LOW CARBON LIVING CRC

# RP3044: Mainstreaming Low Carbon Retrofits in Social Housing

## Final Report

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## Peer Review Statement

The CRCLCL recognises the value of knowledge exchange and the importance of objective peer review. It is committed to encouraging and supporting its research teams in this regard.

The individual monitoring and evaluation reports have been provided to the relevant Housing Providers for review. Comments were considered and addressed by the author(s) as appropriate.

The current final report has been provided to the Steering Committee for comment.

Australian Government
Department of Industry, Innovation and Science
Business Cooperative Research Centres Programme

# CONTENTS



# LIST OF FIGURES

## EXECUTIVE SUMMARY

This report provides a summary of activities completed under the CRC for Low Carbon Living RP3044 'Mainstreaming Low Carbon Retrofits in Social Housing'. This two-year project provided real world evaluation of a range of energy efficiency upgrades undertaken in Social Housing properties around NSW, considering changes in energy consumption, thermal conditions, and tenant perceptions of the upgrade.

The report is structured in the following way:

Section 1 presents the project background and objectives;

Section 2 provides an overview of the methodology employed for the various activities undertaken in the study;

Section 3 gives a concise summary of the key reports and deliverables from the current project.

Full details of the project findings are located in the specific deliverable, included as an appendix to the current reports. The deliverables from the current project were:

i. A summary of existing processes for upgrading and maintenance of Social Housing properties.

ii. A targeted review of evidence of direct and co-benefits of energy efficiency upgrades in low-income dwellings in Australia.

iii. Detailed monitoring and evaluation reports for the installation of energy efficient technologies in a sample of Social Housing properties, Technologies assessed include reverse cycle air-conditioning, heat pump hot water systems, wall insulation and double-glazing.

iv. A Guide to Implementing Low Carbon Retrofits For Social Housing.

## 1. PROJECT BACKGROUND AND OBJECTIVES

In late 2016, The University of Wollongong Sustainable Buildings Research Centre commenced a project designed to assist community and public housing providers to embed and optimise low carbon retrofits and refurbishments into their property maintenance and upgrading processes. The project, Mainstreaming Low Carbon Retrofits in Social Housing, aimed to assist social housing providers to implement cost-effective upgrades to their housing stock to improve energy efficiency and thermal comfort.

The key research objectives of the current project were to determine:

1. What is the current energy performance of the community housing stock, in terms of base building energy performance, tenant practices, and thermal comfort?
   a) What is the current performance of community and public housing stock, particularly with respect to parameters that influence the balance between energy consumption and the health and well-being of tenants?
   b) What are the everyday energy practices that make a house a home for community housing tenants?
   c) What energy dilemmas are faced by community housing tenants?

2. What are the current practices and tools used by community and public housing providers to assess their existing building stock (at both portfolio and individual building levels) for purposes for retrofit and renovation?
   a) How can these processes and tools be improved, particularly with respect to facilitating the uptake and implementation of low carbon community housing improvements?
   b) What are the needs of Social Housing Providers in relation to retrofits and upgrades and how can this project best support them in relation to low carbon retrofits and upgrades?

3. What are the specific and overall quantitative and qualitative direct and co-benefits that flow from low carbon and energy efficiency

upgrades to public and community housing (to tenants, providers and government)?

In order the answer these research questions, the project consisted of three main activities, namely:

- Activity 1: Assess the business case for low carbon retrofits in Social Housing. This activity included a review of existing processes for the upgrade and maintenance of Social Housing properties, as well as a review of the existing evidence base regarding the direct benefits, co-benefits and risks related to implementing energy efficiency upgrades in low income properties.
- Activity 2: Development of resources to support low carbon Social Housing retrofits and refurbishment. This included a co-design process to build on the understanding of existing processes and identify opportunities to support low carbon upgrading. It also included revision of existing auditing and retrofit allocation processes employed by the University of Wollongong (UOW) to develop bespoke resources for the Social Housing sector.
- Activity 3 - Living Laboratory implementation and evaluation. The major activity in the current project was the establishment of embedded living laboratories in Social Housing properties, where the internal conditions, energy consumption, and lived experiences of social housing tenants was explored with respect to thermal comfort and energy consumption. This included evaluation of the effectiveness of a range of upgrades implemented under a number of different upgrade schemes.

The work was carried out in close collaboration with several stakeholders, including the NSW Office of Environment and Heritage (OEH), the NSW Land and Housing Corporation (LAHC), and a range of Housing Providers including Evolve Housing, Housing Plus, Housing Trust, and Aboriginal Housing Office. Comment and additional input was sought from other Housing providers as appropriate throughout the course of the project.

