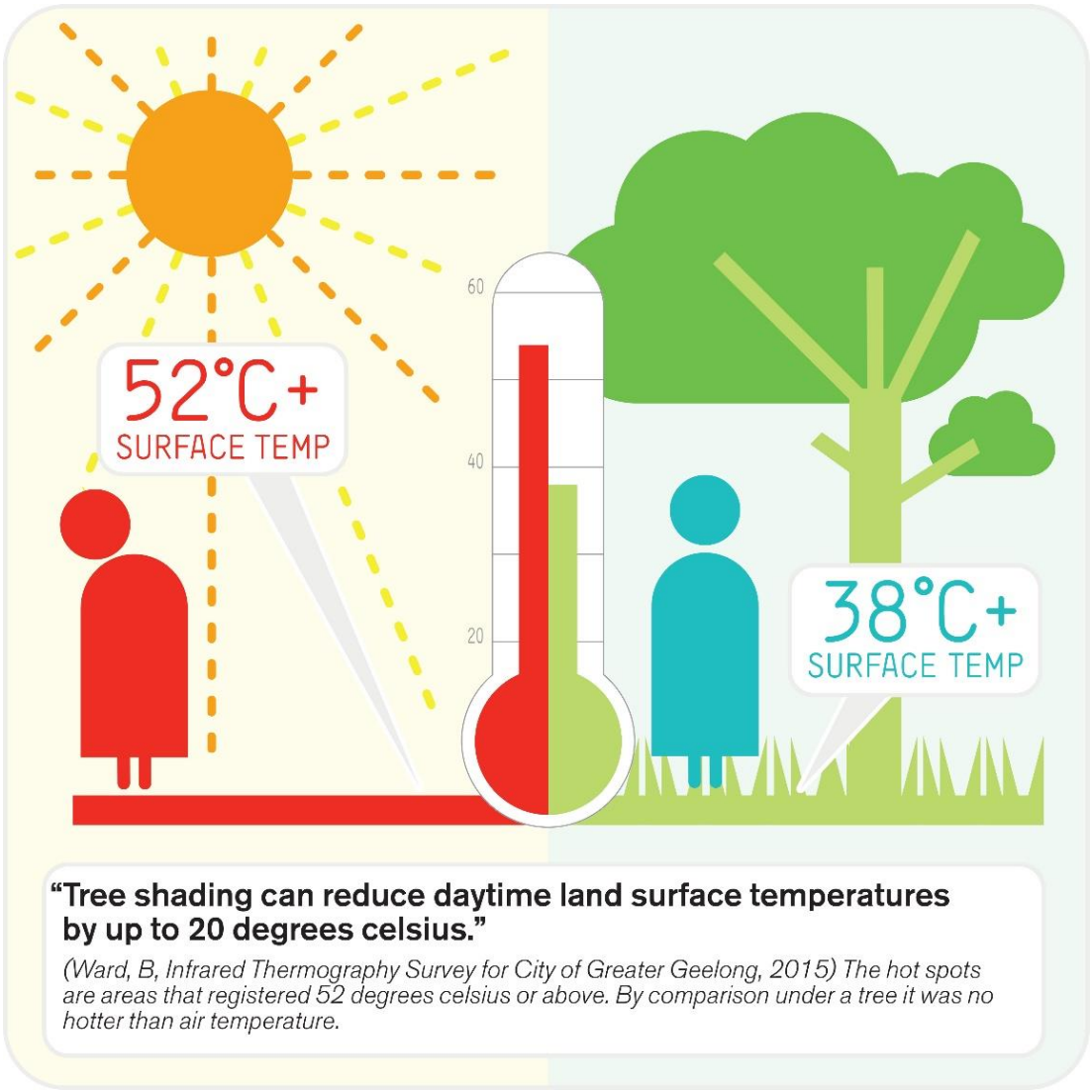
Each property presented a different challenge and retrofit packages were determined by property condition, resident needs and the hierarchy set out below (as detailed in figure 4).

1. **Improve building fabric** through commercially available technologies proven to influence thermal performance including external shading, draught-proofing and insulation. These measures are predominantly 'set and forget' meaning that the resident does not have to take action for them to be effective. This can be important when new residents take over the property. Many of these measures also improve comfort during both summer and winter, thereby reducing energy costs and carbon emissions required to heat and cool homes.[15]

2. **Provide natural cooling through green and blue infrastructure.** Green infrastructure (trees and vegetation) can shading has been proven to improve thermal comfort within and around buildings and reduce energy demands for summer cooling through shading and evapotranspirative cooling.[16] Evapotranspiration, alone or in combination with shading, can help reduce peak summer air temperatures by 1–5°C. Surfaces shaded by trees can commonly be 11–25°C cooler than the peak temperatures of unshaded materials. As figure 3 shows however, on days of extreme heat the temperature difference under a tree canopy can be more than 30°C lower that unshaded areas. Vegetation can also reduce solar radiation reflected from ground and building surfaces. Studies have also found an increased area of urban green space near the home to be an important factor in reducing health impacts of heatwaves.[17] Blue infrastructure (water) is critical in ensuring that the vegetation can provide these cooling benefits.

[15] Sustainability Victoria (2015). Energy efficiency upgrade potential of existing Victorian homes.
[16] Del Barrio (1998). Analysis of the green roofs cooling potential in buildings. Energy and Buildings, Volume 27 Issues 2, 179-193;
[17] Tan, J., Zheng, Y., Song, G., Kalkstein, L.S., Kalkstein, A.J. and Tang, X. (2007). Heat wave impacts on mortality in Shanghai, 1998 and 2003. International Journal of Biometeorology, 51, 193-200.

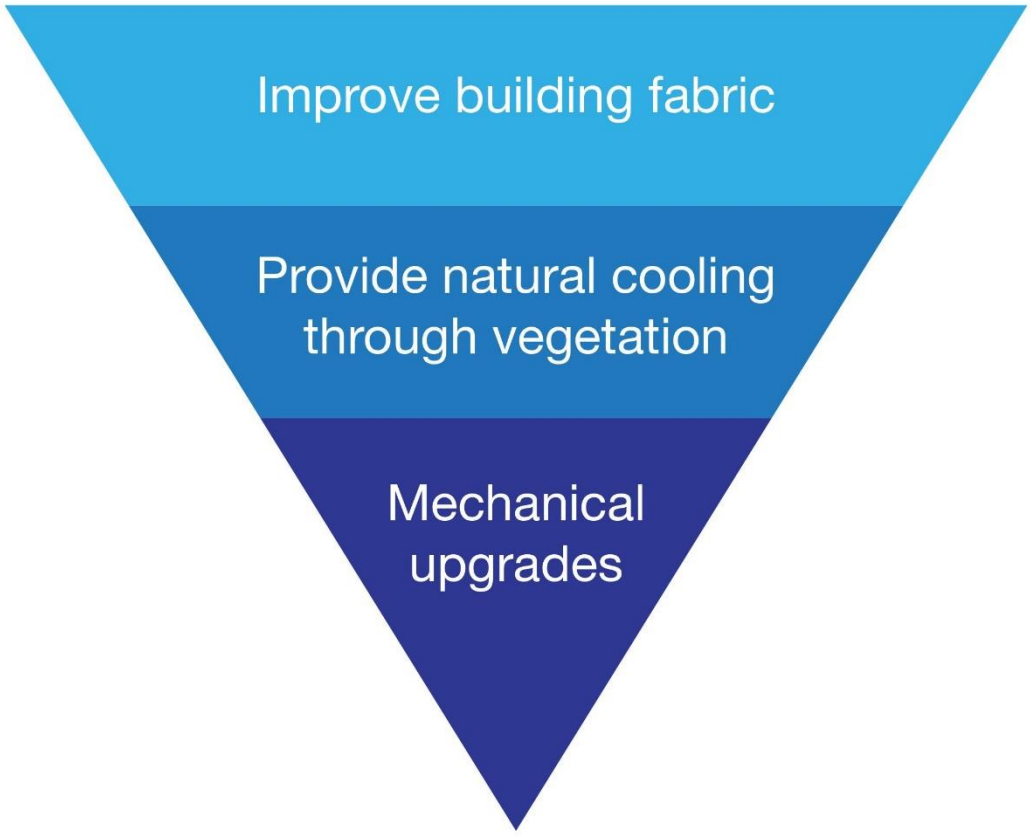
Figure 3: Shading potential of trees



3. **Mechanical upgrades** including fans and split system air-conditioners. Whilst air-conditioning has been shown to reduce heat related morbidity[18] these interventions were the least desirable option for retrofits. As these measures do not change the underlying thermal performance of the dwellings they are ineffective during blackouts, which are more likely to occur during heatwaves. In addition, they may increase the UHIE through waste heat, along with carbon emissions and resident's energy bills.

[18] Ostro, Rauch, Green, Malig and Basu, (2010). The effects of temperature and use of air conditioning on hospitalisations. American Journal of Epidemiology, 172(9): 1053-61

Figure 4: Retrofit hierarchy adopted by this study



(Source: MEFL)

2 Key findings

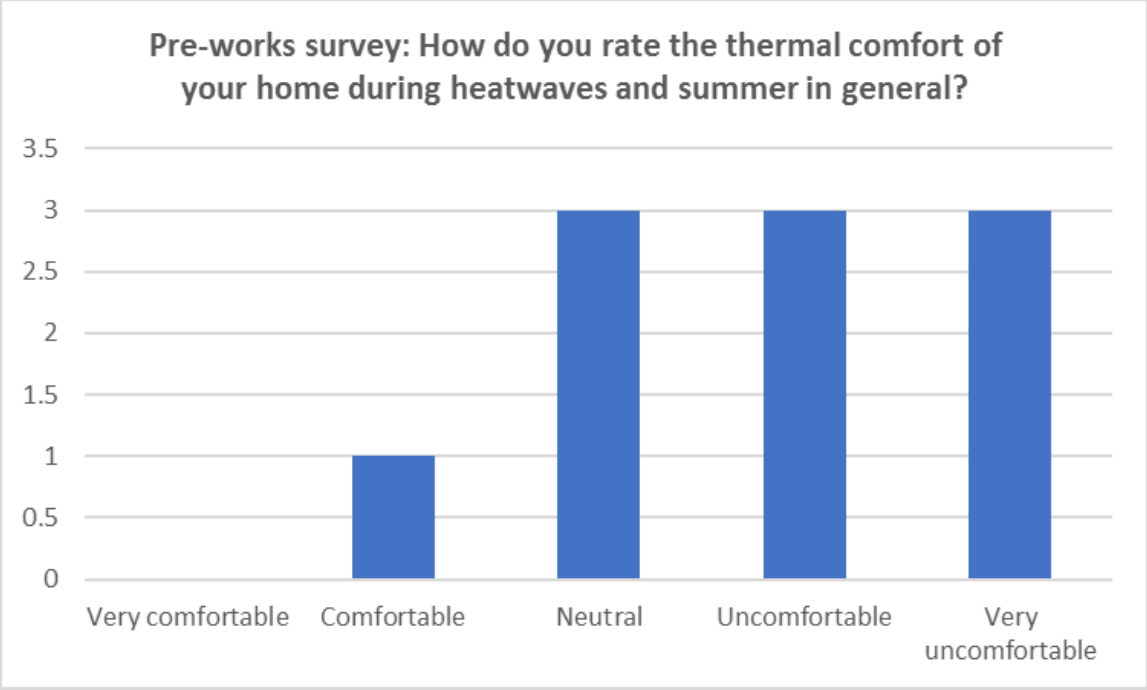
2.1 Many properties experienced severe heat prior to the upgrades, putting the health and wellbeing of the occupants at risk

Thermal performance indicators – resident perception

At the start of the project all residents were surveyed to assess their perception of the thermal comfort of dwellings. For the purpose of the survey thermal comfort was defined as 'the residents' satisfaction with the temperature'.

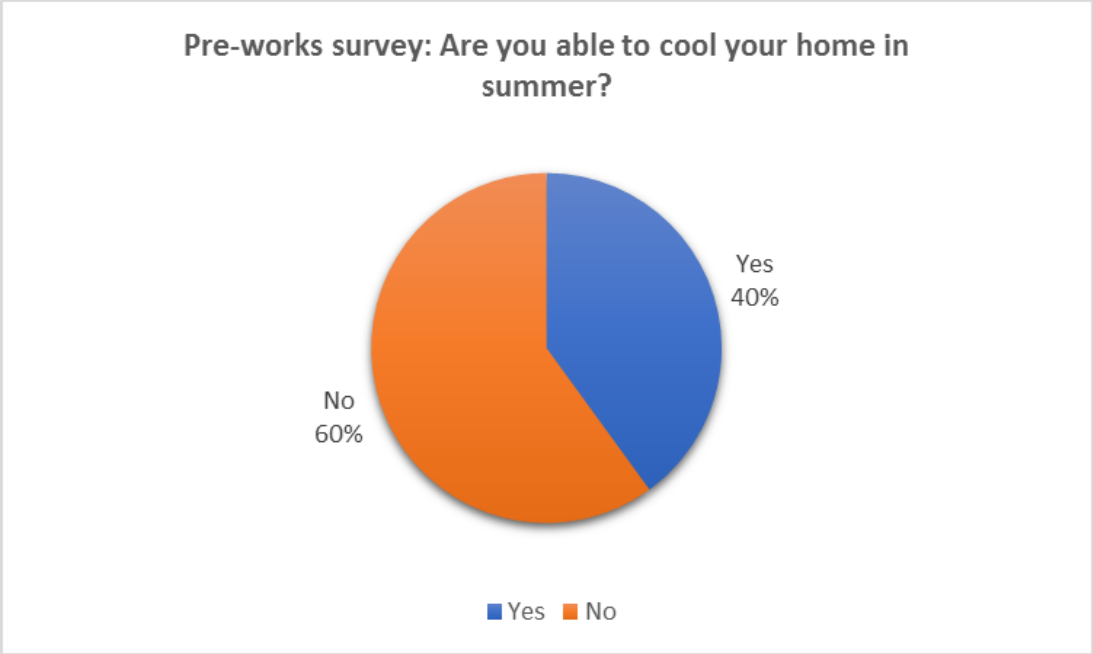
60% of those surveyed reported that their homes were hotter inside than outside, 60% reported feeling very uncomfortable or uncomfortable during heatwaves and summer in general.

Figure 5: Resident perception of thermal comfort pre-works



(Source: pre-works survey undertaken 25th to 27th October)

Figure 6: Residents perception of whether they can cool their homes during summer



(Source: pre-works survey undertaken 25th to 27th October)

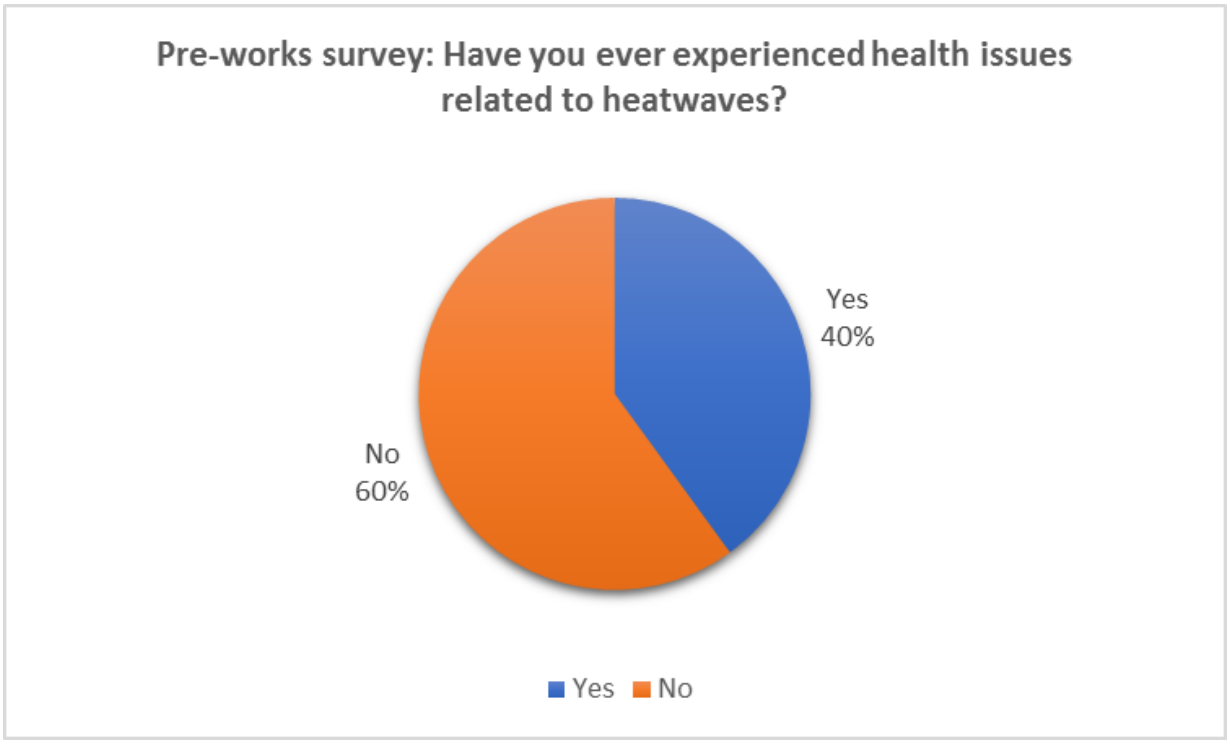
Whilst 40% of residents stated that they could cool their homes in summer 90% of those surveyed reported that they experienced problems sleeping in summer, all attributing this to the heat inside their homes.

> *"I usually go to bed at 2am when it is very hot"*
>
> *"It' difficult to get a good sleep during summer"*
>
> *"I keep the blind down in my bedroom but it's still really hot."*
>
> *"I prefer to sleep on the floor than in my bed. My bedroom is too hot."*

It was common for the residents to change their sleeping areas to cooler places within their home, even if this meant the whole family sleeping on the floor. One of the residents often moved to stay with their son and his family in their home during periods of extreme heat to avoid exacerbating their health issues. Whilst the resident was able to avoid the worst impact of the heat they reported that their preference would be to remain in their own home during summer if possible.

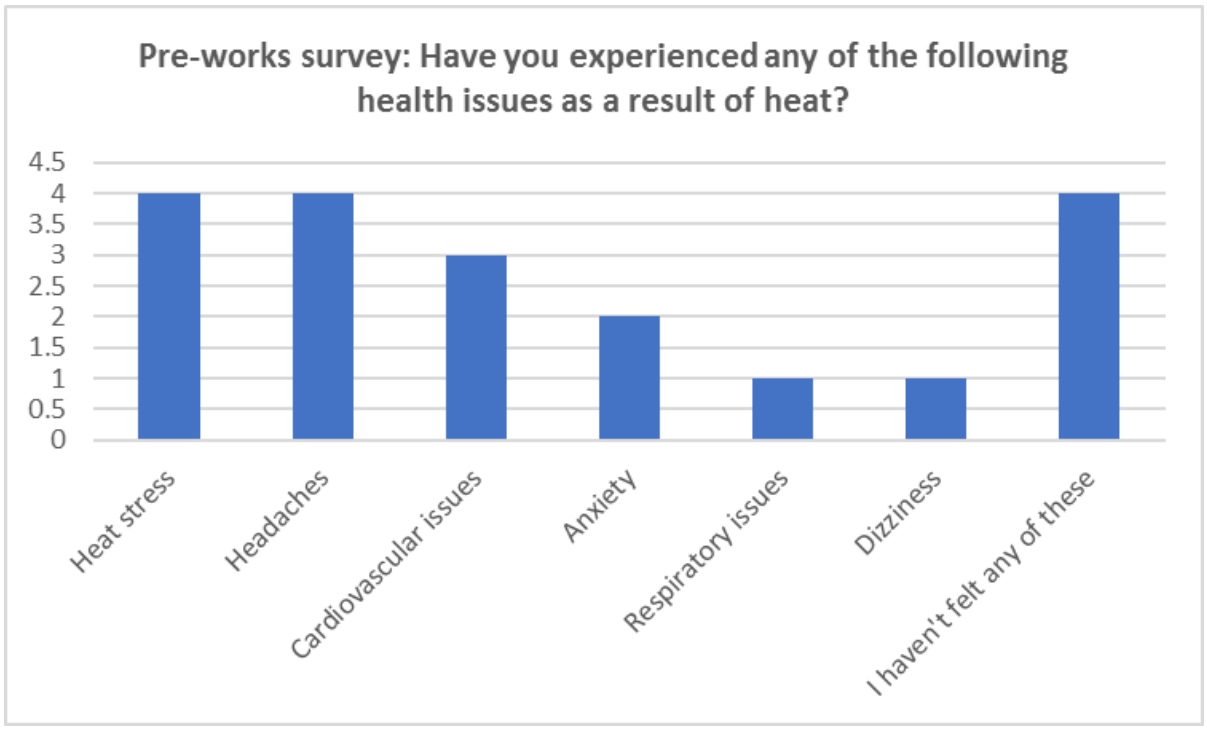
60% of residents also reported they had experienced health issues related to heatwaves. These included heat stress, headaches, cardiovascular issues, anxiety, respiratory issues and dizziness.