Three embedded living laboratories were established to monitor the real-world performance of three upgrade programs. The living laboratory households were due to receive a low carbon upgrade, and the monitoring project was designed to evaluate the effectiveness of the building upgrades. The monitored properties were in Port Kembla, Western Sydney, and the NSW Central and North West regions. The buildings studied were due to be upgraded under one of three concurrent retrofit programs:

- NSW OEH Home Energy Action (HEA) program: HEA is a $76.8 million energy efficiency assistance program that helps low income households reduce their energy bills, including a partnership with community housing providers to upgrade community housing properties (HEA properties were in Western Sydney, and Central and North West NSW).
- NSW Department of Industry Port Kembla Community Investment Fund (PKCIF): As part of a consortium with UOW, the Community Housing provider Housing Trust received funding to upgrade the energy efficiency of their community housing properties in the Port Kembla suburb.
- NSW Land and Housing Corporation (LAHC) were undertaking a project to remove asbestos external wall cladding from their public housing properties in the central west NSW. This work included the installation of new external wall cladding and retrofitting wall insulation. Double-glazing was also piloted in three homes (LAHC properties were in Central West of NSW).

# 2. METHODOLOGY

## 2.1. Project Planning

Following project inception, a detailed project plan was created, including an expected work breakdown structure, and task timeline. A draft project plan was presented to the steering committee at the initial steering committee meeting to facilitate project co-design with the utilisation partners. Numerous changes were made to the project plan considering discussions, particularly discussion regarding the existing maintenance processes utilised by LAHC and other Housing Providers, and the potential utilisation of tools that may arise from the current project. A live project planning document was maintained throughout the life of the project, to capture major changes.

## 2.2. Human Research Ethics Approval

The research protocol for all relevant research activities was reviewed and approved by the UOW Human Research Ethics Committee (HREC). Two separate protocols were approved for:

i. The in-home energy assessment, monitoring and interviews with social housing tenants (UOW reference: HREC 2016/967), and

ii. Interviews with social housing asset managers and executives to understanding existing tools, processes, and needs (UOW reference: HREC 2017/548).

Numerous amendments were made to the protocols over the course of the project, most notably to allow for the inclusion of Aboriginal Housing as a living laboratory.

## 2.3. Recruitment of Community Housing Providers.

A major activity in the early stages of the project was to recruit Housing Providers to participate in the Living Laboratory activity and support the research team in the recruitment of participants.

Whilst the current project has provided useful information for evaluation of the effectiveness of the various upgrade programs outlined in Section 0, the evaluation was not included as an integral part of the upgrade programs development. This introduced numerous challenges and constraints that had to be negotiated in the current project. Initial discussion had been held during project proposal development with several housing providers considering upgrades regarding potential involvement with the current project.

Housing Providers were not required to support the project financially, and the individual involvement of Housing Providers was negotiated on a case-by-case basis.

Discussions were held with numerous Housing Providers to establish interest and willingness to participate, and then determine whether an effective evaluation could be made with the implementation constraints. In several cases, Housing Providers were not willing to participate due to concerns regarding delivery of the upgrades within the OEH contractual timeframes. The project team worked closely with the OEH HEA Community Housing team (for providers involved in the HEA program) to allay these concerns, with differing success.

Collaboration agreements were developed to manage the interactions between UOW and the Housing Providers. Collaboration agreements were signed with LAHC, Housing Trust, Housing Plus, Evolve, and the Aboriginal Housing Office.

- LAHC were undertaking a project to remove asbestos external wall cladding from their public housing properties and were retrofitting wall insulation to these properties. As well as the wall-insulation, double-glazing was trialled in three properties that were being monitored, as a direct result of involvement in the current project. The project timelines were aligned well with the current living laboratory work, and the project team were able to select preferred properties to approach from a relatively large sample. The LAHC Manager of Environmental Sustainability was well engaged with RP3044 and acted as chair of the Project Steering Committee.
- Housing Trust were engaged with the current project through the Sustainable Port Kembla Project. Funding was awarded to a consortia including UOW to upgrade the energy efficiency of a small number of Housing Trust Community Housing properties. These were upgraded based on recommendations arising from an in-depth home-energy assessment completed by the UOW research team, as well

as ongoing engagement with both the Housing Provider and the tenants. High staff turnover at the Housing Trust over the project life was a key challenge for this living laboratory.

- Housing Plus, Evolve and Aboriginal Housing Office were all participants in the OEH Home Energy Action program. Evolve properties received a Heat Pump hot water system upgrade; Housing Plus properties received an efficient air conditioner as a source of winter heating, and Aboriginal Housing Office properties received an efficient air conditioner and solar photovoltaic system, along with ancillary works. In all three cases, the monitoring and evaluation project had to be adjusted to accommodate the retrofit implementation timeframes, typically resulting in short pre-retrofit evaluation periods.

A recurring issue throughout the current project was the high rate of staff turnover within Housing Providers. The project was often reliant on a single contact within an organisation, and turnover of the key staff created many difficulties. This appears to be a common issue in the Community Housing sector.

## 2.4. Living laboratory monitoring

### 2.4.1. Recruitment of tenants

Recruitment of the householders for this study was undertaken in collaboration with the relevant Housing Providers. The process followed in each case varied based on the level of engagement of the providers, and the specific contexts (e.g. location of living laboratory, ability to contact tenants). The typical recruitment process was as follows:

- The Housing Provider identified a list of properties that were scheduled for upgrade. UOW identified preferred properties and properties to exclude, based on attributes such as location and available fuel sources (preference for electric only households).
- UOW or the Housing Provider sent a letter to all properties not excluded by UOW informing them of the monitoring project and providing an opportunity for the tenant to opt-out of further contact or involvement in the study.
- The Housing Provider supplied UOW with a list of contact details for tenants who were scheduled to receive an upgrade.
- The UOW project team mailed a participant information sheet (PIS) to tenants and followed up with a phone call to verbally explain the project, and the PIS.
- A follow up scheduling phone call was completed prior to the home energy assessment visit to confirm interest, answer any questions raised in the PIS and arrange the home visit.
- Home visits were then completed. At the commencement of the home visit a summary of the key points in the PIS were provided to the tenants, and the detail contained in the consent form (included in Appendix A) was explained to the tenants. The home energy assessment commenced when signed consent was received from the tenant. Tenants who did not agree to complete the home assessment were excluded from further contact.
- At the end of the home energy assessment, and again at the end of the monitoring period, tenants were supplied with $50 gift card as a token of appreciation for their involvement in the study.

### 2.4.2. Building Characterisation Audits

A home energy assessment was undertaken in all buildings which participated in the study. The data collected included building physical and thermal characteristics, occupant behaviours and preferences, and major systems and appliances in the houses. Photographs of key items were taken for validation of collected data. A revised version of UOW's Building Characterisation Tool (BCT), developed during the Energy+Illawarra Project (Cooper et al., 2016), was created for the current project to collect the audit information.

The original BCT tool was a comprehensive surveying tool which combined physical inspection of important building attributes with an in-depth home-owner questionnaire. The current project team revised the BCT to better suit the social housing sector. More focus was placed on building physical features, and efforts were made to shorten the audit time from ~ 2 hours to ~1 hour. The tool was implemented in html and accessed onsite using tablet computers.

The BCT used in the current project captured relevant data from discussions with the occupants. The second section of the tool collected information on occupant practices. A comments section was also provided for the auditor to capture any additional comments such as “we are home most of the time but out Wednesday afternoons for shopping”. The remaining sections of the tool recorded information regarding the building structure and major appliances used in the dwelling. Full details of the assessment tool are included as Appendix 3.

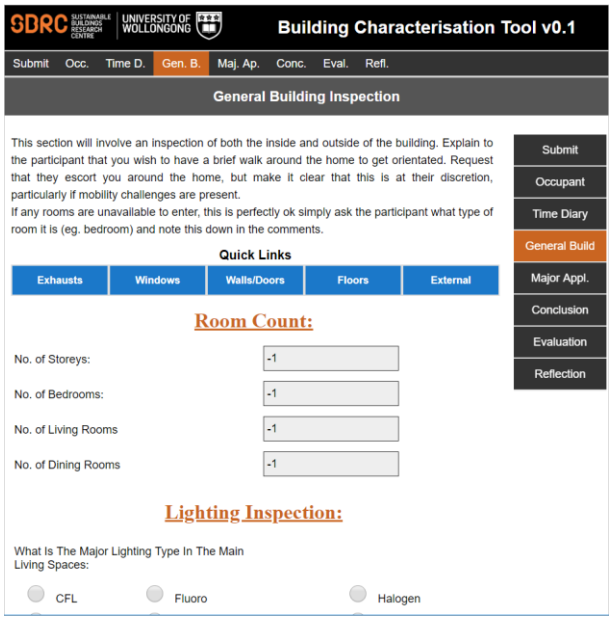


Figure 1. Example section from the Building Characterisation Tool employed for the current project.