Figure 7: Residents perception of health issues related to heatwaves



(Source: pre-works survey undertaken 25th to 27th October)

Figure 8: Residents perception of specific health issues experience as a result of heat



(Source: pre-works survey undertaken 25th to 27th October)

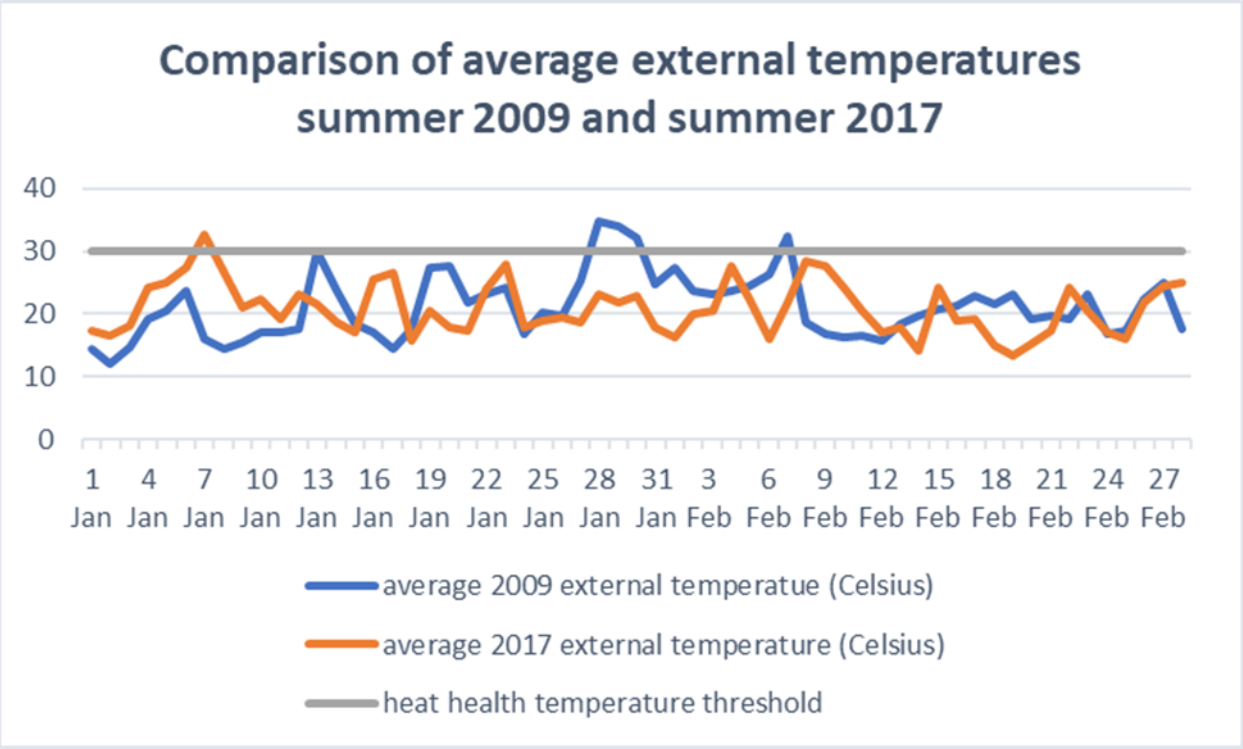
In addition, residents consistently reported being more concerned about how hot their home will get and the health impacts when a heatwave is forecast rather than the cost of cooling or changes to their routine.

Thermal performance indicators - Temperature loggers

As resident perception of thermal comfort is subjective we also installed data loggers in each property to capture information on the internal temperature and humidity.

It should be noted that there were no heatwaves experienced during the study period (i.e. three consecutive days where the average external temperature exceeded the heat health temperature threshold for Melbourne). For reference figure 9 compares the average temperatures during January and February 2017 with January and February 2009, when a heatwave of the type forecast to become more frequent was experienced.

Figure 9: Average external temperatures Jan/Feb 2009 and Jan/Feb 2017



(Source: BOM data for Essendon weather station)

The data loggers found that prior to upgrades the internal temperatures in many of the properties often exceeded levels deemed safe for occupant health and wellbeing.

One of the measures used to measure thermal comfort is the indoor Discomfort Index (DI). This measure has been in use for over 40 years and is regularly utilised due to its ease of use and physiological significance.[19] It provides a measure of air temperature and humidity, two factors contributing to heat stress, but excludes other potential physiological effects due to air movement or radiation. Full details of the definition used are included in annex 2.

The threshold DI measures in this study are:

- < 22 No heat stress is encountered
- 22-24 Most people find a mild sensation of heat
- 24- 28 Heat load is moderately heavy, people feel very hot
- > 28 Heat load is severe, people at increased risk of heat illness

[19] CSIRO 2013: Pathways to climate adapted and healthy low income housing, Final Report: CSIRO, National Climate Change Adaptation Research Facility, 2013.

Given the requirement to install measures such as insulation and draught-proofing before temperature became too hot for contractors to work we were unable to measure internal temperatures for all properties before initial works began.

For those properties where no substantial works were undertaken before the end of January we could measure the DI before works.

Table 1: Maximum DI of properties prior to works undertaken

	Maximum DI	Works installed at that point
CC5	27	Ceiling fan and draught-proofing
CC7	28.1	Ceiling fan
CC8	28.5	Ceiling fan
CC9	29.5	Ceiling fan
CC10	28.9	Ceiling fan

In properties where we needed to begin works prior to January we were unable to measure the DI on hot days (i.e. above 30c) before works. The maximum DI was slightly lower as listed below.

Table 2: Maximum DI of properties during retrofit

	Maximum DI	Works installed at that point
CC1	25.5*	Draught-proofing and insulation
CC2	25.1	Draught-proofing
CC3	25.5	Insulation
CC4	26.2	Draught-proofing and insulation
CC6	26.7	Draught-proofing and green infrastructure

* The data logger for CC1 only worked from 23/1/17 to 14/4/17

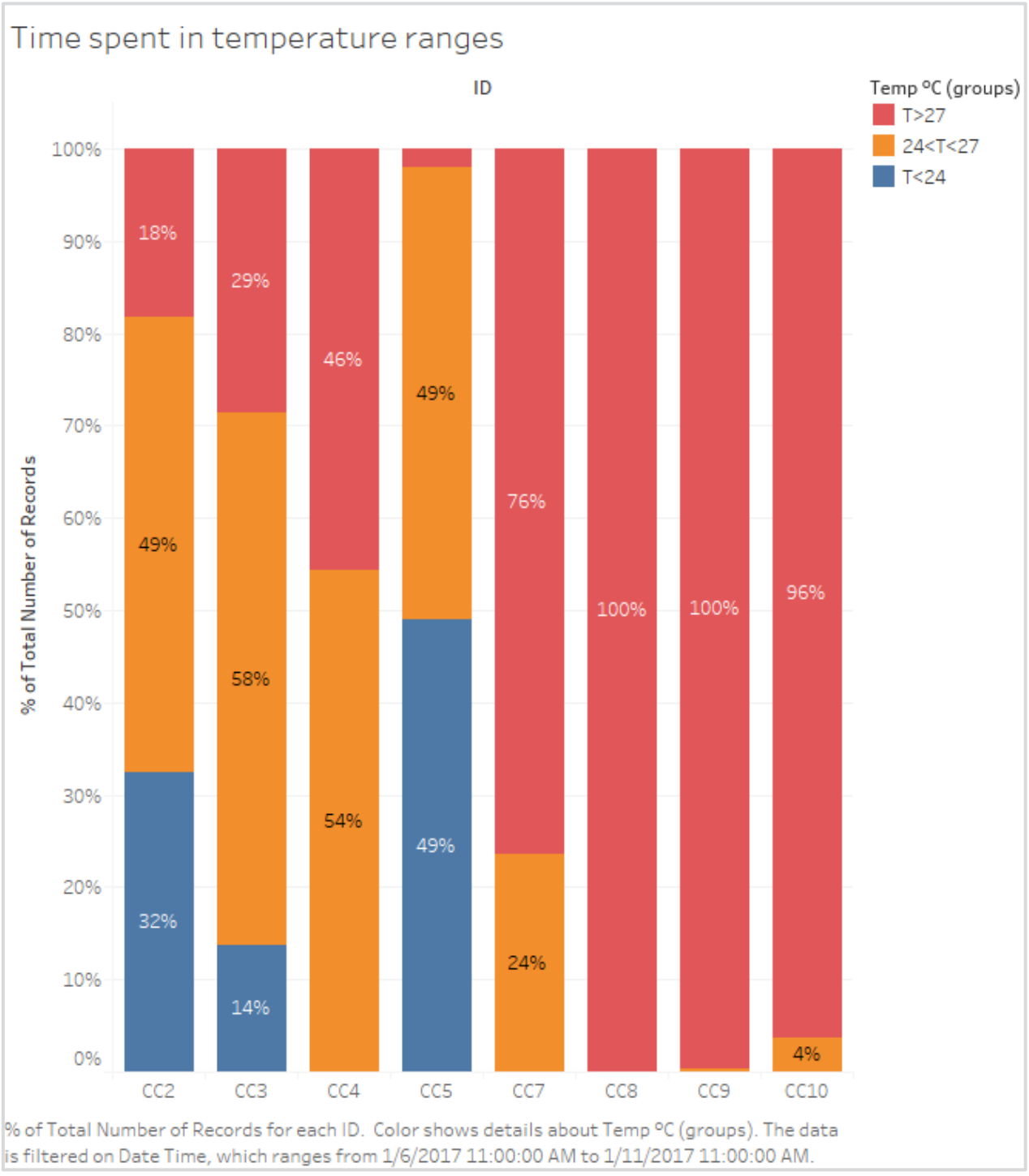
The data shows all properties reached levels where people feel very hot and many reached levels that put residents at increased risk of heat illness.

Given the resident responses on experiencing problems sleeping due to overnight heat we also analysed the temperature fluctuations in properties over the 24-hour period on hot days. This is significant because another study in Melbourne has found that the average daily mortality for people aged 65 years or over increases sharply to between 19 and 21% once overnight temperatures exceed 24°C.[20]

As figure 10 illustrates the temperature inside properties CC4, CC7, CC8 and CC9 failed to drop below 24 degrees Celsius at any point (day or night) during the hot weather event from 6 to 11 of January.

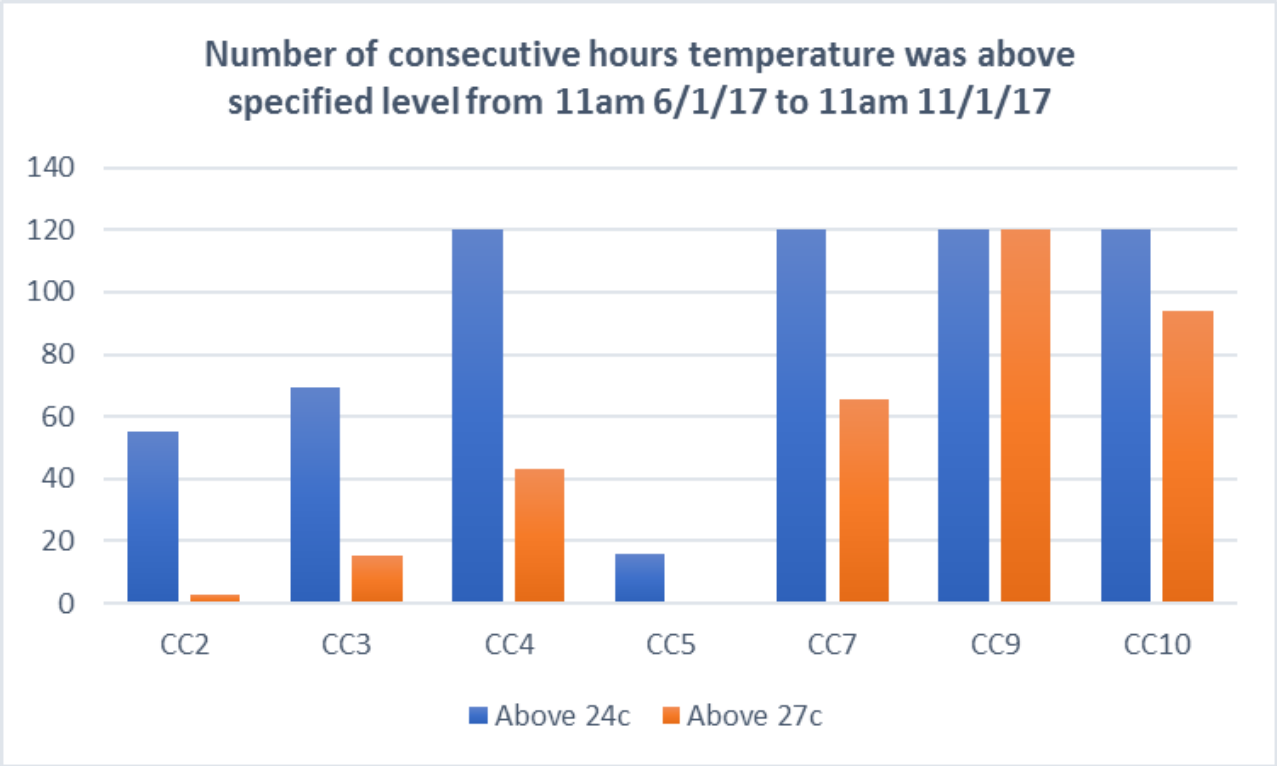
[20] Nicholls, N., Skinner, C., Loughnan, M. and Tapper, N. (2008). A simple heat alert system for Melbourne, Australia. International Journal of Biometeorology, 52(5), 375-384

Figure 10: Number of hours internal temperatures in specified ranges during hot spell in January 2017.



(Source: data loggers)

Figure 11: Number of consecutive hours internal temperatures above 24c during hot spell in January 2017.



(Source: data loggers)

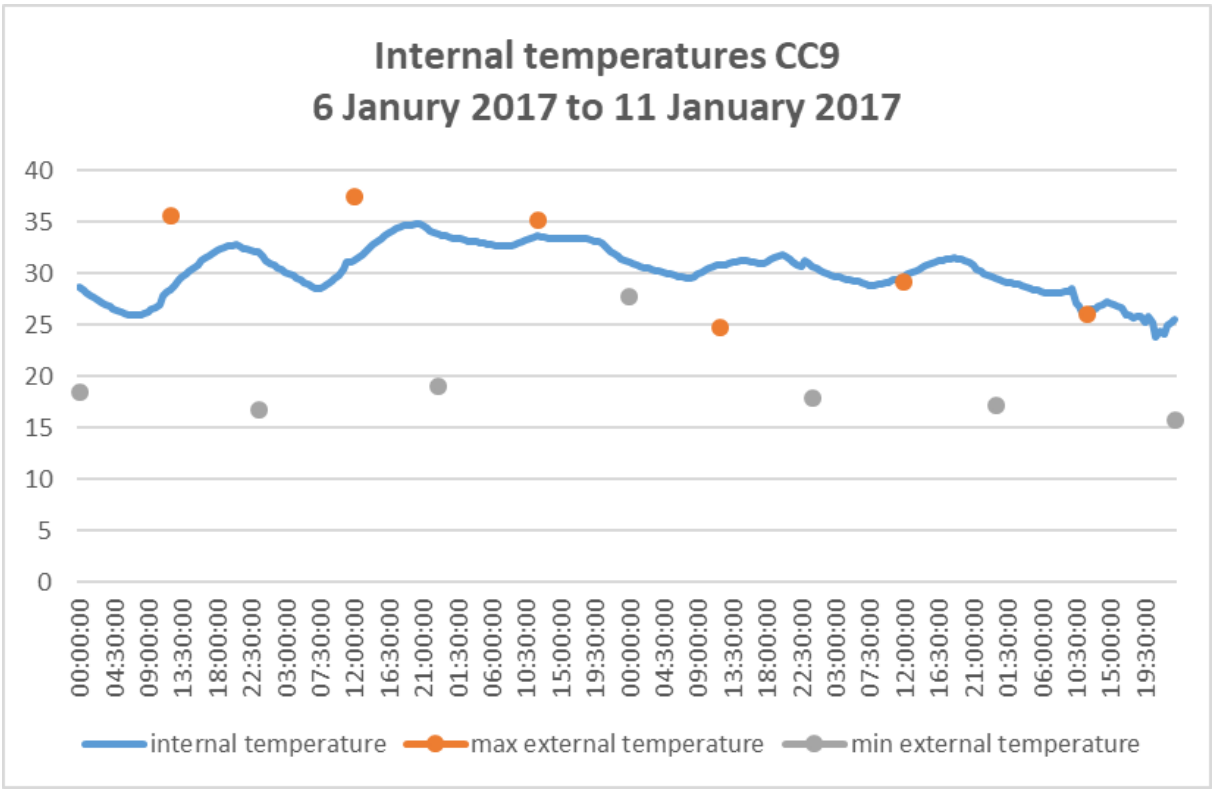
As detailed in figure 11, all properties apart from CC5 experienced a period of 55 hours or more where internal temperatures failed to drop below 24 degrees Celsius. During this period half the properties monitored experienced a period of 43 hours or more where internal temperatures failed to drop below 27 degrees Celsius.

Extended periods of high internal temperatures were most pronounced in the apartments (CC7, CC9 and CC10). This is because the construction type (concrete/metal), thermal mass of the building and lack of ventilation mean that it heats up quickly and retains the heat long after the external temperature has dropped.

As illustrated in figure 12 below in CC9 the internal temperature failed to drop below 27.1c at any point during this 5-day period and it was over 28 degrees Celsius for 119 consecutive hours. Even in this short period this exceeded the UK's standard for overheating where no more than 1% of annual occupied hours (87.6 hours annually) is over an operative temperature of 28˚C in living rooms.[21]

[21] Environmental design: CIBSE guide A. (2015). London: CIBSE

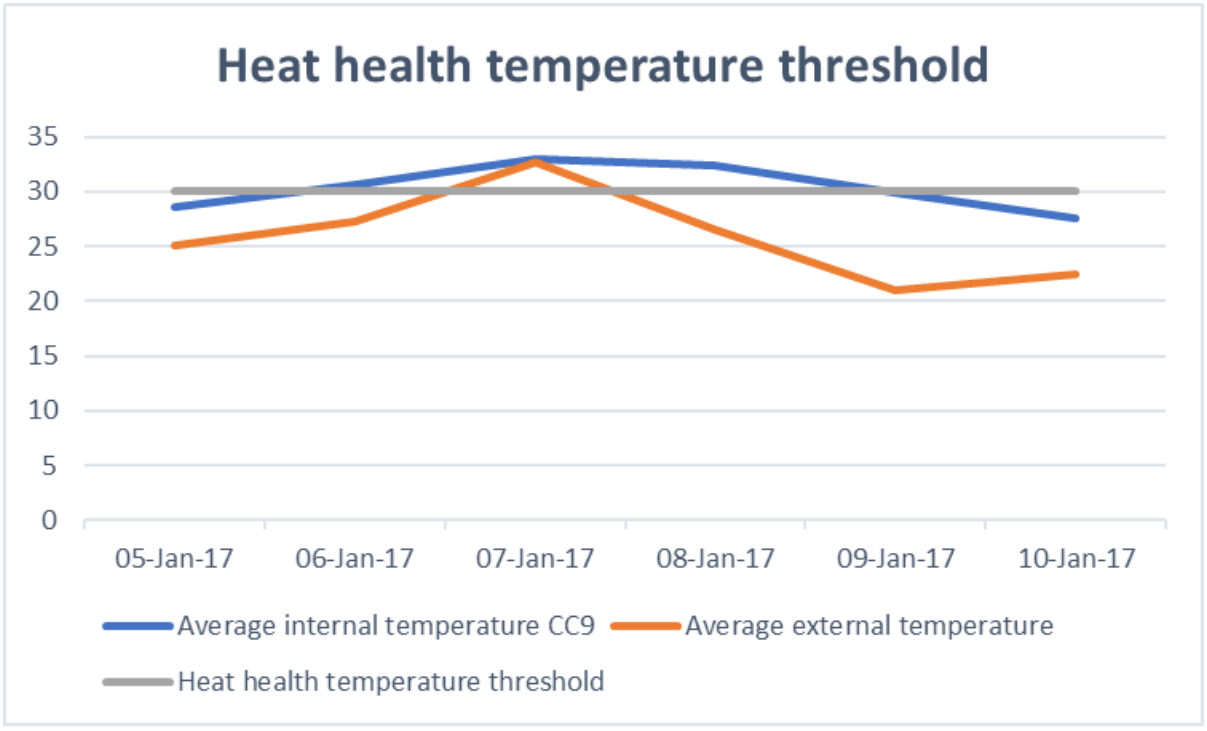
Figure 12: Internal temperatures by hour at CC9 during hot spell in January 2017.