The tool collected information organised in the following sections:

1. Occupant questions: house and energy usage information as reported by the occupant;
2. Time diary: how the occupant used the home, including typical daily, weekly and seasonal variations;
3. General Build: the main construction details for the house;
4. Major Appliances: capturing the relevant details of the main energy consuming appliances in the property; and
5. Evaluation: which provided an on-site assessment of the appropriateness of a range of typical retrofit options.

### 2.4.3. Thermal and Energy Monitoring

Thermal and energy monitoring was used to determine actual thermal conditions in the home, and to identify when major appliances were in use. Temperature and relative humidity were recorded in several locations around the homes. Two sensors were employed in the current study:

- HOBO UX100-003 temperature and relative humidity data loggers. These sensors were configured to log temperature and relative humidity at 20-minute intervals. Logger datasheet is included as Appendix 2.
- MAXIM iButton temperature and temperature/humidity data loggers (DS1922L/DS1923). These sensors were configured to log temperature and/or relative humidity at 1-hour time intervals.

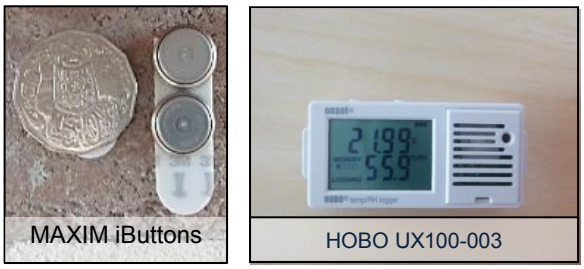


Figure 2. HOBO and iButton temperature and relative humidity loggers employed in the current study

The HOBO logger was installed in the main living area (the area the tenant reported spending the most time), and the iButtons were distributed around the house. Typically, temperature iButtons were installed in the master bedroom, second bedroom or second living area, and temperature/humidity iButtons were installed in the bathroom. In houses where there was mould present the temperature/humidity iButton was placed in the location where the issue was identified.

Energy consumption was monitored using WattWatchers Auditor 6M energy monitors. The device measures electricity consumption on six (6) circuits at the dwelling distribution board. The device was configured to measure energy consumption at one (1) minute intervals, by default the device also logs consumption at five (5) minute intervals (the five-minute data is stored locally for 30 days). A licensed electrician installed the device in the property’s distribution boards. Energy consumption data was also requested from the energy distributors for those monitored properties for which consent was received from the 1st Jan 2017 to the 15th October 2018.


Figure 3. Example installed WattWatchers Auditor 6M

Half-hourly external weather data was downloaded from the Bureau of Meteorology (BOM) website. Observations were downloaded for all the Australian weather stations using an automatic script to create a complete dataset of the weather data available online. Data from six stations were used for the current study. More information and further details on the location of each station can be found on the BOM website.

### 2.4.4. Ethnographies

For a subsample of Living Laboratories, participants were approached regarding interest in involvement in ethnographies during the home energy audits. Tenants were invited to participate in a one-hour semi-structured interview, to sketch a floor plan of their home, to complete a Home Energy Diary and to participate in a follow-up conversation of around 40 minutes. The tenants were supplied with a Participant Information sheet with the contact details of the researcher. Appointments were made at a time and place convenient for the tenant. This was usually in their home or at a local café. Tenants agreed to participate and received a $50 shopping voucher to compensate them for their time at commencement of the project and another voucher on completion.

The semi-structured interview was designed to gather information from the tenant about how they make their homes welcoming, safe and comfortable while still being aware of the cost of energy. The questions investigated five themes:

- Getting to know you;
- Socialising;
- How they warmed the home in winter and cooled it in summer;
- How the home was ventilated; and
- Concerns about their energy costs.

Participants had a chance to ask the researcher any questions about the project before signing a consent form that acknowledged what data would be collected, how it would be stored, how their privacy would be protected and how the data would be utilised and disseminated. All interviews and follow up conversations were audio recorded and transcribed.

At the conclusion of the interview participants were supplied with a floor plan of their home and invited to colour areas of the home that were hot in summer, cold in winter, to trace air-flow pathways and identify the presence of mould (if any). In addition to the mapping activity, The Home Energy Diary provided a place for participants to record their daily energy practices over a two-week period. They were asked to record the times they turned on and off appliances, opened and closed doors and windows, and to reflect on their health and emotional well-being in relation to their energy costs. The diaries included space to provide sketches, doodles or diagrams to illustrate their practices.

A round of follow-up conversations were conducted after the energy efficiency upgrades had been undertaken. The follow up conversation utilised the data collected from the first interviews, maps and Home Energy Diaries and provided an opportunity to identify impacts of the project including perceived changes to comfort and health, altered energy practices, concerns about energy costs, and social and emotional well-being. Participants were invited to complete a further Home Energy Diary.

Narrative and discourse analysis was conducted using Nvivo 11 qualitative software and inductive and deductive coding were employed on transcribed interview and conversational data. Maps and diaries were comparatively analysed allowing links and commonalities to be traced across the different data sources.

## 2.5. Review of processes for upgrading and maintenance of Social Housing properties

An interim report was prepared which focused on developing clarity regarding the system in which Social Housing providers currently operate, and the processes and practices employed to meet current maintenance requirements. A review of

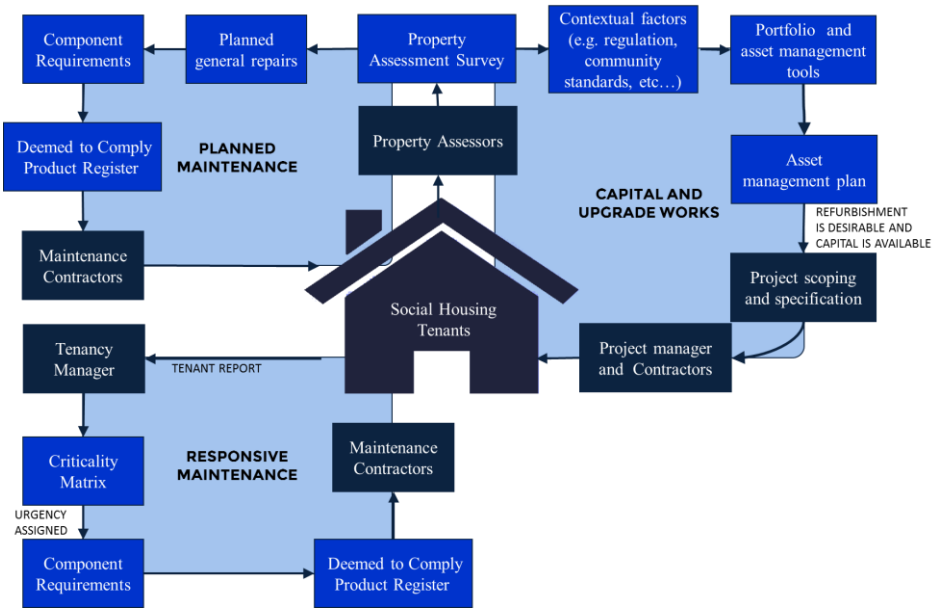


Figure 4. Main maintenance and upgrading processes within the Social Housing Sector.

relevant literature, specifically including regulatory and other maintenance obligations and existing guidance for the sector was completed, and this was supplemented with a series of interviews with stakeholders in the Social Housing sector. Preliminary opportunity identification was undertaken recording possible future uses for outcomes from the current project, and best way to support the uptake of low carbon upgrades in this sector. The findings and opportunities identified in this report were considered in a workshop with the RP3044 steering committee, as well as invited representatives from a number of engaged CHPs. The development of a simple guide to low carbon retrofitting in social housing, providing a summary of options, current evidence and relevant case studies was identified through this process as a relevant output from the current project, which could be expected to be well utilised within the sector.

## 2.6. Review of evidence of retrofit benefits.

A second interim report was prepared which provided a targeted review of studies that have examined the effects of energy efficiency interventions for low income properties. The report presented finding related to the direct benefits to be expected to result from a range of the most commonly applied interventions; the review was limited to studies that had measured real-world impact or were highly relevant simulation studies in appropriate building types and climates. The current evidence base regarding co-benefits was also reviewed, including the link between low internal temperatures and health risk, exposure to high internal temperatures, housing energy interventions, and health risk, and internal hygrothermal conditions, mould risk and health implications. Differing levels of evidence were found for each of the different health risks. The interim report attempted to distil a large amount of complex information into a concise, usable summary of the current state of research for the Community Housing sector and was used to inform the content of the low carbon implementation resources that was prepared as part of the current project.

# 3. SUMMARY OF PROJECT DELIVERABLES

An executive summary of the various deliverables throughout the RP3044 project is provided below. The full reports are in each case provided as an Appendix to the current report.