(Source: data loggers and BOM data)

More concerning, whilst Melbourne did not experience a heatwave in the study period this property did. As figure 13 shows the average internal temperature for this property exceeded the heat health temperature threshold for Melbourne (30 degrees Celsius) for three consecutive days, from 6th to 9th January 2017.

Figure 13: Internal temperature in CC9 during hot spell in January 2017 against heatwave threshold



(Source: data loggers and BOM data)

This data raises substantial concerns because whilst external maximum temperatures rose above 35c for three consecutive days during this period the external minimum temperatures dropped below 20 degrees Celsius for all but one of the dates.[22] In an official Melbourne heatwave the average of maximum and minimum temperatures must be above 30 degrees Celsius for 3 consecutive days, providing little respite from the heat overnight.

With these types of heatwaves predicted to get more frequent and extreme it is alarming to think what the experience and health impacts from such an event would be for residents in several of these properties.

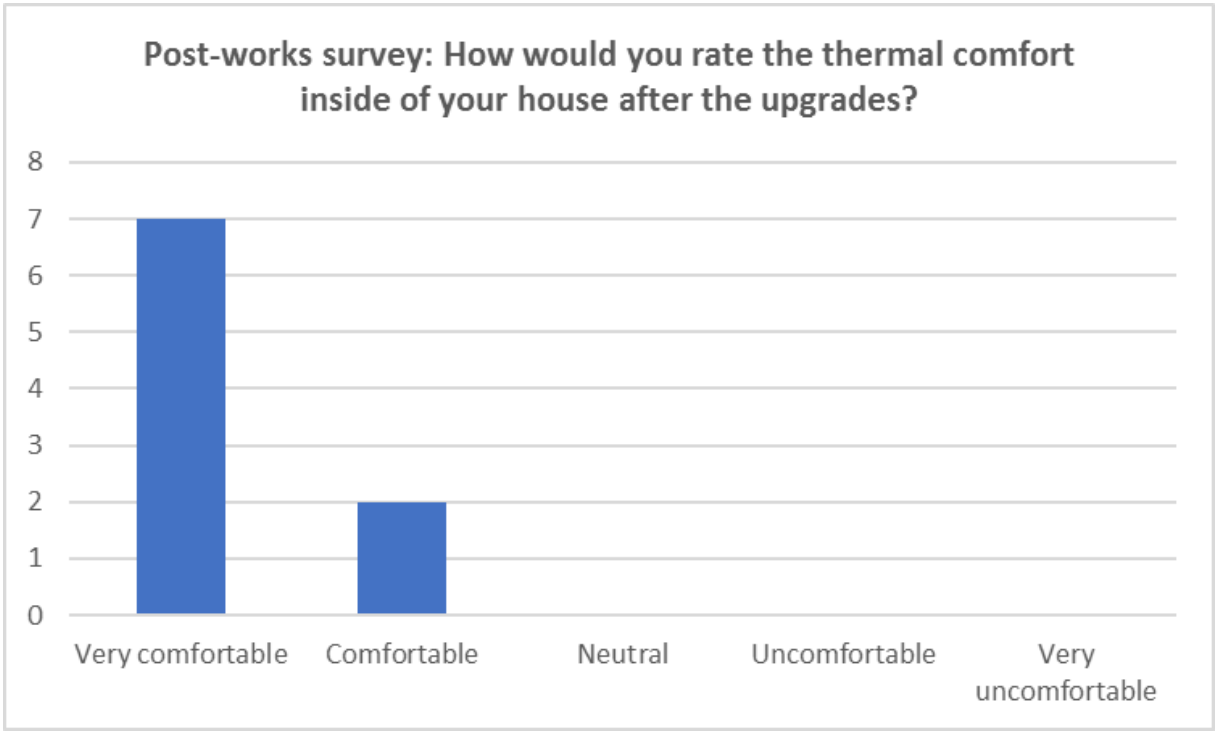
2.2 All occupants reported improvements in thermal comfort following retrofits

Thermal performance indicators – resident perception

Following the retrofits all the residents surveyed[23] reported that they were now able to cool their homes over summer. All residents surveyed also reported that their '*house feels a lot cooler when it is hot outside*.'

78% of those surveyed reported that the thermal comfort inside their homes was '*very comfortable*' and 22% reported that it was '*comfortable*.' 78% of those surveyed noted improvements in ventilation following works, stating that it feels '*less stuffy'* inside now.

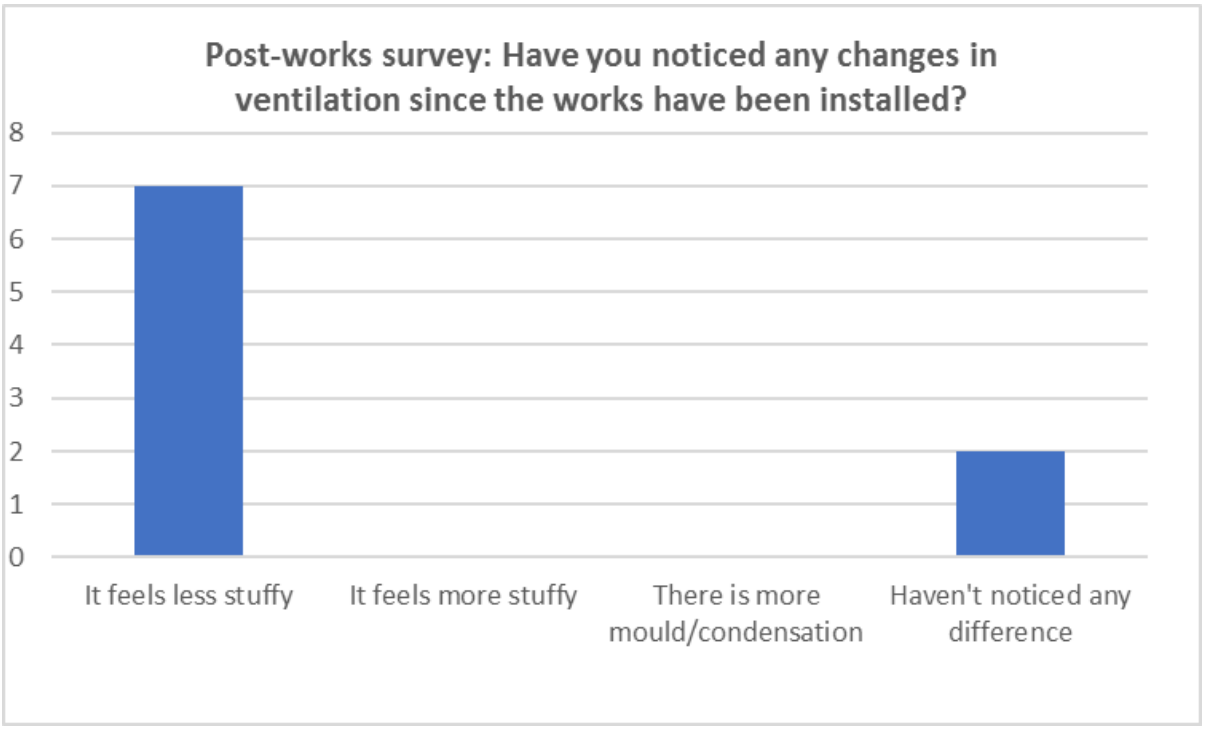
Figure 14: Resident perception of thermal comfort of home post-works



(Source: post works survey completed 21st to 26th of April)

[22] See Annex 3 for external temperature data during survey period
[23] Note that one of the residents did not participate in the final survey

Figure 15: Resident perception of ventilation post-works



(Source: post works survey completed 21st to 26th of April)

Each resident received a bespoke package of measures so it was not possible to determine which measure residents found most effective. Those who had received air-conditioning all rated this as their preferred retrofit measure however they were able to appreciate the benefits of all measures.

"I've been amazed how much difference simple things like draught-proofing make."

"I love all the trees."

"It's been really cool. I appreciate that."

"The draught-proofing and insulation have made a big difference to my thermal comfort."

"Usually in the evening it was very hot in here. After the blind went in it's been much cooler. We feel so much more comfortable now."

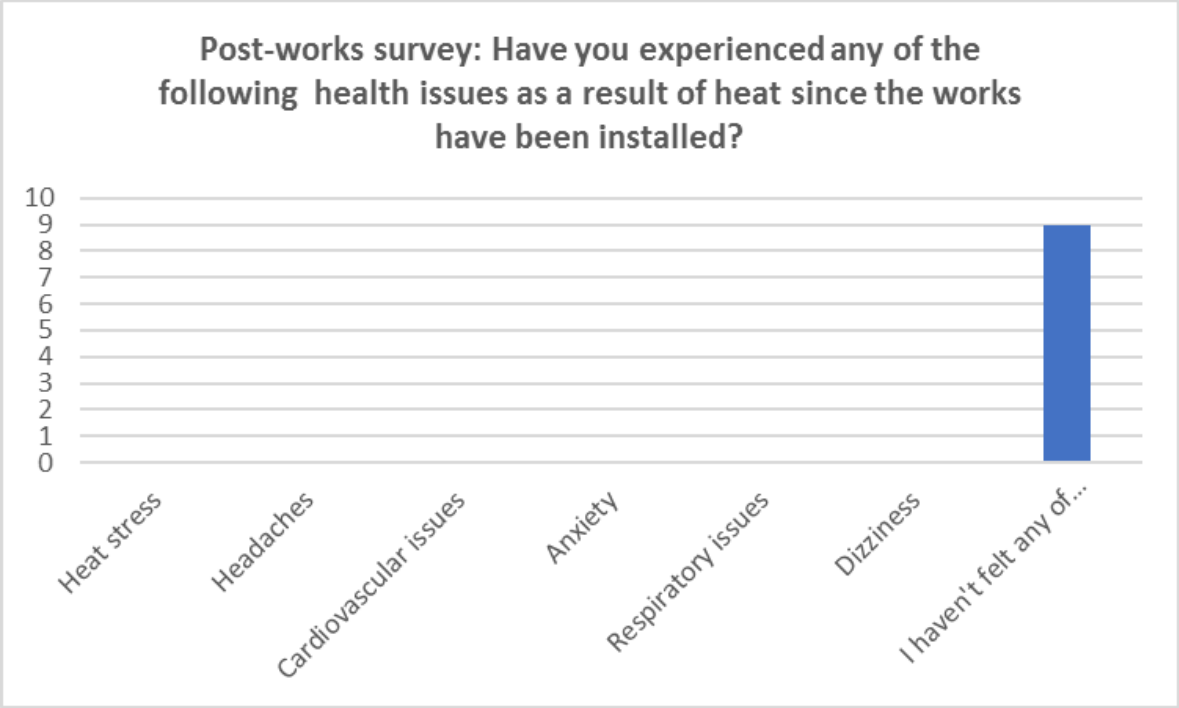
78% of respondents reported that they were sleeping better since the retrofits and none reported experiencing any health issues because of heat since the works had been installed. Whilst this could be explained by the fact that there were no heatwave conditions during this period the feedback from several of the residents reported that they felt their health had improved since the retrofits. This was especially the case for those residents who had air-conditioning installed.

"Now I can sleep at night. Before I was tossing and turning all night."

"I'm happy for everything [the project has delivered], but first of all my health."

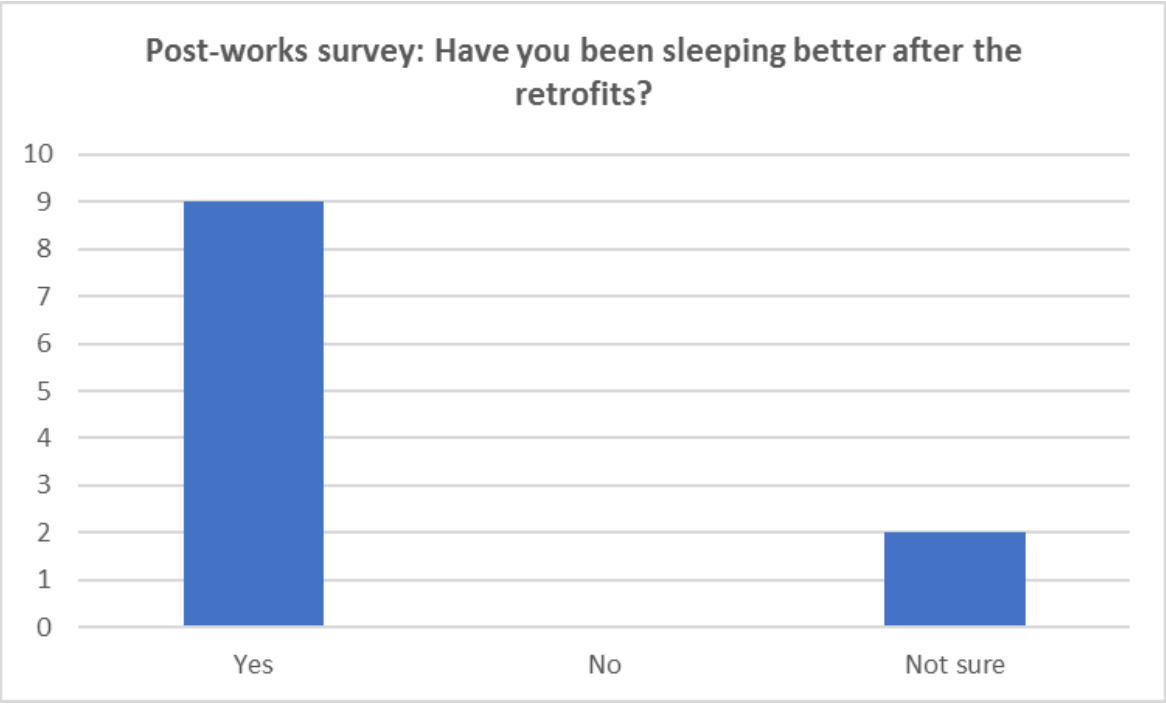
"Because of the medication I'm on, I get hot and cold flushes. The biggest benefit of the program is that I'm now able to adjust the temperature to compensate for that."

Figure 16: Resident perception of health issues as a result of heat post-works



(Source: post works survey completed 21st to 26th of April)

Figure 17: Resident perception of sleep patterns post-works



(Source: post works survey completed 21st to 26th of April)

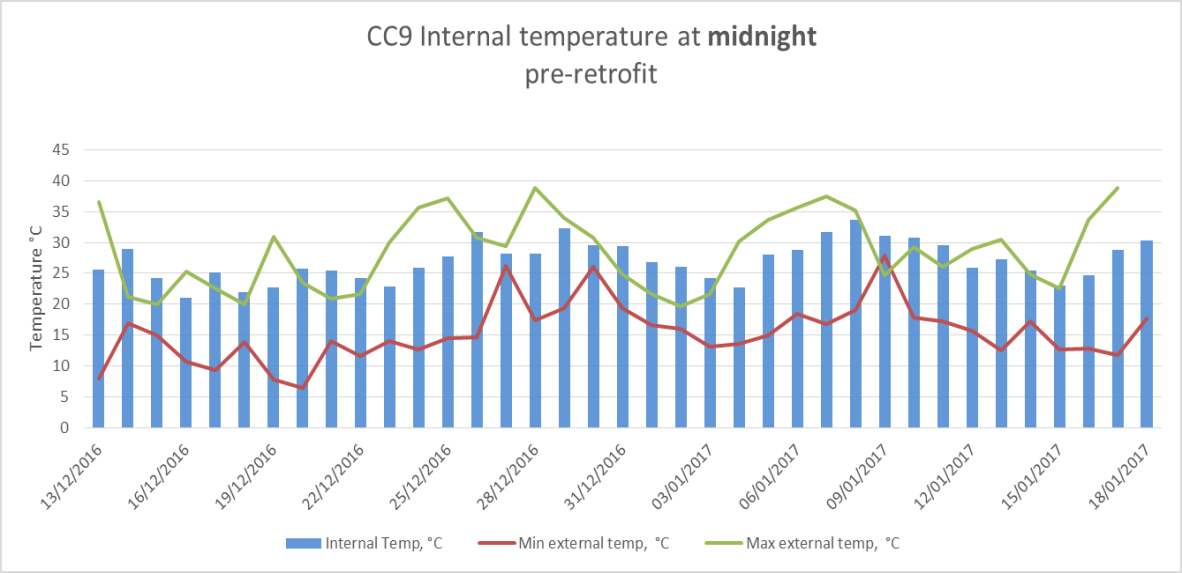
Thermal performance indicators – data analysis

As noted above it is not possible to assess the impact of the retrofit measures on the Discomfort Index as we do not have comparative data from a previous summer and even during the period studied there were no replicable temperature patterns. As figures 26, 27 and 28 show however it is clear that installation of air-conditioning in CC7, CC8 and CC9 had an immediate impact, lowering DI below 25.

As noted prior to the upgrades property CC9 experienced the highest temperatures at night time. Figures 18 and 19 below show that prior to the retrofit the temperature at midnight within CC9 exceeded 30 degrees Celsius on seven occasions during the 38-day monitoring period. It only fell below 24 degrees Celsius at midnight on 8 occasions. **The maximum temperature recorded at midnight was 33.7 degrees Celsius on 8th January 2017.** The maximum external temperature that day was 35.2 degrees Celsius.

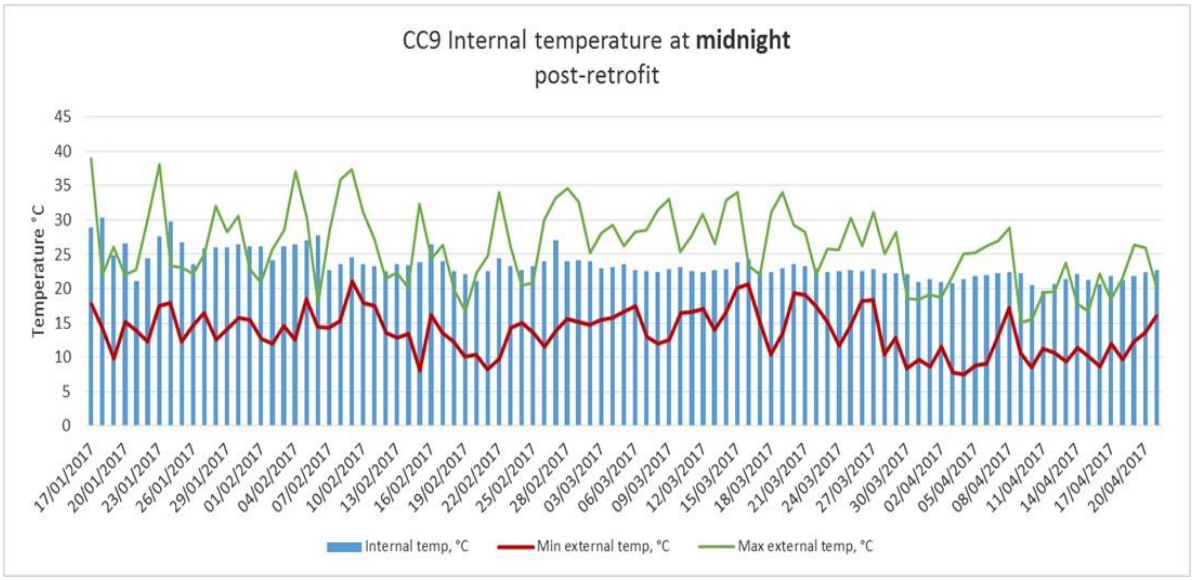
The property was fitted with a ceiling fan on 23 December 2016 and air-conditioning on 6 February 2017. In the subsequent 74 days of monitoring the temperature at midnight never exceeded 27 degrees Celsius and it only exceeded 24 degrees Celsius at midnight on seven occasions due to the use in the newly installed air conditioners.