## 3.1. Deliverable: Summary of Existing Processes for Upgrading and Maintenance of Social Housing Properties

The summary of existing process for upgrading and maintenance of social housing provided a review of the regulatory and business context in which Public, Community and Aboriginal housing providers operate. A brief outline was provided of the organisational structure of the Social Housing sector in NSW, including key statistics regarding ownership and management status of the various Housing Provider groups, as well as key objectives outlined in the *Future Directions for Social Housing* report.

A review was undertaken of national and state legislation and regulation, as well as FACS standards, which relate to the management of energy efficiency and thermal comfort in Social Housing properties. The typical processes employed by Social Housing providers to meet the obligations were mapped, using published material, interviews and workshop validation. This is shown in Figure 4.

The financial situation of the Social Housing sector was also highlighted. The Social Housing sector operates with tight financial constraints, which has previously been identified as resulting in a substantial maintenance shortfall. The financial context is highly relevant to attempts to mainstream, low carbon retrofits, which typically require increased capital expenditure for upgrading beyond minimum maintenance standards.

Existing external funding opportunities for implementing energy efficiency upgrades were reviewed, and several potential opportunities to support mainstreaming of low carbon retrofitting within the current systems were identified. The relative value and priority of these opportunities was workshopped with the RP3044 steering committee, as well as invited representatives from several engaged CHPs, which informed the RP3044 project plan, as well as future priorities.

The full interim report is included as Appendix A

## 3.2. Deliverable: Targeted review of evidence of direct and co-benefits of energy efficiency upgrades in low income dwellings in Australia

Low income occupants, and social housing tenants, are highly vulnerable to energy price rises and extreme weather conditions and face specific barriers to accessing energy efficient dwellings and improvements. Further, low income occupants often use little energy and rely on compensatory measures to cope with energy bills, such as minimising the use of heating and cooling. This means that traditional cost-benefit assessments, considering the benefit of utility bill reduction only, are often unfavourable for low income dwellings. However, low income tenants are also the most likely to receive non-energy benefits, or co-benefits, from energy efficiency upgrades.

There has been much research in recent years attempting to quantify the various co-benefits of energy efficiency interventions. There has been a significant focus on health co-benefits, particularly for low income populations. The links between housing and health are complex, although a number of previous reviews have identified a correlation between poor housing and poor health. In the context of health and housing, vulnerability is a function of exposure to unhealthy housing environment, sensitivity to housing environment, and adaptive capacity, as summarised in Figure 5.

More vulnerable groups, such as the sick, the elderly, and the unemployed (all demographics which are more highly represented in social housing than the general population), are more likely to live in poor quality housing. These groups are also likely to spend a greater amount of time at home, exposed to the environment in the home (Thomson *et al.* 2009). Low income groups are also more likely to have a lower adaptive capacity to deal with unhealthy environments.

There have been several high-quality studies and reviews of evidence published in recent years. However, the studies identified and reviewed for the current study were typically from other countries, and it is not clear how applicable the results are to the Australian climate. The targeted review considered the evidence of direct benefits from different energy efficiency measures in

Australia, and the evidence for health impacts from improved winter heating, improved resilience to summer heat wave events, and measures to minimise mould and dust mite risk.

Low internal ambient temperatures are likely to be an important issue in Australia. Whilst much of Australia experiences mild winter conditions, Australia experiences a relatively high occurrence of excess winter deaths. This is consistent with previous studies which have linked high excess winter deaths to climates with mild winters; explanatory factors for this in other locations include energy inefficient and difficult or expensive to heat homes, and adaptive behavioural actions (such as winter clothing levels). High-quality reviews have found consistent and increasingly strong evidence that energy efficiency interventions which increase winter warmth may improve the health of occupants, particularly in children, the elderly, and those with pre-existing health issues. In studies where the cost-benefit has been calculated, the health co-benefits vastly outweigh the direct energy benefits. However, there remains significant uncertainty regarding the direct causal pathways linking energy efficiency interventions aimed to reduce winter cold, and health outcomes.

There is less developed evidence regarding the impact of energy efficiency interventions on heat-related health risk, as compared with low internal temperatures. Heat waves are a major natural hazard in Australia, responsible for the death of more people than all other natural hazards combined, and low income populations are at greater risk of morbidity and mortality from heat wave events. Major simulation studies have shown that energy efficiency interventions to dwellings would be expected to reduce the health risk of heat wave events in Australia, although, in climates with hot and humid summers, air-conditioning will be increasingly required to maintain a safe indoor thermal environment. However, there is a lack of evidence regarding the direct causal relationship between exposure to heat stress (e.g. as measured by discomfort index) in homes and health outcomes in Australia and the likely impact of energy interventions.

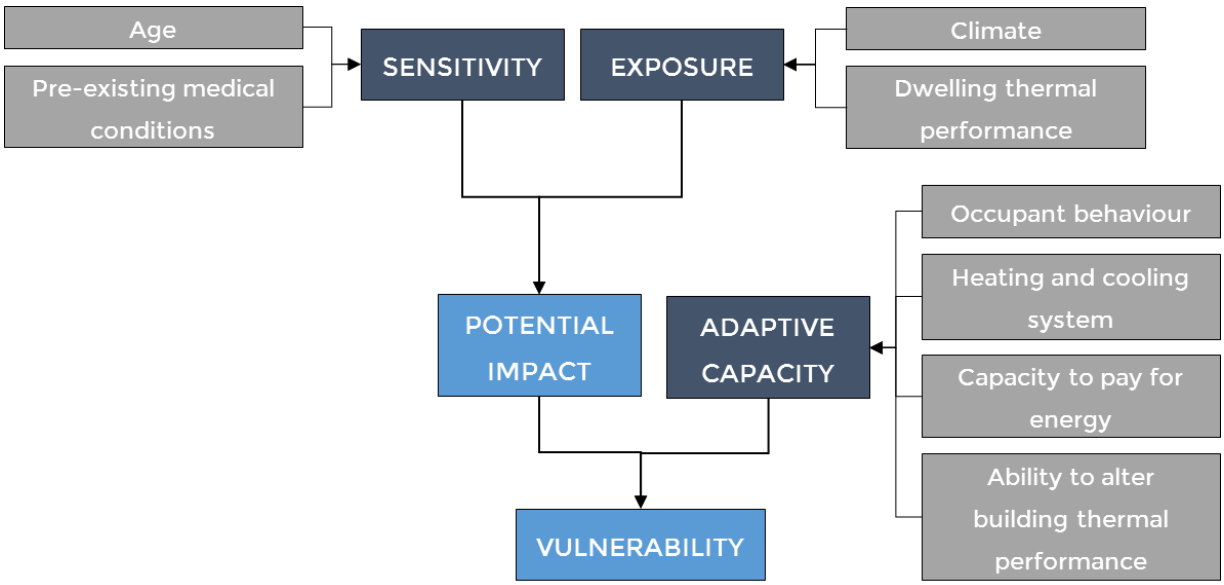


Figure 5. Key factors influencing vulnerability to health risks in housing, adapted from Allen Consulting Group (2005).

The risk of mould growth in homes, and therefore negative health outcomes from exposure to mould and dust mites, is closely related to the hygrothermal conditions in a home, particularly the presence of low internal ambient temperatures, and associated condensation. A recently published review of evidence found 'moderate to very low-quality evidence that repairing mould-damaged houses and offices decreases asthma-related symptoms and respiratory infections compared to no intervention in adults.' (Sauni *et al.* 2015). Interventions to reduce mould risk, as opposed to those focused on cleaning and chemical treatment of mould, generally focus on increasing internal ambient temperatures. There is some evidence that heating system improvements, improvements to

insulation, and improved air-tightness and controlled ventilation can reduce mould risk and occurrence, which may result in decreased respiratory illness.

The current targeted review found there is some evidence that low income tenants in social housing in Australia may realise health benefits as a result of energy efficiency interventions, and there is some evidence from international studies that the financial benefits may be substantial. The strongest evidence relates to benefits from increasing winter warmth above identified risk threshold temperatures; there is also evidence of benefits from reducing internal temperatures during summer heat events and reducing the occurrence of mould in homes. However, the link between health outcomes and energy efficiency interventions is exceedingly complex, and there are numerous confounding factors affecting any study in this space. Therefore, the understanding of the exact causal pathways linking energy efficiency interventions and health outcomes, and the relative importance of those pathways, is still limited. Further, there is currently insufficient evidence to make an estimate of the actual financial impact from co-benefits resulting from a specific energy efficiency intervention or package of interventions. There is a need for high quality, randomised controlled trials of interventions in multiple climate zones, such as the recently commenced Victorian Healthy Homes Program (Sustainability Victoria 2018).

The full interim report is included as Appendix B.

## 3.3. Deliverable: Evaluation of living laboratory monitored data and reporting to stakeholders.

A detailed monitoring report was provided to each participating organisation. The monitoring reports included baseline information about the performance of the monitored properties relative to the other monitored properties, as well as to relevant national benchmarks. An evaluation of the energy efficiency upgrades implemented in each property was then presented, using appropriate metrics for the living laboratory. Where available, the findings of the ethnographic research were also presented, including findings related to tenants experience of balancing energy bills, health and comfort, and the qualitative experience of the upgrade.