Figure 18: Internal temperature at midnight at CC9 pre-works



(Source: data logger and BOM)

Figure 19: Internal temperature at midnight at CC9 post-works



(Source: data logger and BOM)

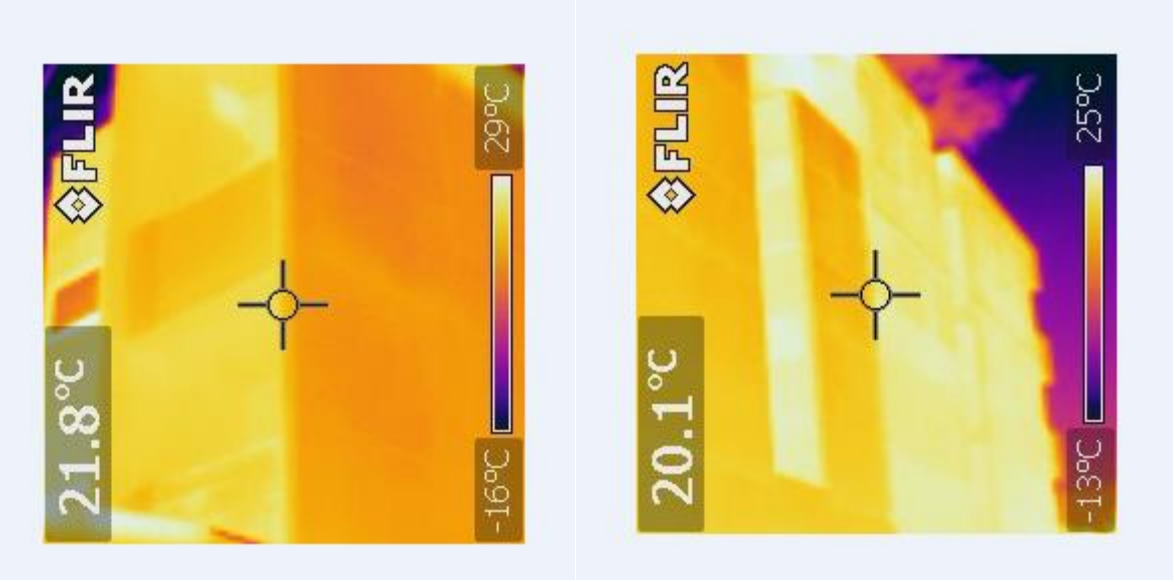
This pattern was replicated across the other apartments, such as CC7 where the temperature at midnight prior to retrofit was above 27 degrees Celsius on 15 occasions but below 27 degrees Celsius at midnight on all dates following the retrofit.

2.3 Poorly designed apartments provide limited retrofit options

As detailed in the methodology, we sought to prioritise building fabric upgrades and natural cooling through vegetation over mechanical upgrades. This is because whilst air-conditioning can be an effective way to ensure thermal comfort is at safe and healthy levels, it can be unreliable in heatwaves. This was experienced in Adelaide and Sydney in the summer of 2017 in which city-wide demand for air conditioning results in power blackouts.[24] Therefore, reliance on air conditioning can increase urban heat risk if a house is only liveable with air conditioning. Furthermore, split system air-conditioners contribute to the UHIE because they release hot air outside the building, thus making the surrounding area warmer. They also have the potential to increase energy bills and carbon emissions as a result of their use.

Despite this, we found however that the four apartments in the apartment building (CC7-CC10) offered minimal options for either building fabric or natural cooling upgrades. Their location in a five-storey apartment block with 100% site coverage and no open space meant that passive cooling measures such as external green infrastructure (vines or canopy) and external blinds were too difficult to retrofit. For example, retrofitting a green wall onto a façade of the building far exceeded the budget of the Cooling Communities project. In addition, given the recent construction of the apartment building there was less need for additional draught-proofing or insulation. Consideration was given to installing external louvered screens to protect glazing from the sun, however on investigation the cooling benefits these would provide were limited due to the metal façade of the building also being extremely warm.

Figure 20: Thermal images of apartment block (CC7-CC10) showing higher temperature of metal facades



(Source: K. Skidmore - taken 23 February 2017 standing outside the building. External temperature was 22.6 degrees Celsius)

Before taking the decision to install air-conditioning we installed an additional ceiling fan in each property and reviewed the resident perception and temperature and humidity data.

[24] http://www.smh.com.au/environment/weather/sydney-weather-energy-minister-pleads-for-help-to-avoid-heatwave-power-blackout-20170209-gu9po9.html and http://www.abc.net.au/news/2017-02-09/nsw-weather-possible-power-shortages/8257112

In the summer survey, all four residents reported that there had been '*not a significant difference*' in the comfort of their home during hot days. Three reported that they were had been '*not very comfortable*' during the hot periods in December and January and one reported feeling '*not comfortable at all.*'

Residents noted:

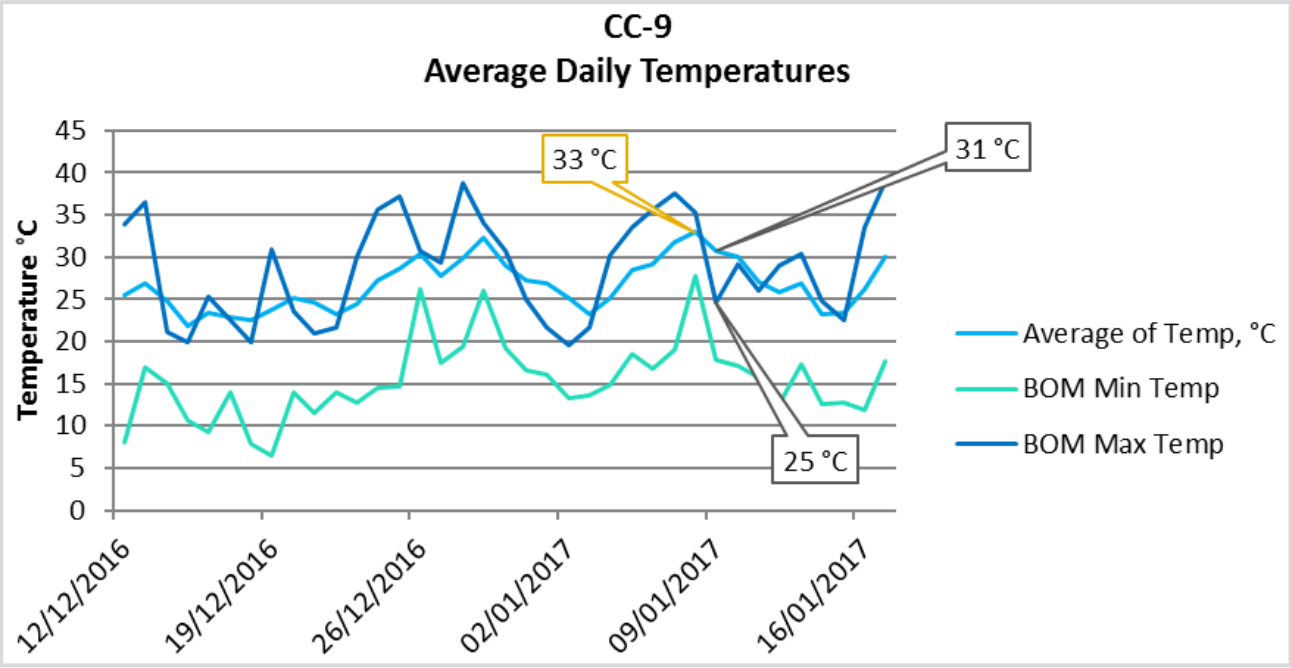
"the bedroom was still pretty hot after installing the ceiling fan."

"It's not enough with only the ceiling fan in the bedroom."

The temperature data from CC9 confirms that the fans installed on 23 December had limited impact on their own.

At the end of the hot period in early January the average daily temperature inside the apartment had risen to 33 degrees Celsius. Even when the temperature outside dropped it took several days for the temperature within the apartment to fall below 25 Celsius, due largely to the lack of natural ventilation. On both 1st and 9th January the internal temperature exceeded the external one by 6 degrees Celsius.

Figure 21: Average internal temperature in CC9 prior to retrofit

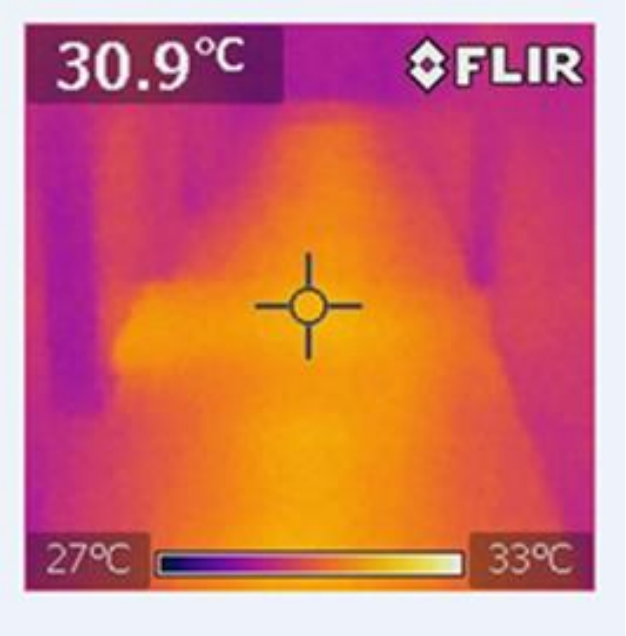


(Source: data loggers and BOM)

Whilst CC9 recorded the highest temperatures due to its location on the 4th floor and western orientation with exposed window glazing and the metal façade which also reflected onto this glazing, the data showed that all four apartments in the apartment building experienced similar patterns of heat accumulation during and following hot periods.

A key issue with the design of these apartments is the lack of natural ventilation and absence of any cross ventilation between windows and rooms. All apartments have sealed bedroom windows. a single external sliding door to the balcony and a front door which opens on to a hall with limited ventilation. The lack of openable windows is due to the immediately adjacent railway station and efforts to reduce railway sound in the apartments. The building also has no external shading devices for exposed windows, whilst a metal cladding as an architectural design feature radiates heat and then reflects the heat back into the apartments.

Figure 22: Thermal image shows temperature inside the hall at apartment block (CC7-CC10)



(Source: K. Skidmore - taken 11am on 23 February 2017. External temperature was 22.6 degrees Celsius)

"***It's an oven in summer"***
Resident describing hallway in apartment blocks CC7-CC10

"It gets so hot in the afternoon you could fry and egg on it. I work in the building trade so know what I'm talking about. It's a recipe for disaster."
Resident describing metal cladding on their balcony

Given the lack of other cooling options available the decision was made to install energy efficient split system air-conditioning units into all four properties.

Whilst this building is unlikely to be built in Moreland today due to several advances in planning policy[25] it highlights the importance of considering thermal comfort during design. This is especially important for apartments where retrofit options are limited. It is also critical to assess the performance of existing apartments to ensure they provide adequate protection from heat.

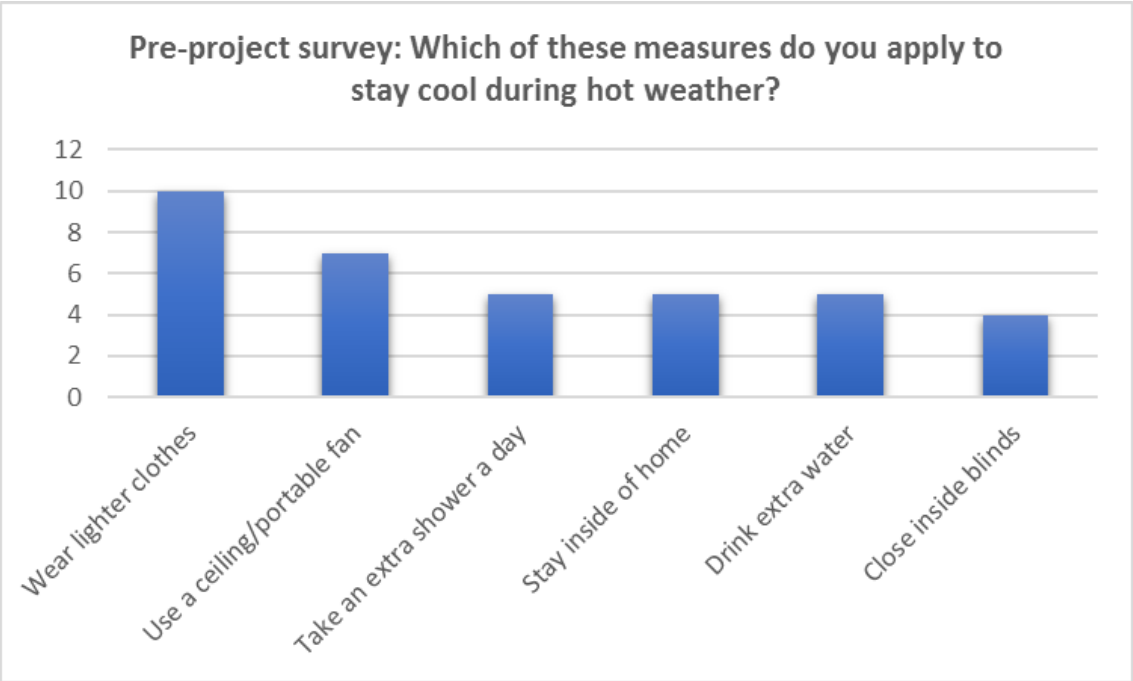
The findings from this study echo those of the Melbourne University Thrive Research Group who note that '*existing apartments are at the greatest risk of causing heat stress, due to the lack of or inadequacy of mechanical cooling, and often poorer building fabric thermal performance.*'[26]

[25] Environmentally Sensitive Design clause in Moreland's Planning Scheme, the Better Apartment Design Standards and Moreland Apartment Design Code
[26] Jensen, Chu, Cadorel and Hes, (2017), 'Living Well – Apartments, Comfort and Resilience in Climate Change.' Thrive

2.4 Resident behaviour is important to ensure benefits are maximised

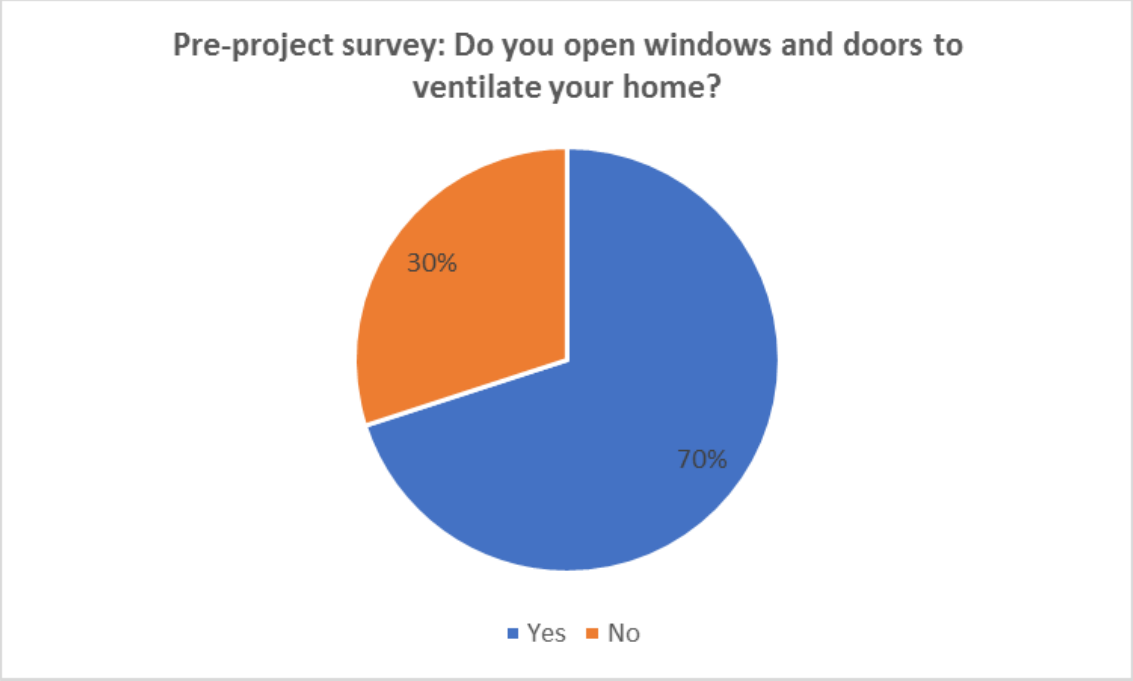
Residents already understood many actions they could take to improve the thermal comfort of their homes. At the start of the project 70% of residents reported opening windows and doors to ventilate their homes in summer and 70% used portable or ceiling fans as one of the main ways they kept cool during summer. Many residents who had received air-conditioning and ceiling fan retrofits were using them in combination to cool the properties cost-effectively.

Figure 23: Resident actions to keep cool in summer pre-works



(Source: pre-works survey undertaken 25th to 27th October)

Figure 24: Resident use of ventilation pre-works



(Source: pre-works survey undertaken 25th to 27th October)

Residents had been involved in the decision making process on the measures to be installed on their properties however after the works were installed there was still a clear need to check in with residents to ensure that thermal comfort and cost saving benefits were being realised. This was especially the case for mechanical and green/blue infrastructure upgrades which require resident action.

A pamphlet with information about the retrofits was distributed to all residents, containing information such as: how the solar panels work, how the air conditioners work, etc.

Key issues we found were:

1. Residents require information on how to maximise benefits of upgrades

- In one of the properties the fan was on the winter setting rendering it ineffectual if not contributing to excess heating in summer. The resident was not aware of the switch or its function.
- One of the residents who received solar PV did not understand how solar functioned or that he may need to approach his energy company to ask for his fortnightly payment plan be reduced to reflect the reduction in energy being used.
- One resident did not understand that the awnings were retractable and would have left them down continually, potentially causing issues in winter.
- All residents were eager to care for the vegetation planted so that it would grow and provide cooling benefits. Many however were unsure about the best way to care for their new plants and requested guidance on how best to do this.

2. There is a need to check in with residents post-installation to ensure upgrades are being utilised effectively

- Despite receiving instructions from the installer, one resident did not understand the purpose or functioning of the downpipe diverter and would not have utilised it.
- One of the residents initially left air-conditioning on continually (even during the night and when out of the building) as he misunderstood this was what the installer had suggested.
- One resident was unable to move her awnings up and down due to the position they were in, so decided to leave them up so they would not be a hazard in high wind.

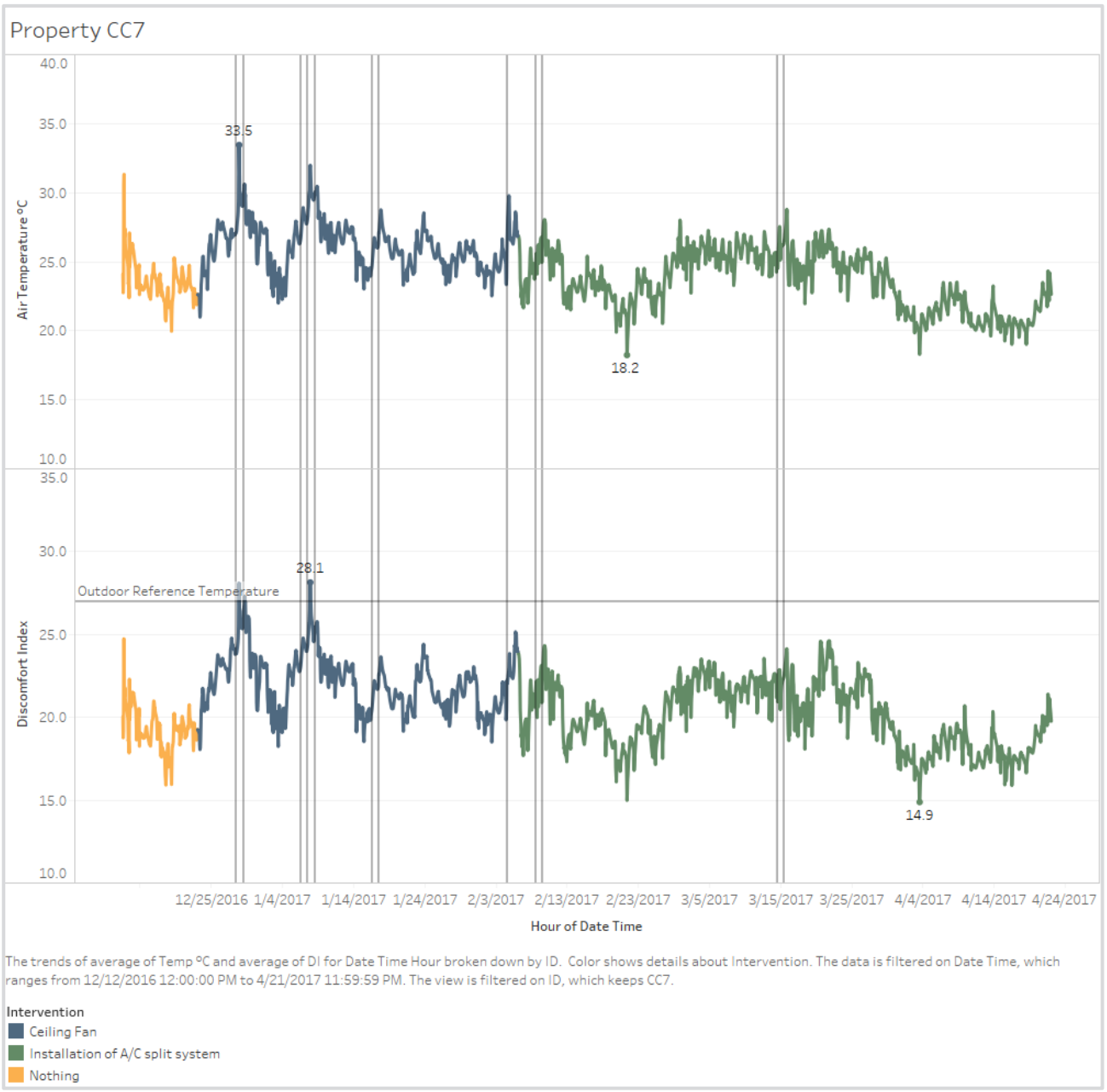
3. Mechanical cooling can be impacted by a range of factors

The temperature data loggers also showed significant differences in behaviour of the residents in the apartment block who had air-conditioning and fans installed. Whilst some of the variation in usage can be attributed to periods when the resident is away from home (and therefore not cooling their home) there is also potential for differential usage patterns due to concern over energy bills or health issues.