The key findings from the baseline evaluation were:

- There was substantial variation in total electricity consumption in the monitored social housing properties. The highest average daily energy consumption was 72 kWh/day in Narrabri, and the lowest was 4 kWh/day in Port Kembla.
- There was substantial variation in electricity consumption relative to the appropriate Australian Energy Regulator benchmark value in the monitored social housing properties. The highest average discrepancy was + 209% in Narrabri, and the lowest was -74% in Bathurst.
- Many properties experienced winter temperatures below the WHO recommended threshold temperature for a substantial proportion of the winter period. Of the 38 properties 22 had a living room temperature below 18 $^{o}$C for over 50% of the winter period.
- Overheating during the summer period was less of an issue in the monitored properties, based on proportion of time outside WHO recommended threshold values. Of the 38 properties 8 were above 26$^{o}$C for over 50% of the summer period.
- The retrofit outcomes were mixed and varied according to location, Housing Provider, implemented upgrade and tenants. The sample size was not sufficient to provide program level evaluation across the various upgrade and climate groups; however, a range of possible outcomes resulting from the various upgrades were reported. In some cases, for instance the Aboriginal Housing Properties in Narrabri, it seems likely that the experience of the monitored properties may not have been reflective of the broader program.
- The tenant experience of living in Social Housing, living in fuel poverty and concerns and anxieties regarding energy costs were regularly reported. Compensatory measures to minimise energy costs were also common.
- Tenant perceptions of the upgrades were varied according to location, housing provider and implemented upgrade.

Detailed monitoring reports were provided to:

- Land and Housing Corporation, providing evaluation of the effectiveness of wall insulation and double-glazing upgrades;
- Housing Plus, providing evaluation of the effectiveness of the installation of efficient reverse cycle air-conditioners for winter warming;
- Evolve, providing evaluation of the effectiveness of installation of heat pump hot water systems;
- Aboriginal Housing Office, providing evaluation of the effectiveness of efficient air-conditioners to replace inefficient window wall units, alongside photovoltaic panel installation, and;
- Housing Trust, providing evaluation of the effectiveness of a range of bespoke upgrades based on recommendations of a home energy assessment;

The full monitoring reports are available as Appendices C-G

## 3.4. Deliverable: Guide to Implementing Low Carbon Retrofits For Social Housing Tenants

A concise guide targeted at Social Housing providers considering implementing upgrades to improve the energy efficiency performance or thermal comfort of dwellings in their stock was prepared as part of the current project. The guide summarises the outcomes of several recent research projects completed nationally by a variety of individuals and organisations. Much of the information presented in the resource was developed specifically for the current project, and additional relevant information was taken from the CRC Low Carbon Living 'Guide to Low Carbon Residential Buildings – Retrofit' which was developed concurrently by UOW. The Guide to Implementing Low Carbon Retrofits for Social Housing Tenants consolidates new and existing information into a targeted, simple to use reference for Social Housing asset managers and others involved in Social Housing upgrades. The new research was focussed on NSW, however many of the recommendations will be relevant throughout Australia. The guide therefore presents concise information on key considerations for improving energy efficiency in relation to each maintenance process, as well as specific information for some of the key retrofit opportunities.

The full Guide is included as Appendix H.

## 4. REFERENCES

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Sustainability Victoria (2018). Outcomes evaluation of the Victorian Healthy Homes Program: a staggered parallel group cluster randomised controlled trial assessing the thermal comfort and health benefits of home energy efficiency improvements. Sydney Australian New Zealand Clinical Trials Registry.

## APPENDICES

Appendices to the report included as below:

- APPENDIX A: Summary of Existing Processes for Upgrading and Maintenance of Social Housing Properties.
- APPENDIX B: Targeted review of evidence of direct and co-benefits of energy efficiency upgrades in low-income dwellings in Australia.
- APPENDIX C: Evaluation of reverse cycle air-conditioning installations. Report for NSW Aboriginal Housing Office.
- APPENDIX D: Evaluation of Heat Pump Hot Water System replacements. Report for Evolve Housing.
- APPENDIX E: Evaluation of reverse cycle air-conditioning installations. Report for Housing Plus.
- APPENDIX F: Home Energy Characterization, Retrofit Allocation, and Energy Monitoring results. Report for Housing Trust.
- APPENDIX G: Evaluation of wall insulation and double-glazing retrofits. Report for NSW Land and Housing Corporation
- APPENDIX H: Guide to Implementing Low Carbon Retrofits For Social Housing Tenants