Whilst few residents reported turning the fan or air-conditioning off when they felt hot inside to save money most were yet to receive a bill for the summer period or on a payment plan so hadn’t seen an impact on energy bills.

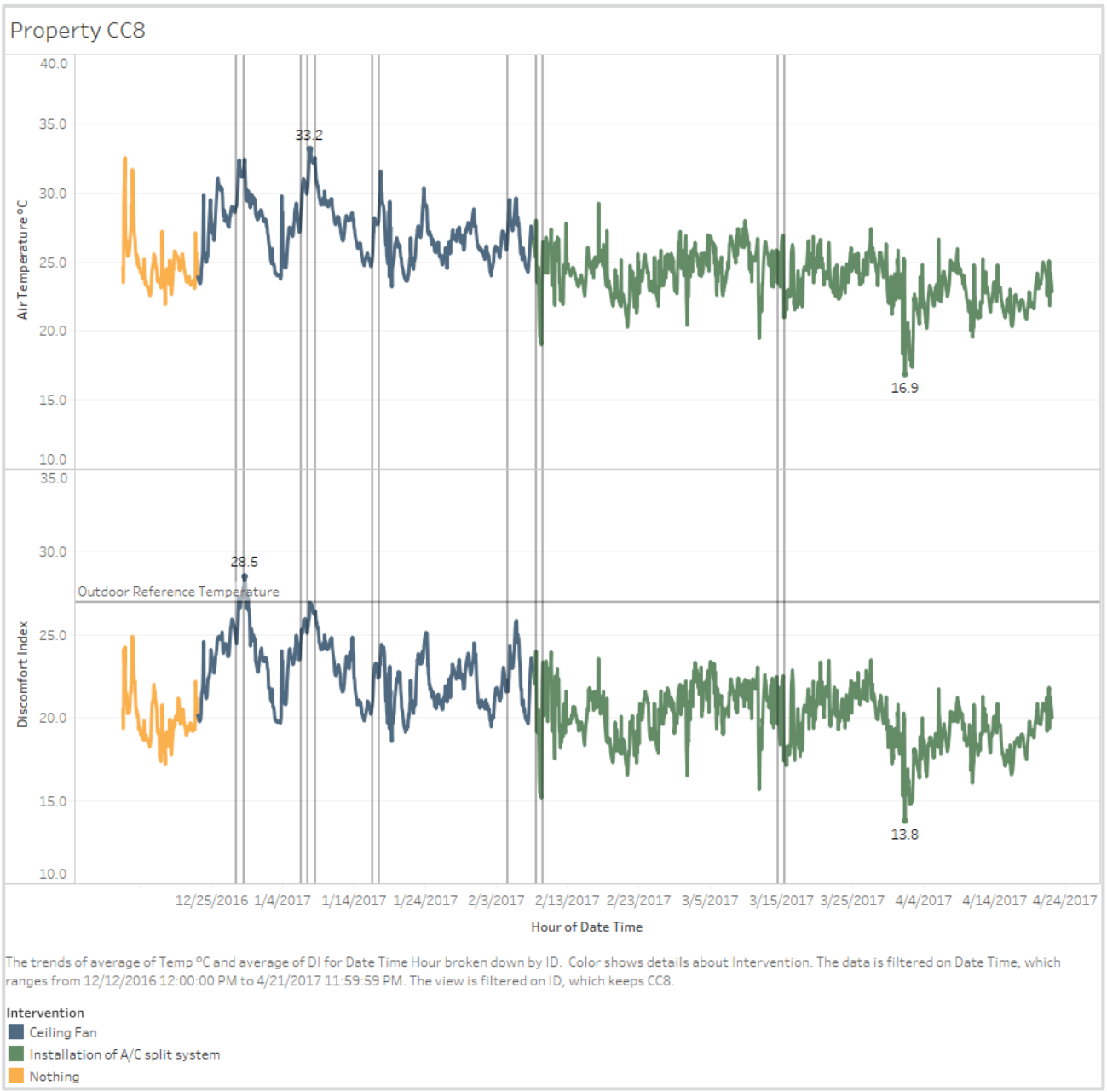
Residents in both CC8 and CC10 live with psychological conditions. This may help explain the variations in temperatures within these properties following the installation of air-conditioning.

Figure 25: Internal temperature and DI - CC7



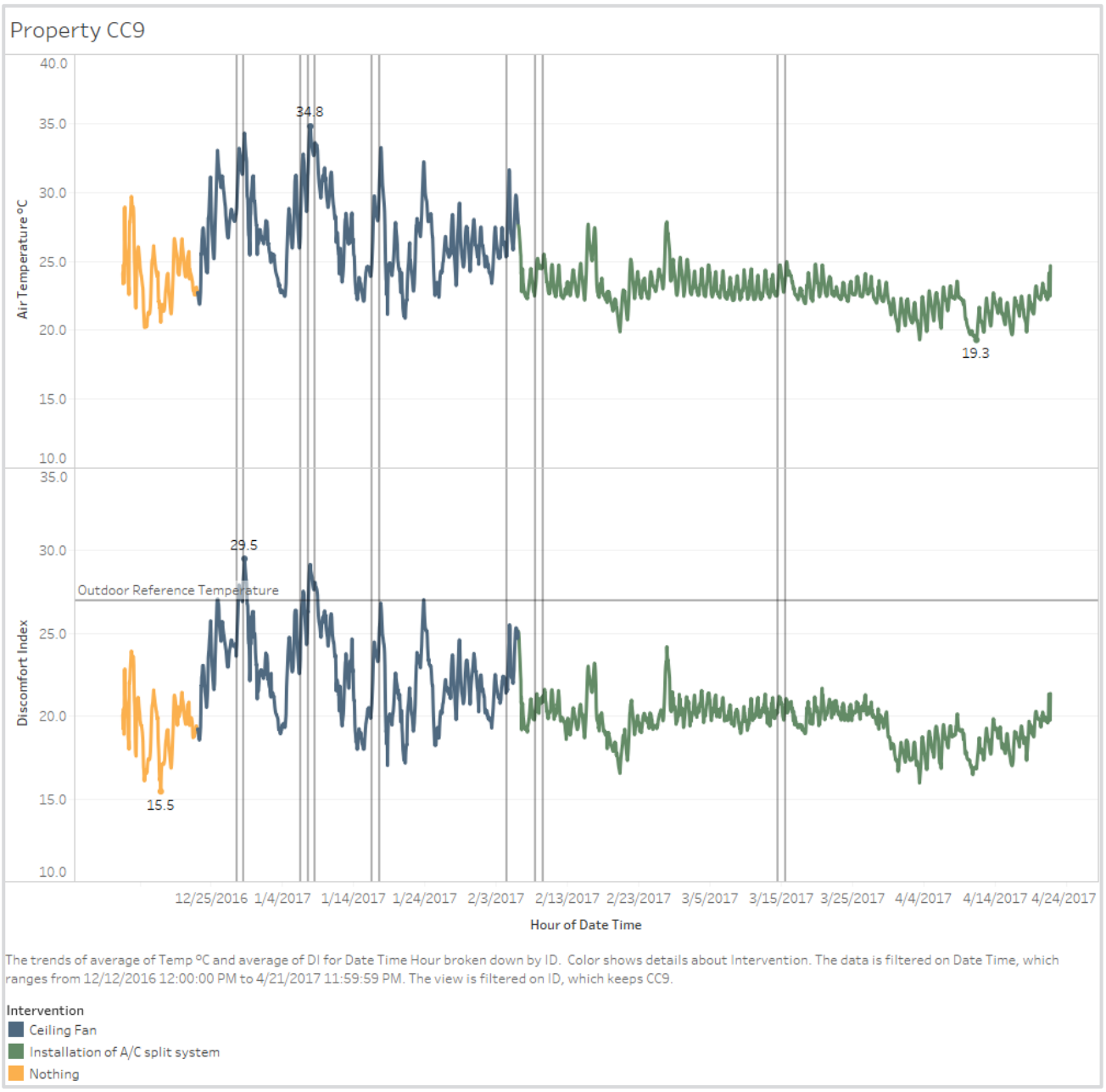
(Source: data loggers)

Figure 26: Internal temperature and DI – CC8



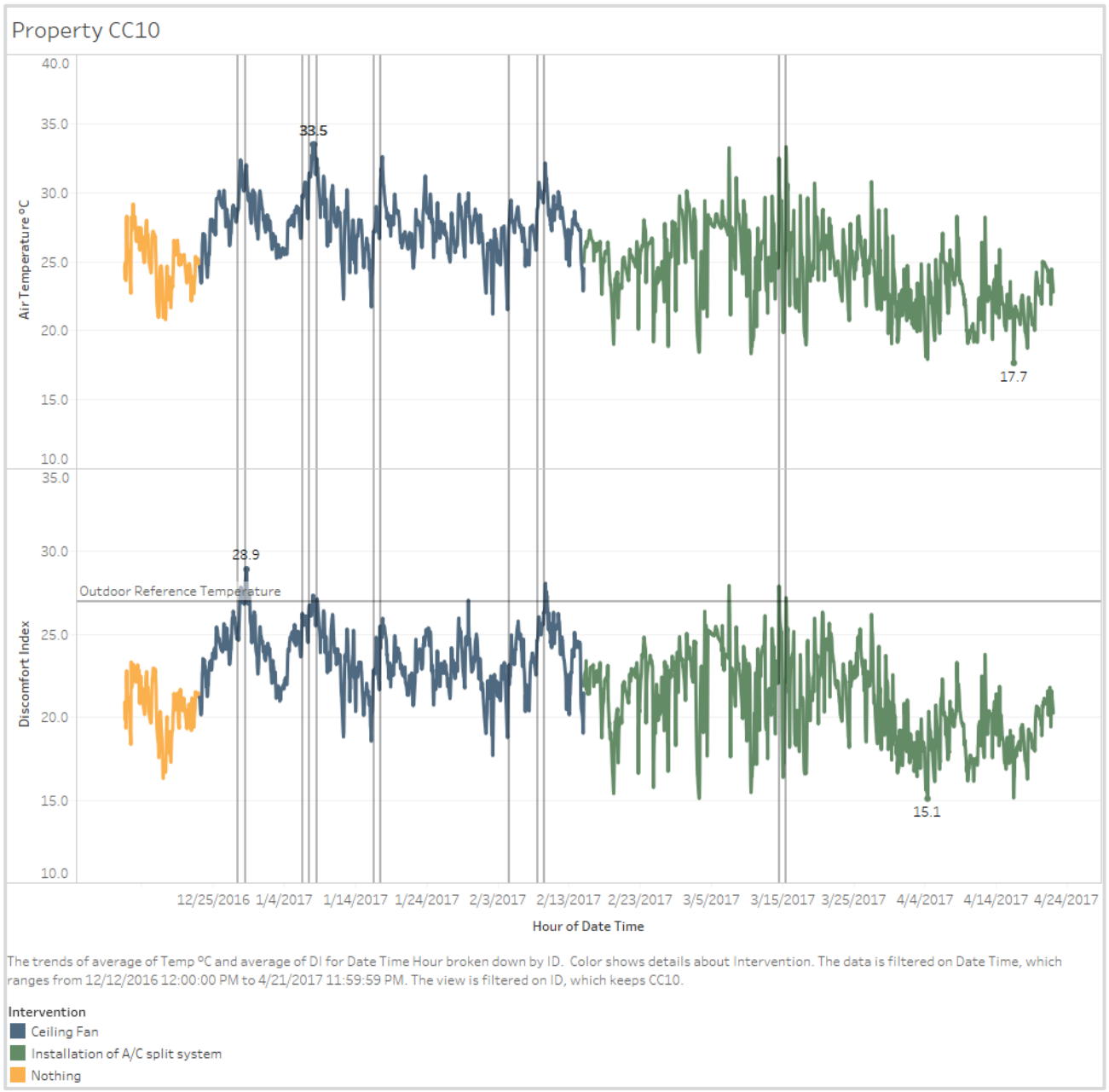
(Source: data loggers)

Figure 27: Internal temperature and DI – CC9



(Source: data loggers)

Figure 28: Internal temperature and DI – CC10



(Source: data loggers)

Given the variations in resident behaviour it would be preferential to prioritise retrofit measures which require little action from residents, such as insulation, draught-proofing and natural shading (i.e. deciduous trees).

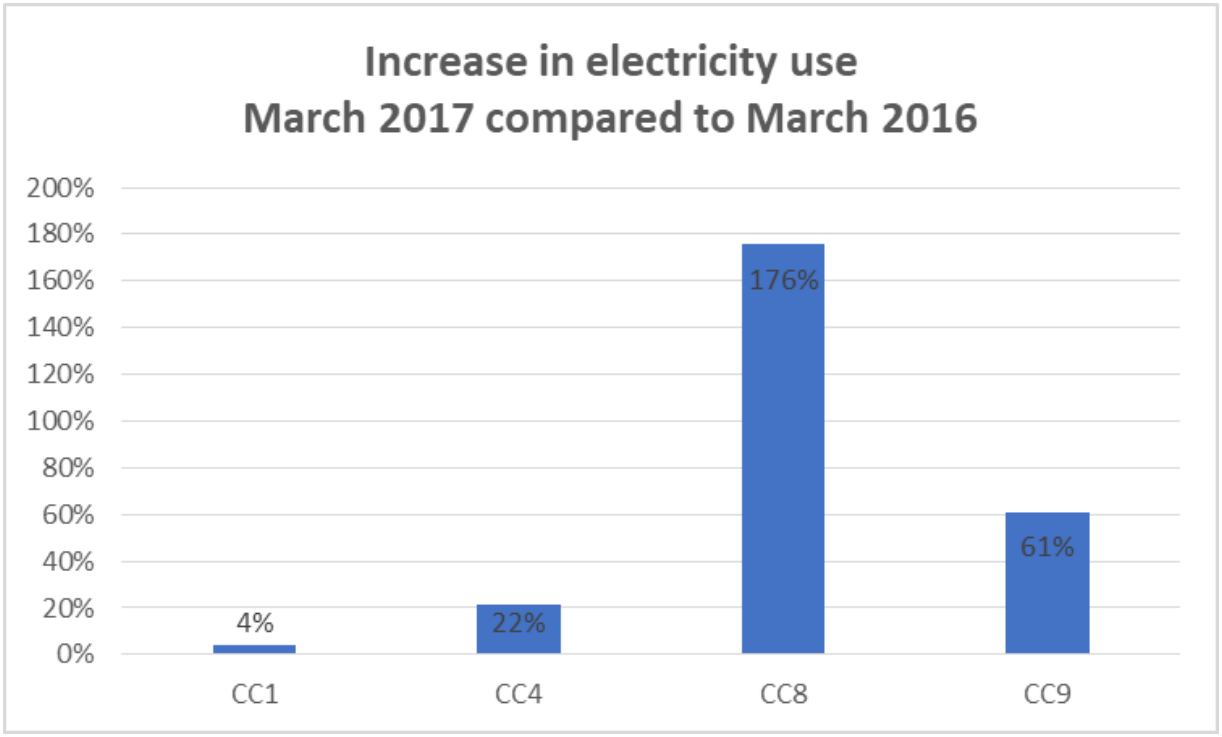
Where retrofit measures are installed that require more action by residents it is important to ensure that adequate instructions are provided and check in with residents post-installation to ensure that benefits are being maximised.

2.5 Cost impacts of fitting air-conditioning could be offset with solar PV

Billing data was analysed from four properties where air-conditioning was installed (CC1, CC4, CC8 and CC9) to assess the economic impact on residents given the evidence base that indicates low income households limit use of cooling devices to reduce energy bills despite discomfort.[27] [28]

Air-conditioning was installed at properties during February 2017 and whilst the sample size was too small to draw any significant findings it was clear that all tenants used more electricity in March 2017 compared to March 2016. As figure 29 shows this ranged from a 4% increase to a 176% increase. It should be noted that the resident at CC8 had experienced a change in circumstances which meant they were now at home during daytime and on medication requiring additional heating and cooling. The increase in electricity use cannot therefore be attributed solely to installation of air-conditioning.

Figure 29: Electricity usage March 2017 (following installation or air-conditioning) compared to March 2016



(Source: smart meter data)

Despite this increase in electricity usage in March the two properties that received a solar PV upgrade in April 2017 (CC1 and CC4) saw an overall reduction in electricity usage of between 9-15% over the four months from 1 Feb to 31 May. Given that the solar PV panels will generate electricity throughout the year installing a small solar PV system would be expected to offset the additional costs of operating an energy efficient split system air-conditioner and return cost savings to residents.

[27] Cornwell, Amin, Houghton, Jefferson, Newman and Rowley, 2016 'Energy Poverty in Western Australia: A comparative analysis of drivers and effects.' Bankwest Curtin economics centre, Perth

[28] Chester, 2013, 'The impacts and consequences for low-income Australian households of rising energy prices.' Department of political Economy, The University of Sydney.

2.6 Residents were very satisfied with the program

All residents surveyed responded that they were 'very satisfied' with the Cooling Communities program. The main reasons provided were because homes were now more comfortable to live in.

> "*Biggest benefit has been my comfort*."
>
> *"Because it has made a big difference in regards of the internal heat*."

Several of those who had received insulation and draught-proofing also reported that they had noticed an improvement in thermal comfort at the start of winter too, with properties much warmer.

Many residents reported that they had received upgrades they never would have thought possible. One of those who received air-conditioning noted that he was planning to take money out of his superannuation to pay for it himself, although he couldn't afford to do this. Another reported that she had started to look for private rental properties with air-conditioning as she knew her social housing provider would not install it at her property.

> *"It was like all my Christmases came at once. Anything that was added was a bonus. I couldn't believe it after 17 years. My job is to enjoy it*."
>
> *"It has too much helped me as I don't have money to buy air conditioning and was looking for private rent with air conditioning. Now rest of my life is happy*."

3 Discussion

From the project and discussions with project stakeholders the following issues were identified.

3.1 Existing building and planning requirements need to do more to promote passive design

a. Whilst the apartment building reviewed as part of this project would be unlikely to be granted a planning permit today this is due to local policies Namely, the Moreland Apartment Design Code, Amendment C142 and Clause 22.08 of the Moreland Planning Scheme, which contains the Environmentally Sustainable Design policy reviewing passive design, reduced reliance on mechanical cooling and emphasis on natural ventilation and natural cooling. State building and planning policies do not have adequate requirements for cooling through passive design.

3.2 There is a lack of funding for social housing providers to improve existing properties

a. Whilst state government recently announced funding packages to retrofit thousands of public housing properties with measures that will improve residents thermal comfort there is are no similar funding options available to Social Housing Providers. Several stated that they rely on small grant funded projects, such as this one, to deliver significant energy efficiency upgrades.

b. All the social housing providers we met with were keen to provide residents with housing that is safe and healthy however funding for all upgrades outside of essential repairs is limited. Priority is usually given to upgrading kitchens, bathrooms, floor coverings, painting and structural repairs, however a few social housing providers are beginning to incorporate draught-proofing and insulation works into maintenance upgrades. One of the social housing providers also fitted several properties with window film following concerns raised by the study.

c. Some social housing providers noted that they would be unlikely to retrofit external shading (notably retractable awnings and shade cloth) due to restricted maintenance budgets.

d. Whilst some older residents may be able to access funds to upgrade their properties and maintain their gardens through the Commonwealth Home Support Program this is not commonly understood by residents or social housing providers.

3.3 Existing policies within Social Housing Providers may restrict effective retrofit options

a. Several social housing providers have a policy not to install air-conditioning (whether funded by themselves or residents) unless the resident has a specific medical condition requiring cooling. This is traditionally due to concerns over maintenance requirements. Some social housing providers are however starting to replace faulty gas heaters with split system air-conditioning.

b. Some social housing providers prefer to concrete over outside areas of their older residents' properties to make them easier for residents to maintain.

3.4 Lack of knowledge about the impacts of UHIE on residents' health

a. Whilst social housing providers must provide accommodation that is 'safe, secure and affordable'[29] they do not traditionally assess the thermal performance of their dwellings as part of their property conditions reports.

b. Social housing providers are usually unaware if their properties are located in areas with high vulnerability to UHIE.

c. Social housing providers do not generally consider thermal comfort or resident vulnerability to heat stress when allocating residents to properties.

d. Many social housing providers lack technical skills on the potential for trees and other vegetation to improve thermal comfort and reduce resident's energy costs. Others view the garden as the resident's responsibility.

e. Many social housing providers do not understand additional UHIE impact of concreting over gardens and the role green infrastructure can play in reducing heat.

[29] Housing Registrar and Department of Treasury and Finance, (2014), "Performance Standards for Registered Housing Agencies'

4 Recommendations

4.1 Social housing

1. Ensure new homes provide adequate protection from UHIE without reliance on air-conditioning.

Given the impacts of heat stress on vulnerable residents' health it is critical that new homes provide adequate protection from increasingly hot summers without extensive retrofit requirements. This is especially the case for apartments where opportunities for retrofitting measures are limited.

Buildings must not have cooling loads so high that they are only able to be occupied in heat waves with air conditioning, as this presents unreasonable risk during summer blackouts. Reliance on air conditioning also risks residents' health if they are unable to afford to operate the system or have psychological health conditions that hinder their ability to effectively regulate their body temperature.

Decisions made in the design process will have a significant impact on how homes perform in heatwaves. Incorporating passive design measures at this stage will help avoid higher cost measures later. Through passive design principles it is possible and financially viable to design buildings in Melbourne's climate (and warmer climates) which do not rely on mechanical cooling to make them adequately liveable. Designing buildings this way will ensure they provide protection from heat during black-outs, do not contribute to the UHIE or become unaffordable to cool due to rising energy prices.

2. Assess thermal performance of their existing portfolio and prioritise properties for retrofitting.

It is clear from the study that a significant amount of the existing social housing stock fails to provide residents with adequate protection from heatwaves.

We suggest that social housing providers incorporate assessment of thermal performance into their existing property condition reports. This data will enable social housing providers to understand which properties require urgent works and prioritise available resources.

Capturing this data will also enable social housing providers to include the thermal performance of the property as a consideration when allocating properties to residents. For example, residents with health conditions that are worsened by extreme heat should not be housed in properties where temperatures are high. This would help ensure those with health issues exacerbated by heat are placed in suitable properties.

3. Prioritise building fabric upgrades and natural cooling retrofit options.

As the study illustrates the retrofit works required to improve thermal performance would differ for each property according to age, condition, typology etc. When retrofitting properties social housing providers could consider prioritising building fabric upgrades, especially insulation and draught proofing. As well as cooling residents in summer these measures will keep residents warmer in winter. This is vital given that more Victorians die from prolonged exposure to cold than heatwaves.

These 'set and forget' measures require less action from residents (other than ventilation which was well understood by those in the study) and should deliver cost savings to residents as well as reducing carbon emissions. Installing these measures first will also ensure that if mechanical cooling is required it will be more effective, minimising its cost, carbon and UHIE impacts.

Greater emphasis could also be given to natural cooling through vegetation (ie shading from deciduous trees). Whilst benefits from these measures will take longer to be realised they are relatively inexpensive and provide wellbeing benefits above the other measures as well as helping to reduce the UHIE in the wider realm. Whilst those in the study were keen to care for their new plants it is possible that future residents would not be able to, so landscaping should be designed to provide cooling benefits whilst minimising maintenance. Where possible WSUD measures (such as rainwater tanks and downpipe diverters) should be installed with vegetation to mitigate the cost and water impacts.

Whilst the waste heat generated by split system air-conditioners compounds the UHIE they can play an important role for those with health issues exacerbated by the heat and properties with limited retrofit options. Split system air-conditioners are also increasingly seen as an efficient heating appliance, especially when looking to move properties off gas. Current systems can provide up to 80% reduction in energy use compared to an electric resistance heater and is roughly consistent with a gas space heating system in terms of efficiency, however the efficiency of split systems continues to improve. Where possible a small solar array should be installed with a split system air conditioner to mitigate the cost and carbon impacts.

4. Engage residents in the retrofit process

Residents know how the different rooms in their homes perform in heat and how they use each room. Residents were therefore a critical source of information when deciding which measures would be most effective for each property. We therefore suggest that social housing providers include residents in the decision-making process for retrofitting properties.

This is especially the case with the green infrastructure upgrades. Given that the trees and vegetation will require ongoing maintenance it was important to allow the residents to choose from a range of suitable options. Providing the residents with trees and vegetation of their choice engaged them in the process and will help ensure they continue to provide care as needed.

4.2 State Government

5. Strengthen building and planning requirements to ensure all homes provide adequate protection from UHIE without reliance on air-conditioning.

This project has clearly demonstrated the necessity for state-wide building and planning provision to increase requirements for natural ventilation and natural cross ventilation.

Statewide requirements for building new homes that are not reliant on air-conditioning are unclear. The recently released Better Apartment Design Standards require consideration of cooling loads for apartments via the ‘Energy Efficiency’ standard (maximum cooling loads between 21Mj/sq m – 30MJ/sqm in Melbourne). However, the maximum loads specified via these standards will still result in reliance on mechanical cooling during peak summer periods. In addition, these standards also only apply to apartments.

We propose that state government consider developing an agreed metric to evaluate heat risk reflecting the absence of air-conditioning during blackouts and include this as a mandatory requirement for all new homes.

6. Provide funding options for social housing providers to deliver retrofits.

Social housing providers identified funding as the key barrier preventing them from rolling out similar programs across their portfolio. Income for social housing providers is limited as they are required to keep rents affordable so urgent upgrades are prioritised.

Funding options for retrofits could include:

- Funding to upgrade the thermal performance of the worst performing social housing properties in similar a program to the current public housing retrofits.
- Exploration of how Victorian Energy Efficiency Target (VEET) funds can be targeted towards social housing retrofits, given that draughtproofing and insulation will also deliver energy efficiency outcomes.
- Ensuring social housing providers are fully aware of the opportunities for residents to fund works through Commonwealth Home Support Programme (CHSP) or National Disability Insurance Scheme (NDIS) packages.

7. Explore funding options to help social housing tenants afford to cool their homes

State government could also explore funding options to ensure social housing tenants can afford to cool their homes including:

- Expanding the eligibility criteria for the Medical Cooling Concession to cover all those vulnerable to heat stress, potentially including all vulnerable groups living in identified UHIE hotspots.
- Providing a central revolving fund for social housing providers to deliver a 'solar savers' program across their portfolio, where residents repay the costs of the solar from their electricity savings.

8. Undertake detailed thermal image mapping of urban areas to identify UHIE hotspots

The UHIE is not a phenomenon that exists exclusively within municipal boundaries. To enable local councils to identify residents at most risk of UHIE state government should fund detailed thermal image mapping of urban areas across Victoria.

4.3 Local councils

9. Publish data on UHIE hot spots and work with stakeholders to target resources in priority areas

Following the model set out in annex 2 local councils can identify residents vulnerable to UHIE in their municipality. They should publish the data and promote it to all service delivery stakeholders (including social housing providers), enabling and encouraging them to target resources at priority areas and consider how best to support clients in these areas when heat health warnings are issued.

Additionally, local councils can also work with social housing providers to provide additional shading from trees for their properties. Council can prioritise planting of additional street trees outside the property or work with social housing providers to plant additional trees on the property itself. They can also provide technical guidance to ensure selection and placement of tree species maximises the delivery of their cooling benefits arising from both the provision of shade and evapotranspiration.

10. Ensure that new homes provide adequate protection from UHIE without reliance on air-conditioning.

Until there are clearer state wide requirements, councils must consider cooling loads in new dwellings as part of the planning assessment process and ensure that policies promote passive design.

Council's will need to continue to critique designs and way to use passive designs measures (i.e. improved cooling, external shading devices, using shading from existing vegetation, etc) to ensure new dwellings can withstand summer heat. This includes reviewing the location of windows, their orientations, use of the rooms the windows are situated, adjoining shading and glazing specification.

4.4 Wider stakeholders

11. Explore options to unlock additional funding for social housing upgrades

Wider stakeholders (including federal government and investors) could explore options for investment in the social housing sector that delivers additional funding for development of new homes which provide adequate protection from UHIE.

There are emerging opportunities for investors to develop innovative partnerships with social housing providers including the Victorian Social Housing Growth Fund, Managed Investment Trusts (which provide discounts on capital gains tax for those investing in social housing), and the upcoming establishment of the National Housing Finance and Investment Corporation in 2018.

Annex 1: Overviews of property retrofits

A1.1. CC1

- 3-bedroom detached single storey house, brick construction (circa 1960) in low-density area.
- Large west facing grassed backyard.
- Gas space heating and no cooling.
- Small west facing structure (music room) at rear of property is exposed all day, creating heat gain in house.
- Limited opportunity for cross-ventilation

Residents:

- 2 residents in their 60s. They have lived in the property for 33 years.
- One of the residents has a cardiovascular medical condition that is impacted by heat

Key issues to note:

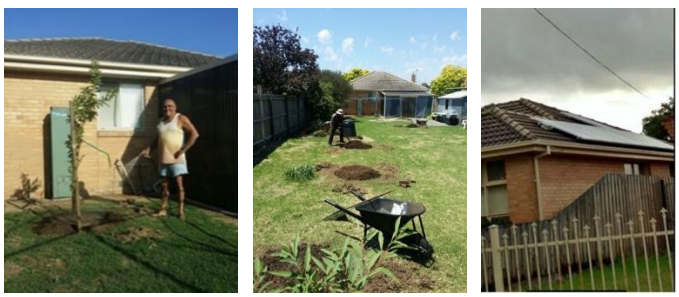
- Residents complain of hot nights and problems sleeping during extreme heat.
- Residents are often unable to utilise the music room at rear of property due to impact of heat on health. This had been their key space for socialising with friends.
- Residents previously requested installation of air-conditioning on health grounds.

Table 3: Measures installed at CC1

Measure	Comments	Cost (ex GST)
Pre - assessment	Experts evaluation and assessment	$150.00
Draught-proofing	Internal and external doors, wall vents and exhaust fan	$961.37
Insulation	Top up existing R2 ceiling insulation to R4 with premium quality polyester insulation.	$1,239.91
Vegetation	5 trees and 30 shrubs for micro-climate vegetation and activation and 7 trees for shade.	$805.84
WSUD measures	2000L rainwater tank installed to reduce cost impacts of additional water requirements from vegetation	$1,765.00
Ceiling fan	Mercator Caprice Energy Saving Fan with LED installed in main bedroom	$415.00
Split System air-conditioner	Daikin Cora 3.5kW installed in lounge room	$1,890.00
2.08kW solar PV system	Will offset cost and environmental impacts of air-conditioning	$3,524.54
Contingency	Re-planting shade trees. New location after the installation of PV system	$100.00
Total cost		**$10,851.65**



Garden before



After: Garden and solar panels

A1.2. CC2

- 3-bedroom detached single-storey house, brick construction (circa 1960) close to major roads and railway track
- Most windows have aluminium roller shutters
- Concrete west facing backyard with little shading or vegetation
- Gas ducted heating used for heating. Older box style air-conditioner and portable heaters used for cooling.
- Recently upgraded by landlord with draught-proofing for external doors and ceiling insulation

Residents:

- 1 resident in their 60s. They have lived in the property for 13 years.

Key issues to note:

- Resident complains of hot nights and problems sleeping during extreme heat.
- Cross-ventilation opportunities limited on hot days as rear doors and windows are closed to prevent heat from the concreted backyard radiating into the house.

Table 4: Measures installed at CC2

Measure	Comments	Cost (ex GST)
Pre-assessment	Experts evaluation and assessment	$150.00
Draught-proofing	Internal and external doors	$1,193.12
Shade cloth	To provide shading from west facing window and in garden	$769.43
Vegetation	3 trees and 30 shrubs for micro-climate vegetation and activation and 11 trees for shade. Additional street trees have been scheduled for planting outside the property.	$470.07
WSUD measures	Downpipe diverter and garden hose to reduce cost impacts of additional water requirements from vegetation	$268.00
Total cost		**$2,850.62**



Backyard before



After: shade cloth

A1.3. CC3

- 3-bedroom detached single-storey house, brick construction (circa 1960) in low-density area.
- East facing small grassed backyard.
- Two reverse cycle air-conditioning units – used for heating and cooling.
- Partial shade provided through existing green infrastructure and external blinds.

Residents:

- 1 resident in their 60s and one resident in their 40s. They have lived in the property for 43 years.
- One resident has a respiratory medical condition that is exacerbated by heat.

Key issues to note:

- Resident reports feeling comfortable in property during heatwaves due to existing air-conditioning, internal blinds and external shading from trees.
- House is not well sealed due to a door designed for disabled access which has a 1 inch gap.
- Trees provide shading for roof but not west facing windows.
- Resident unable to benefit from natural ventilation due to security concerns (there is no screen/security door).

Table 5: Measures installed at CC3

Measure	Comments	Cost (ex GST)
Pre-assessment	Experts evaluation and assessment	$150.00
Draught-proofing	Internal and external doors	$594.07
Insulation	Top up existing R2 ceiling insulation to R4 with premium quality polyester insulation.	$1,312.26
Retractable awnings	On north facing window	$736.00
Total cost		**$2,792.34**



Image showing retractable awning

A1.4. CC4

- 2-bedroom attached single storey unit, brick construction (circa 1965), northerly aspect
- Close to Moonee Pond Creek area
- Small backyard
- Shading provided by electric blinds in the lounge and main bedroom
- Reverse cycle air-conditioner providers heat in winter but residents report it does not work on cooling cycle

Residents:

- 2 residents in their 20s. They have lived in the property for 2.5 years.
- One resident lives with a psychological condition and the other lives with a physical condition, requiring use of a wheelchair.

Key issues to note:

- One of the bedrooms does not have windows preventing natural ventilation
- Backyard is not accessible to one of the residents due to her disability
- House is draughty, with large gaps around windows, doors, extractor fans and dog door.
- Residents reported experiencing anxiety and headaches during extreme heat.
- Residents noted that they cannot afford to stay cool during summer.

Table 6: Measures installed at CC4

Measure	Comments	Cost (ex GST)
Pre-assessment	Experts evaluation and assessment	$150.00
Draught-proofing	Wall vents, exhaust fan, replacement of dog door, internal and external doors, piping	$1,101.31
Insulation	Top up existing R2 ceiling insulation to R4 with premium quality polyester insulation.	$822.88
Ceiling fan	Mercator Caprice Energy Saving Fan with LED installed in main bedroom	$456.50
Split System air-conditioner	Daikin Cora 3.5kW installed in lounge	$1,890.00
2.08kW solar PV system	Installed to offset cost and environmental impacts of air-conditioning	$3,524.54
Contingency	Fix power point of the extraction fan, got damaged during insulation. Install a wire to earth in the ceiling (ceiling fan installation) and emission of a safety certificate.	$250.00
Total cost		**$8,195.23**







A1.5. CC5

- 4-bedroom detached single storey house, brick construction (circa 2000), in dense urban area.
- Small south facing backyard with minimal vegetation.
- Lounge and main bedroom are north facing with large floor to ceiling unshaded windows.
- Cooling provided by ducted evaporative cooling system. Heating is gas ducted.

Residents:

- Family of 5 (2 adults in 40s and three children aged 10-15). They have lived in the property for 9 years.

Key issues to note:

- In summer it is too hot for the family to sleep in bedrooms. Instead they open the windows and sleep in the lounge.
- Evaporative cooling system does not work effectively due to the length of the ducting running through the hot roof cavity.

Table 7: Measures installed at CC5

Measure	Comments	Cost (ex GST)
Pre-assessment	Experts evaluation and assessment	$150.00
Draught-proofing	Internal doors	$650.51
Insulation	Top up existing R2 ceiling insulation to R4 with premium quality polyester insulation.	$2,514.61
Retractable awnings	Main bedroom window	$1,460.00
Vegetation	5 trees for shading, 4 shade climbers, 1 edible shrub and 2 shrubs for microclimate.	$805.84
WSUD measures	1000L rainwater tank installed to reduce cost impacts of additional water requirements from vegetation	$925.00
Ceiling fan	Mercator Caprice Energy Saving Fan with LED installed in main bedroom	$415.00
Total cost		**$6,920.96**



Images showing: retractable awning, vegetation and ceiling insulation

A1.6. CC6

- 4-bedroom attached single storey house, brick construction (circa 2000), in dense urban area
- Small concreted west facing backyard with minimal vegetation.
- Lounge and kitchen are north/west facing with large floor to ceiling windows. These have small eaves but these provide little shade.
- Cooling provided by two portable coolers. Heating is gas ducted.

Residents:

- One resident in their 70s and resident in their 60s. They have lived in the property for 5 years.
- Residents do not have proficiency in English.
- One resident has cardiovascular health issues.

Key issues to note:

- Resident reports home is 'not at all comfortable' in summer in general, heatwaves and extreme heat events.
- Portable coolers are expensive to run and provide limited relief (only one area).
- On hot days residents sleep in lounge rather than bedroom due to heat. In the daytime they spend much of the time in shaded areas of nearby park.
- Main bedroom, lounge and kitchen windows face the west facing concreted area which heats up on hot days radiating heat into the property.

Table 8: Measures installed at CC6

Measure	Comments	Cost (ex GST)
Pre-assessment	Experts evaluation and inspection	$150.00
Draught-proofing	Internal and external doors	$619.33
Retractable awnings	Installed on lounge room window	$709.55
Vegetation	1 trees for shading, 2 edible shrubs and 30 shrubs for microclimate, 2 pots. Installation of birdie garden and planting with herbs.	$353.42
WSUD measures	Downpipe diverter installed to reduce cost impacts of additional water requirements from vegetation	$180.00
Ceiling fan	Mercator Caprice Energy Saving Fan with LED installed in main bedroom	$415.00
Contingency	Wire new switch cable to fan. Needed during installation of the ceiling fan in the living room	$100.00
Total cost		**$2,527.90**



Images show: retractable awnings, tree, garden bed and downpipe diverter

A1.7. CC7

- 2-bedroom apartment, construction (2012), on 2nd level of a 5-storey building, dense urban area close to major roads and railway track
- Construction of the apartments is concrete with metal screens attached to the concrete. This results in the apartment heating up very quickly and retaining heat for a long time.
- Apartment has sealed windows in the bedrooms making it virtually impossible to ventilate them. The lounge area has one external door which can be opened.
- Windows are double glazed but the frames are uninsulated aluminium, resulting in significant heat transfer into the apartment.
- Ceiling fan in lounge provides limited cooling.

Residents:

- One resident in their 60s. They have lived in the property for 2 years.
- Resident lives with physical conditions including cardiovascular and kidney medical issues.

Key issues to note:

- Resident reports home is 'not at all comfortable' in summer in general, heatwaves and extreme heat events.
- Resident reports experiencing a range of health issues (heat stress, headaches, anxiety, dizziness and difficulty to breathe) during heatwaves.
- In summer it is too hot for resident to sleep in bedrooms. Instead they sleep on the lounge floor in the lounge or moves out of the property to stay with family as lack of sleep worsens their existing health problems.
- Resident does not like to keep the balcony door (the only external door/window) open at night due to safety concerns.
- Resident previously had portable evaporative cooling unit but found it ineffective in the humid environment.
- This building was refused a planning permit by Moreland City Council, but was approved by VCAT with a requirement for windows to be sealed due to noise issues from the nearby railway.

Table 9: Measures installed at CC7

Measure	Comments	Cost (ex GST)
Pre-assessment	Experts evaluation and inspection	$150.00
Ceiling fan	Mercator Caprice Energy Saving Fan with LED installed in main bedroom	$415.00
Split System air-conditioner	Daikin Cora 3.5kW installed in lounge	$1,890.00
Other costs	Plastering services to cover screw holes after removing ceiling light at the main bedroom	$110.00
Total cost		**$2,565.00**



A1.8. CC8

- 1-bedroom apartment, construction (2012), on 3rd level of 5 storey building, dense urban area close to major roads and railway track
- Apartment construction is concrete with metal screens attached to the concrete. This results in the apartment heating up very quickly and retaining heat for a long time.
- Apartment has sealed windows in the bedroom making it virtually impossible to ventilate. The lounge area has one external door which can be opened.
- Windows are double glazed but the frames are uninsulated aluminium, resulting in significant heat transfer into the apartment.
- Ceiling fan in lounge and portable fans provide limited cooling.

Residents:

- One resident in their 40s. They have lived in the property for 2 years.
- Resident lives with a psychological condition, with medication that makes it hard to regulate body temperature.

Key issues to note:

- Heat builds up in the bedroom due to lack of shading and ventilation.
- On hot days resident sleeps in lounge rather than bedroom due to heat issues.
- Metal cladding on the balcony heats up so much on hot days the resident reports they are unable to touch it. This radiates heat into the apartment.
- Resident reports suffering headaches during hot days.
- This building was refused a planning permit by Moreland City Council, but was approved by VCAT with a requirement for windows to be sealed due to noise issues from the nearby railway.

Table 10: Measures installed at CC8

Measure	Comments	Cost (ex GST)
Pre-assessment	Experts evaluation and inspection	$150.00
Ceiling fan	Mercator Caprice Energy Saving Fan with LED installed in bedroom	$415.00
Split System air-conditioner	Daikin Cora 3.5kW installed in lounge	$1,890.00
Contingency	Core Bore 80 mm hole during installation of split system	$275.00
Total cost		**$2,730.00**



A1.9. CC9

- 1-bedroom apartment, construction (2012), on 4th level of 5-storey building, dense urban area close to major roads and railway track
- Apartment construction is concrete with metal screens attached to the concrete. This results in the apartment heating up very quickly and retaining heat for a long time.
- Apartment has sealed windows in the bedroom making it virtually impossible to ventilate. The lounge area has one external door which can be opened.
- Windows are double glazed but the frames are uninsulated aluminium, resulting in significant heat transfer into the apartment.
- Ceiling fan in lounge and portable fans provide limited cooling.

Residents:

- One resident in their 60s. Resident has lived in the property for 2 years.

Key issues to note:

- Resident reported that they were not very comfortable during the hot days in January 2017.
- Resident wasn't aware fans have winter and summer settings.
- This building was refused a planning permit by Moreland City Council, but was approved by VCAT with a requirement for windows to be sealed due to noise issues from the nearby railway.

Table 11: Measures installed at CC9

Measure	Comments	Cost (ex GST)
Ceiling fan	Mercator Caprice Energy Saving Fan with LED installed in bedroom	$415.00
Contingency	Condensate pump during installation of split system and plaster services to cover screw holes after removing ceiling light at the main bedroom (ceiling fan installation).	$310.00
Split System air-conditioner	Daikin Cora 3.5kW installed in lounge	$1,890.00
Total cost		**$2,615.00**



A1.10. CC10

- 1-bedroom apartment, construction (2012), on 3rd level of a 5-storey building, dense urban area close to major roads and railway track
- Apartment construction is concrete with metal screens attached to the concrete. This results in the apartment heating up very quickly and retaining heat for a long time.
- Apartment has sealed windows in the bedroom making it virtually impossible to ventilate. The lounge area has one external door which can be opened.
- Windows are double glazed but the frames are uninsulated aluminium, resulting in significant heat transfer into the apartment.
- Ceiling fan in lounge and 2 portable air-conditioning units provide limited cooling.

Residents:

- One resident in their 40s. They have lived in the property for 2 years.
- Resident lives with a psychological condition.

Key issues to note:

- Heat builds up in the bedroom due to lack of shading and ventilation.
- On hot days resident sleeps in lounge rather than bedroom due to heat issues. In the daytime resident often visits air-conditioned shopping centre 6km from home.
- Resident is very happy with the apartment other than the heat issues.
- This building was refused a planning permit by Moreland City Council, but was approved by VCAT with a requirement for windows to be sealed due to noise issues from the nearby railway.

Table 12: Measures installed at CC10

Measure	Comments	Cost (ex GST)
Ceiling fan	Mercator Caprice Energy Saving Fan with LED installed in bedroom	$415.00
Split System air-conditioner	Daikin Cora 3.5kW installed in lounge	$1,890.00
Contingency	Plaster services to cover screw holes after removing ceiling light at the main bedroom (ceiling fan installation).	$110
Total cost		**$2,565.00**



Annex 2: Methodology

A2.1. Identifying vulnerable populations

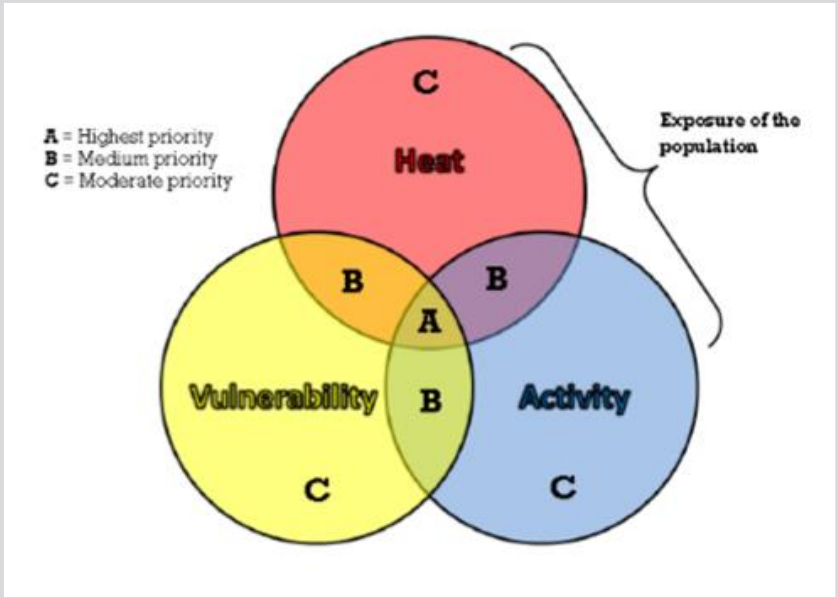
It is clear from the evidence that the negative health impacts of heatwaves are not equally spread across the population. Understanding the risk factors will enable councils and other stakeholders to ensure that resources are targeted most effectively.

Evidence shows that the key risk factors are[30]:

- **Presence of an urban heat island**
- **Land use** – proximity to vegetation, accessibility to emergency response services, quality of housing
- **Age** – older people are at most risk however children also have a greater risk
- **Pre-existing medical factors** – especially those with cardiovascular disease, respiratory disease, psychiatric illness, mental illness, diabetes, neurological disease, obesity and cancer.
- **Socio-economic status**
- **Social isolation**
- **Ethnicity and language**
- **Access to an air-conditioned environment**

Those most at risk will be those who are impacted by multiple factors (as detailed in figure 30 below).

Figure 30: VCCAR diagram identifying residents most vulnerable to UHIE



(Source: Priority for heat mitigation – on pg. 9 of the Urban Forest Consulting report on vulnerability in Moreland.)

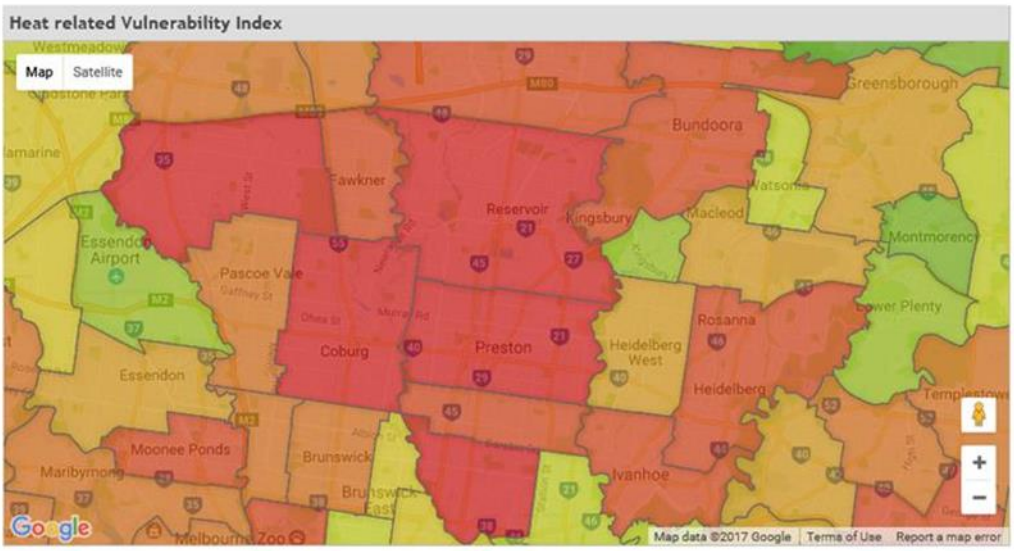
[30] Loughnan, ME, Tapper, NJ, Phan, T, Lynch, K, McInnes, JA, 2013, A spatial vulnerability analysis of urban populations during extreme heat events in Australian capital cities, National Climate Change Adaptation Research Facility, Gold Coast, 128pp.

The process undertaken by Moreland to identify hotspots, priority areas and social housing residents at most risk is detailed below.

1. Utilise existing data

Monash University undertook a high-level analysis of the key risk factors for all Australia cities. This used the used the methodology developed by both the Victorian Centre for Climate Change Adaptation Research (VCCCAR) and the National Climate Change Adaptation Research Facility (NCCARF). See www.mappingvulnerabilityindex.com

Figure 31: NCCARF heat related vulnerability data mapped by suburb



(Source: www.mappingvulnerabilityindex.com)

Whilst this information was useful at identifying that there was a significant issue in Moreland a finer grain was needed to identify priority areas and ensure that Council could target their resources, and those of partner organisations, to reduce the negative impacts of the UHIE on vulnerable communities.

Moreland therefore undertook a more detailed spatial analysis of the vulnerable population as part of the development of it's Urban Heat Island Strategy and Action Plan.

2. Identify hot spots

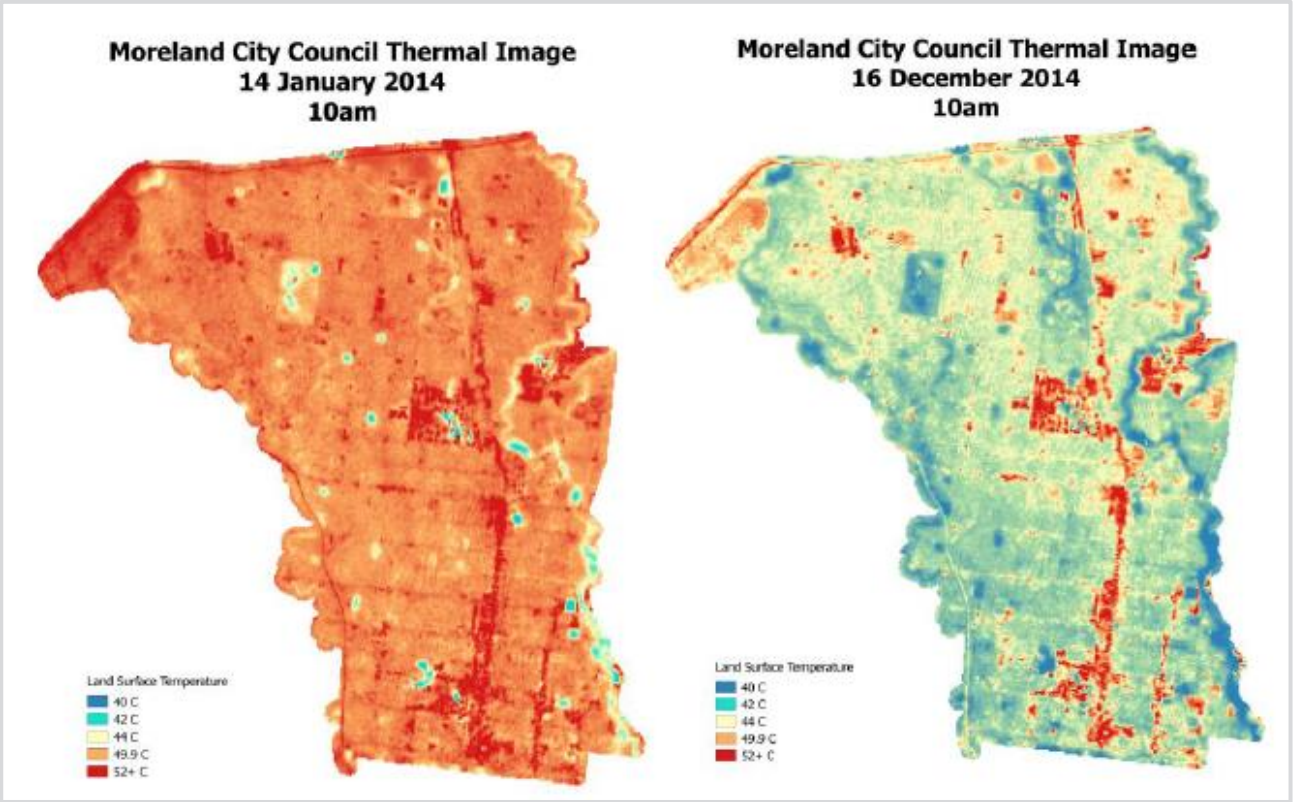
Dr Andrew Coutts and Dr Thu Phan from Monash University undertook 2 additional satellite thermal images for the municipality and analysed the thermal imaging data for Moreland to identify hotspots (ie where Land Surface Temperature was 52 degrees Celsius or above). The images were both taken at 10am on two dates, 14 January 2014 16 December 2014.

Table 13: Land Surface Temperatures in Moreland in January and December 2014

January 2014			December 2014		
Date	Min temp	Max temp		Min temp	Max temp
11th	17	21	13th	14	30
12th	16	20	14th	19	25
13th	13	29	15th	15	22
14th	18	42.8	16th	16	32
15th	27	41.6	17th	12	21
16th	25	43.4	18th	11	25

← LANDSAT IMAGE TAKEN

Figure 32: Land Surface Temperature across Moreland at 10am on 14 January and 16 December 2014



(Source: Urban Heat Island Priority Locations: Moreland City Council, *Urban Forest Consulting,* p. 6)

3. Map your vulnerable populations

Moreland Council then developed a set of data sheets and overlaid these on to the thermal imaging data for the municipality. This also used the methodology developed by both the Victorian Centre for Climate Change Adaptation Research (VCCCAR) and the National Climate Change Adaptation Research Facility (NCCARF) to identify which populations were most vulnerable to the UHIE.

The following indicators were used to determine priority hotspot locations:

Social vulnerability

- Young children aged 0-4
- Older persons living alone
- Socio economically disadvantaged groups
- Those who aren't fluent in English
- Those in public/social housing

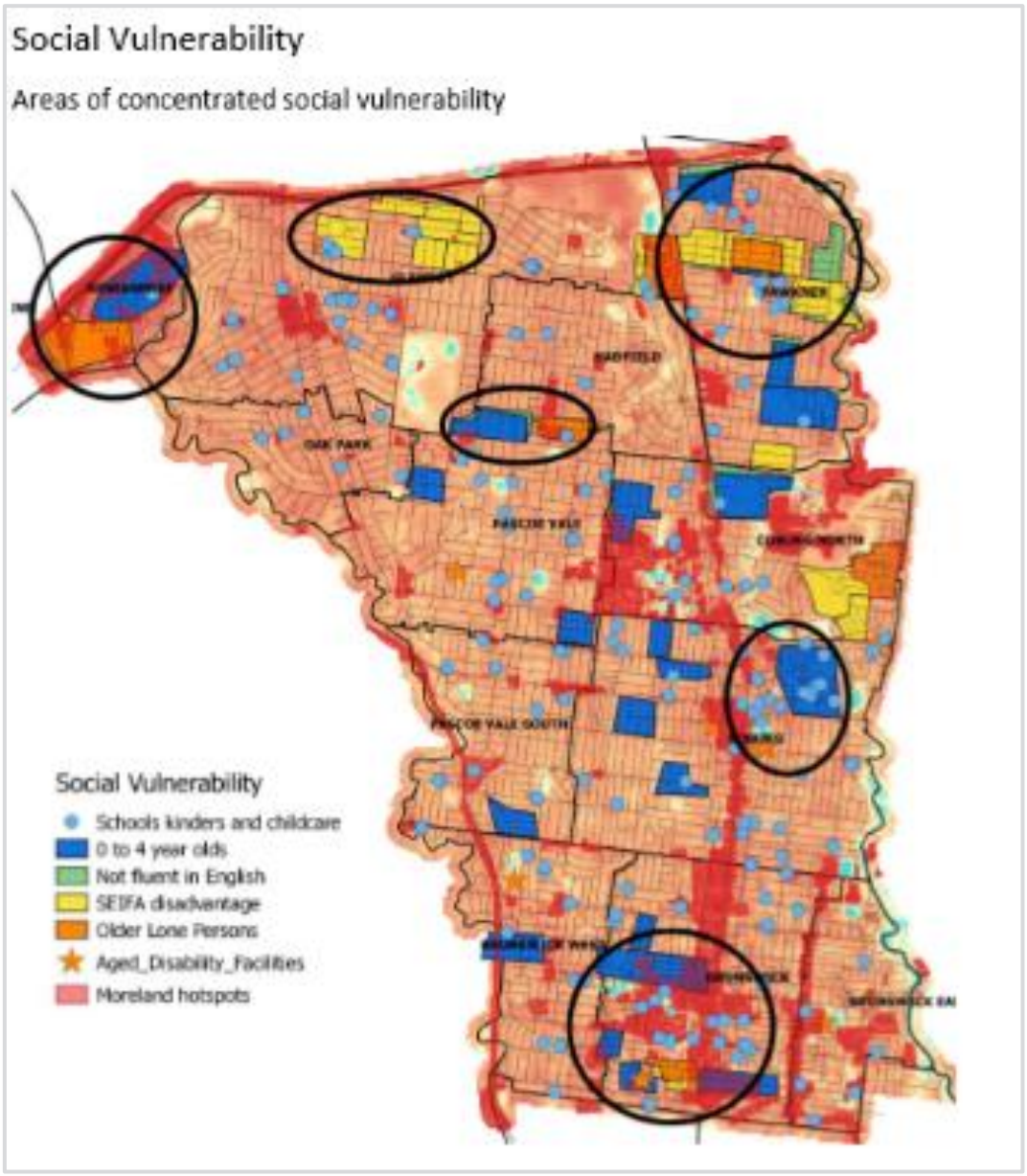
High human activity

- Principal pedestrian network
- Commercial and retail areas
- Neighbourhood activity centres
- Bike paths
- Schools, kindergartens and childcare facilities

Others

- Future zoning and population growth changes

Figure 33: Mapping of Moreland's areas of social vulnerability



(Source: Urban Heat Island Priority Locations: Moreland City Council, *Urban Forest Consulting)*

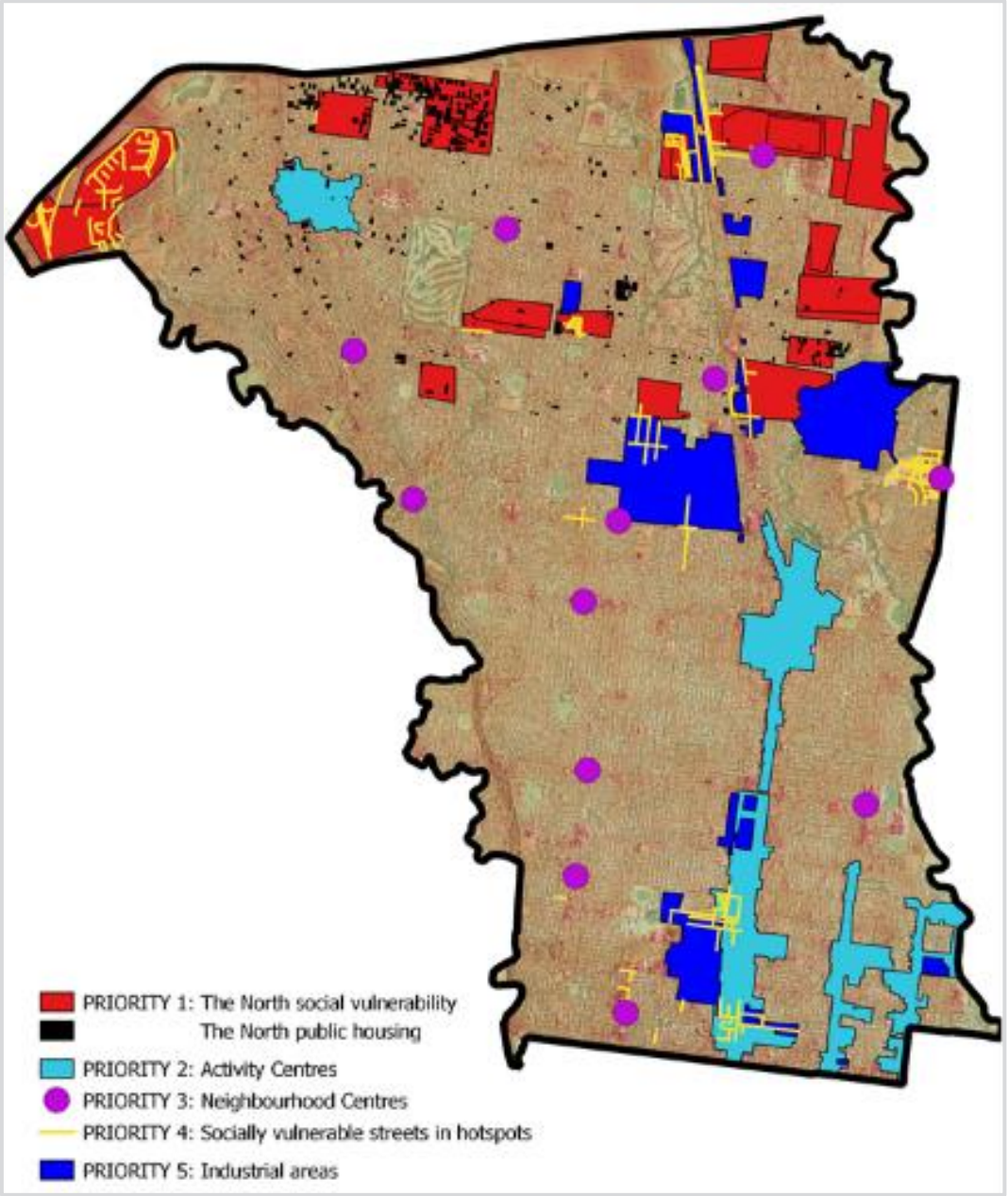
4. Identify priority areas for action

The study identified five priority areas for Moreland, which were used to develop priorities and actions for their UHIE Strategy and Action Plan.

The five priority areas were:

- The north (Gowanbrae, Glenroy, Hadfield and Fawkner)
- Activity centres
- Neighbourhood Centres
- Socially vulnerable streets in hotspots
- Major industrial areas

Figure 34: Mapping of Moreland's UHIE priority areas



(Source: Urban Heat Island Priority Locations: Moreland City Council, *Urban Forest Consulting)*

5. Identify locations of all social housing properties in the priority areas

Whilst some social housing is easily identified due to its clustering there are often numerous individual dwellings scattered across municipalities. To identify these Moreland City Council's Social Development Unit provided details of the social housing providers active in these areas. Social housing providers then provided details of the properties they own and manage.

How to identify social housing properties at most risk of UHIE

- **Step 1** – Utilise existing data
- **Step 2** – Identify hot spots
- **Step 3** – Map your vulnerable populations
- **Step 4** – Identify priority areas for action
- **Step 5** – Identify locations of all social housing properties in the priority areas

A2.2. Identification of properties for retrofits

All social housing properties identified within the priority areas were then analysed to determine priorities for retrofits within the Cooling Communities program. An initial review of the 2015 thermal mapping data shortlisted those with land surface temperatures (LST) over 44 degrees. This excluded a number of properties that benefited from localised cooling, due to factors such as irrigated ovals, the Merri Creek or large tree canopies. Whilst it is noted that temperatures up to 44 degrees are still considered excessive, in the context of the Moreland UHIE, many properties well exceeded 44 degrees at the LST.

From the shortlist, we identified two different Social Housing Providers to work with – Aboriginal Housing Victoria and Housing Choices Australia. Having two delivery partners enabled us to explore different approaches to property maintenance and management, as well as a greater diversity of stakeholders and residents.

Shortlisted properties from these providers were then evaluated against key criteria (typology, condition, age, size, occupant demographics, access to outdoor space and water) to provide a range of different retrofit scenarios.

The SHPs provided Council with a list of properties in Moreland which were evaluated using the following key criteria in order to select the 10 properties for the project:

- Building typology (various dwelling types were desired, including detached dwellings, attached townhouses and apartments in a large building)
- Age of the dwellings (a mix of dwelling ages was selected, ranging in properties constructed in the mid-1950's to 2010)
- Ease of access to the dwelling (the dwelling's needed to be accessible for project members and tradespersons)
- Access to outdoor space and water (to enable trialling greening and water-related retrofit options)
- Review of the dwellings and thermal imagery (to confirm the dwellings exceeded 44 degrees Celsius at LST in the 14 January 2017 heat mapping and to identify potential sources of urban heat, such as major roads or minimal tree canopy)

The above criteria enable the project to provide a range of different housing scenarios, retrofit opportunities and maintenance considerations.

A2.3. Identification of works

Once properties were selected a site visit was undertaken to assess which retrofit activities would be most appropriate for each property. This included a resident survey as well as property assessment.

Whilst the primary objective of the project was to improve the thermal comfort of the property during heatwaves the measures under consideration have a range of wider economic, social and environmental impacts so these were also factored into our decision-making process.

Table 14: Review of retrofit measures

Measure	Thermal comfort	Carbon emissions	UHIE	Cost (resident)	Cost (landlord)	Comments
Draughtproofing (doors & windows)						• Reduces energy bills and improves thermal comfort in summer and winter • Reduces heat when used in conjunction with external shading and cross ventilation
Insulation						• Reduces energy bills and improves thermal comfort in summer and winter • Reduces heat when used in conjunction with external shading and cross ventilation
External shading – shadecloth						• Only provides cost and GHG savings if property uses mechanical cooling
External shading – retractable awnings						• Only provides cost and GHG savings if property uses mechanical cooling
Enerlogic window film						• Only provides cost and GHG savings if property uses mechanical cooling
Therm-a-guard insulating paint						• Potential to increase heating requirements in winter. • Requires roof to be in good condition
Trees and vegetation for shading						• Requires space and ongoing maintenance. • Takes time to grow.
Green wall/roof						• Requires space and ongoing maintenance. • Takes time to grow. • Green roofs require irrigation to deliver cooling benefits through reducing rooftop surface temperatures and minor microclimate benefits.
Green facade						• Requires space and ongoing maintenance. • Takes time to grow
Rainwater harvesting tank						• Provides access to free water to ensure vegetation can be maintained.
Ceiling fans						• Relatively cheap to run • Can improve comfort in summer and winter
Split-system air-conditioning						• Contributes to UHIE • Unable to provide cooling in blackout • Environmental and economic impacts can be minimised by choosing an energy efficient system, using for heating instead of inefficient gas/ducted and installing solar.

Following our initial assessment, we asked our technical suppliers (for building fabric upgrades and green/blue infrastructure) to undertake a detailed audit of each property. This helped us identify which measures would be most effective at each property within the budget available. The findings from this are summarised in table 15 below.

Table 15: Initial analysis of retrofit measures to be applied

Property	Remove gas heater	Ceiling fan	Draught proofing	Awning blinds	Deciduous trees	Louvered Screens	Solar fan	Insulation
CC-1			■	■				■
CC-2			■					
CC-3			■	■	■			■
CC-4	■		■	■				■
CC-5			■		■			■
CC-6		■	■					
CC-7						■		
CC-8						■		
CC-9						■		
CC-10						■		

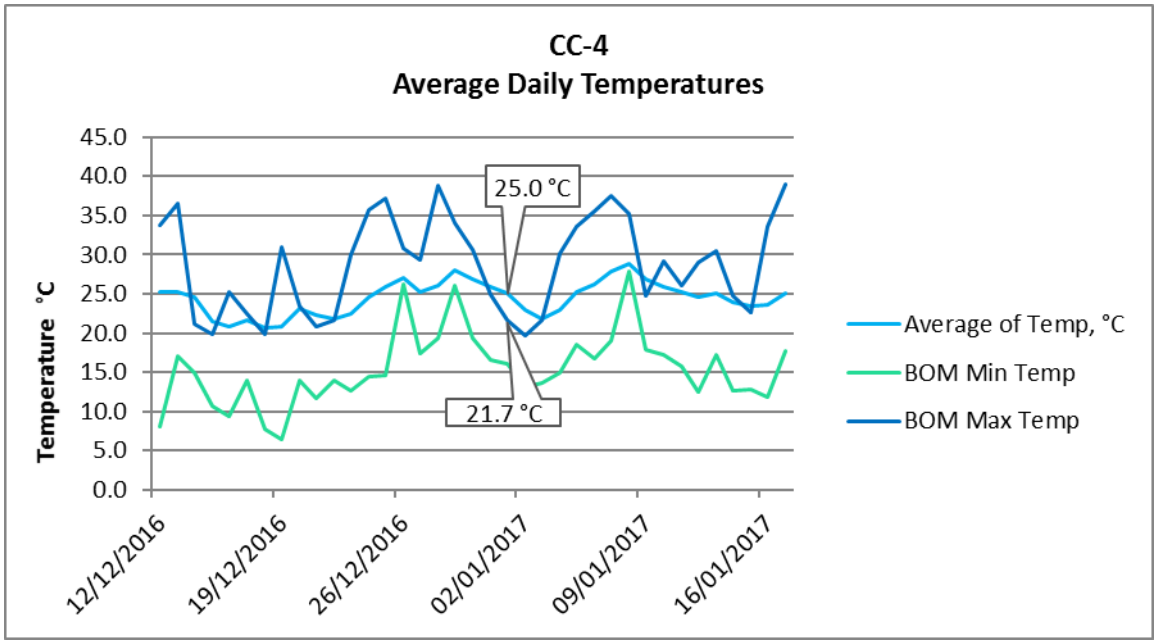
Given the preference for building fabric upgrades over mechanical cooling why did we install air-conditioning in six properties?

As detailed in the report we reviewed the data from the residents and the temperature loggers before deciding to install air-conditioning in apartments CC7, CC8, CC9 and CC10.

This process was also followed at CC1 and CC4 where residents had physical and mental health conditions exacerbated by heat. For both these properties we installed additional measures prior to the monitoring, including draught-proofing and insulation however both properties still recorded a DI above 25 (where more than half the population feels discomfort).

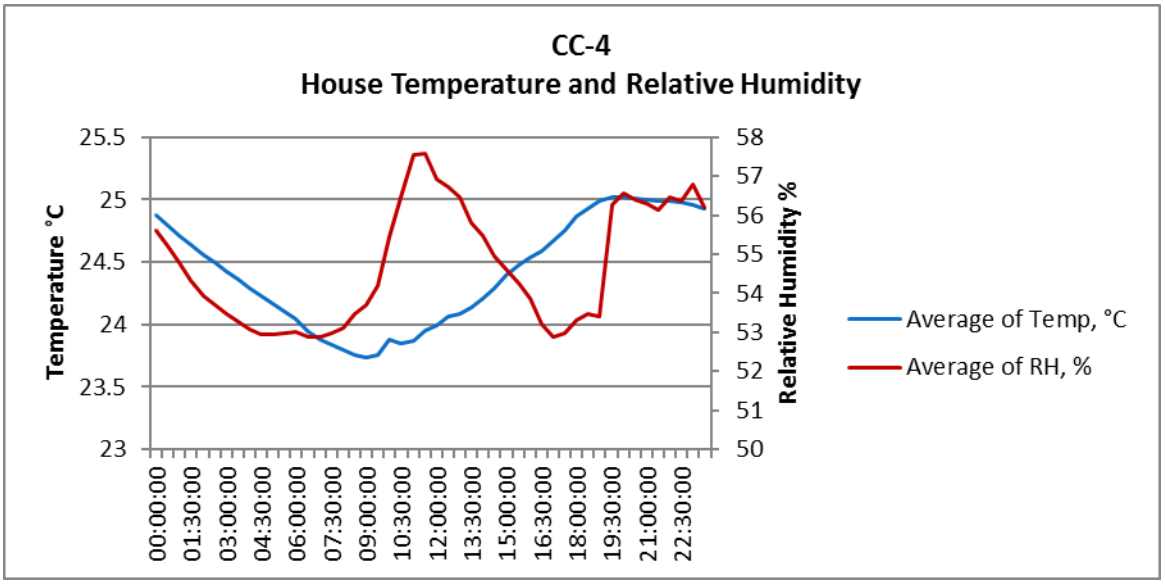
The data from CC4 also showed whilst the property could purge some of the hot air overnight, there were 15 days and nights when the temperature failed to drop below 24 Celsius. The property also experienced high levels of humidity, which causes problems for one of the occupants who is a wheelchair user.

Figure 35: Internal temperature within CC4 before installation of air conditioning



(Source: data loggers and BOM data)

Figure 36: Relative humidity within CC4 before installation of air conditioning



(Source: data loggers and BOM data)

There were issues with the data logger at CC1 so only 11 days of data were captured and none during a heatwave however on two of these days the internal temperature was hotter than the external.

Given the data collected and the health issues with occupants of both CC1 a decision was made to install a reverse cycle split system air-conditioner at both properties along with a 2.08kW solar PV system to help mitigate the negative economic and environmental impacts.

A2.4. Measuring impact

Given the small sample size, the length of the study (6 months) and the fact that no external heatwaves were recorded during the study period we utilised two key data sources to measures impact: resident surveys and data loggers.

Extensive data was gathered about the dwellings and their occupants through face-to-face surveys. These were conducted at three points in the study: prior to works, during summer and post-works. These sought to understand the resident's subjective views on the comfort of the property and whether this changed after the works were completed along with their use of appliances, strategies for coping with extreme heat and health impacts of extreme heat events.

Data loggers were installed into properties in early December after some initial draught-proofing and insulation works had been undertaken. This was because we were aware there would be issues installing these measures during hot periods, so wanted to schedule them as early as possible given the project timelines.

A data logger was placed in each dwelling measuring internal air temperature (Dry Bulb Temperature (DBT, ◦C)) and humidity (Relative Humidity (RH,%)) at 30-min intervals in the main living area. This enabled us to analyse the temperature patterns within each property and ascertain the indoor Discomfort Index (DI). The indoor DI provides a measure of air temperature and humidity, two factors contributing to heat stress, but excludes other potential physiological effects due to air movement or radiation.

Multiple formal definitions of the Discomfort Index appear in technical literature; for the purposes of this study the definition is consistent with that used by the CSIRO in their pathways report (Barnett, et al. 2013), which is the average of the dry-bulb temperature (T_{DB}) and wet-bulb temperatures (T_{WB}).

$$DI = 0.5(T_{DB} + T_{WB})$$

Discomfort Index increases with air temperature and also with humidity, and typically ranges from below 20 for cold and dry conditions to above 35 for hot and humid conditions.

The threshold DI measures in this study are:

- < 22 No heat stress is encountered
- 22-24 Most people find a mild sensation of heat
- 24- 28 Heat load is moderately heavy, people feel very hot
- > 28 Heat load is severe, people at increased risk of heat illness

To understand the barriers and issues for social housing providers we met with both social housing providers both before and after works along with Baptcare, Yarra Housing Trust and Wintringham.

Annex 3: External temperature data for study period

Table 16: External temperatures during study period

Date	Min Temp	Max Temp		Date	Min Temp	Max Temp
12/12/2016	8	33.8		2/14/2017	13.4	20.1
12/13/2016	17	36.5		2/15/2017	8.1	32.3
12/14/2016	15	21.2		2/16/2017	16.2	24.3
12/15/2016	10.7	19.9		2/17/2017	13.6	26.4
12/16/2016	9.3	25.3		2/18/2017	12.2	19.9
12/17/2016	13.9	22.5		2/19/2017	10.1	16.6
12/18/2016	7.8	19.9		2/20/2017	10.4	22.3
12/19/2016	6.5	30.9		2/21/2017	8.2	24.8
12/20/2016	14	23.5		2/22/2017	9.8	34
12/21/2016	11.6	20.9		2/23/2017	14.3	26.3
12/22/2016	14	21.7		2/24/2017	15	20.4
12/23/2016	12.7	30		2/25/2017	13.5	20.8
12/24/2016	14.5	35.7		2/26/2017	11.5	30
12/25/2016	14.6	37.2		2/27/2017	13.9	33.2
12/26/2016	26.2	30.8		2/28/2017	15.6	34.6
12/27/2016	17.4	29.4		3/1/2017	15.2	32.6
12/28/2016	19.4	38.8		3/2/2017	14.7	25.2
12/29/2016	26.1	34		3/3/2017	15.5	28.1
12/30/2016	19.3	30.7		3/4/2017	15.7	29.3
12/31/2016	16.6	24.9		3/5/2017	16.6	26.2
1/1/2017	16	21.7		3/6/2017	17.5	28.2
1/2/2017	13.2	19.6		3/7/2017	13	28.5
1/3/2017	13.6	21.6		3/8/2017	12	31.5
1/4/2017	14.9	30.2		3/9/2017	12.5	33
1/5/2017	18.5	33.6		3/10/2017	16.5	25.3
1/6/2017	16.7	35.6		3/11/2017	16.6	27.7
1/7/2017	19.1	37.5		3/12/2017	17	30.8
1/8/2017	27.8	35.2		3/13/2017	14	26.5
1/9/2017	17.9	24.7		3/14/2017	16.5	32.9
1/10/2017	17.2	29.2		3/15/2017	20.1	34
1/11/2017	15.7	26.1		3/16/2017	20.6	23.3
1/12/2017	12.5	29		3/17/2017	15.3	22
1/13/2017	17.3	30.4		3/18/2017	10.4	31.2
1/14/2017	12.6	24.8		3/19/2017	13.6	34.1
1/15/2017	12.8	22.6		3/20/2017	19.3	29.2
1/16/2017	11.8	33.6		3/21/2017	19.1	28.2
1/17/2017	17.7	38.9		3/22/2017	17.3	22
1/18/2017	14.1	21.9		3/23/2017	15	25.8
1/19/2017	9.8	26.1		3/24/2017	11.7	25.7
1/20/2017	15.2	22		3/25/2017	14.5	30.3
1/21/2017	13.9	22.7		3/26/2017	18.2	26.2
1/22/2017	12.2	30.5		3/27/2017	18.3	31.2
1/23/2017	17.5	38.1		3/28/2017	10.3	25.1
1/24/2017	17.9	23.4		3/29/2017	12.8	28.3
1/25/2017	12.3	23.1		3/30/2017	8.3	18.6
1/26/2017	14.6	22.2		3/31/2017	9.6	18.4
1/27/2017	16.5	25		4/1/2017	8.6	19.1
1/28/2017	12.5	32		4/2/2017	11.5	18.7
1/29/2017	14.2	28.2		4/3/2017	7.8	21.8
1/30/2017	15.7	30.6		4/4/2017	7.5	25
1/31/2017	15.4	22.9		4/5/2017	8.8	25.2
2/1/2017	12.7	20.8		4/6/2017	9	26.3
2/2/2017	11.9	25.6		4/7/2017	13	26.9
2/3/2017	14.5	28.6		4/8/2017	17.2	28.9
2/4/2017	12.6	37.1		4/9/2017	10.6	15.1
2/5/2017	18.5	30.5		4/10/2017	8.5	15.5
2/6/2017	14.4	17.9		4/11/2017	11.2	19.4
2/7/2017	14.3	28.3		4/12/2017	10.7	19.6
2/8/2017	15.3	35.9		4/13/2017	9.4	23.8
2/9/2017	21.1	37.4		4/14/2017	11.4	17.8
2/10/2017	17.9	31.2		4/15/2017	10.1	16.6
2/11/2017	17.5	27.2		4/16/2017	8.6	22.2
2/12/2017	13.6	21.4		4/17/2017	11.9	18.4
2/13/2017	12.9	22.3		4/18/2017	9.6	21.4
				4/19/2017	12.3	26.4

(Source: BOM)

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For a copy of this report or any queries please contact:

The Moreland Energy Foundation Limited: info@mefl.com.au / T. 03 9385 8585 / P.O. Box 276,

Brunswick VIC 3056 / www.mefl.com.au

Moreland City Council: info@moreland.vic.gov.au / 9240 1111 / Locked Bag 10, Moreland VIC 3058 / www.moreland.vic.gov.au