



LOW CARBON LIVING
CRC

Guide to Implementing Low Carbon Retrofits for Social Housing

Acknowledgements

Authors

Daniel Daly, Michael Tibbs, Theresa Harada, Gordon Waitt, Paul Cooper.

Title

Guide to Implementing Low Carbon Retrofits for Social Housing

Date

June 2019

The authors would like to thank staff at the Aboriginal Housing Office, Evolve, Housing Plus, Housing Trust, Land and Housing Corporation and the NSW Office of Environment and Heritage for helping to facilitate this research project, including providing valuable advice and feedback in all stages of the project.

This guide is funded by the CRC for Low Carbon Living Ltd and supported by the Cooperative Research Centres program, an Australian Government initiative.

ISBN: 978-0-9923879-1-4

© 2019 Low Carbon Living CRC



LOW CARBON LIVING
CRC

Disclaimer

Any opinions expressed in this document are those of the authors. They do not purport to reflect the opinions or views of the CRCLCL or its partners, agents or employees. The CRCLCL gives no warranty or assurance and makes no representation as to the accuracy or reliability of any information or advice contained in this document, or that it is suitable for any intended use. The CRCLCL, its partners, agents and employees, disclaim any and all liability for any errors or omissions or in respect of anything or the consequences of anything done or omitted to be done in reliance upon the whole or any part of this document.

Contents

Glossary	4
About This Guide	5
A Roadmap to Low Carbon Social Housing	5
01 Low Carbon Upgrade Options: Step #1	9
Simple actions to save energy	10
Ceiling Insulation, and roof replacement and insulation	11
Improved air tightness	13
Ceiling Fans	15
02 Low Carbon Upgrade Options: Step #2	17
Hot water systems (HWS)	18
Air-conditioning upgrade	22
Solar photovoltaic (PV) panels	25
03 Low Carbon Upgrade Options: Step #3	27
Under-floor Insulation	28
External Shading	28
Adding wall insulation when recladding	30
Window Replacements	30
04 Low Carbon Upgrade Options: Supporting Tenants	32
LED lighting	33
Fridge/Freezer and Television upgrades	34
Internal Window Coverings	34
Air tightness and fabric upgrades	35
Communicating with tenants regarding upgrade works	35
Further Information	37

Glossary

Air tightness

A measure of the air leakage through the building envelope when all external doors, windows and ventilators are closed.

Building envelope

The physical partition between the inside of a building and the external environment, consisting of the building's exterior walls, floor and roof, and exterior doors and windows.

Climate zone

A distinctive climate region within Australia, adapted from the National Construction Code climate zones.

Heat pump

A system that absorbs heat from the surrounding air to heat water without the need for electric element, gas or solar heating.

Continuous hot water

A system that provides continuous flow hot water without the need for a storage tank. Usually gas powered.

LED lighting/ 'light emitting diode'

A small electroluminescent light that is more energy efficient and emits much less heat compared to traditional light sources.

Low emissivity (low -e) glazing

A coating that reduces the amount of heat conducted through glass by around 30%.

National Construction Code (NCC)

A performance-based code that sets out the minimum requirements for safety, health, amenity and sustainability in the design and construction of new buildings (and new building work in existing buildings) throughout Australia.

Natural ventilation

The process of supplying air to and removing air from an indoor space without using mechanical systems.

Off-peak (control load) power

Off-peak power is power that is only available for a household to use at certain times. Control load 1 (off peak 1) makes electric power available between 10pm and 7am only with a reduced tariff of around 10c/kWh. Control load 2 makes electric power available between 10pm and 7am as well as during limited periods through the day with a tariff of around 14c/kWh.

Passive solar design

The design of windows, walls, and floors to distribute solar energy to heat living spaces in winter and cool them in summer.

Retrofit

Relatively minor modifications that increase the efficiency or performance of a building with minimal alterations to its bulk, scale and form.

R-value

A measure of how well a material performs as thermal insulation, or more accurately, the thermal resistance of a material. Under the National Construction Code, the required total R-values for the building fabric vary depending on climate zone.

Single/three phase power

Single phase power is used in most homes in Australia, and has two wires connected to the grid: active and neutral. Three phase power has three active wires and a neutral. It is used in older homes, larger homes, or homes with large electrical loads.

Solar photovoltaics

The conversion of light into electricity using semiconducting materials, typically panels, each comprising a number of solar cells which produce voltage and electric current.

Thermal bridging

Occurs when a conductive material allows an easy pathway for heat flow across a thermal barrier. Common examples include aluminium window frames and wall studs.

Thermal mass

The capacity of a material to absorb and store heat energy, providing a thermal 'buffer' against temperature change.

About This Guide

This *Guide to Implementing Low Carbon Retrofits for Social Housing* is intended as a simple to use reference for social housing asset managers and others involved in social housing upgrades. The guide presents a concise summary of effective energy efficiency options for social housing properties, including:

- Advice on priority upgrades;
- Important things to consider when deciding whether to implement an upgrade;
- Practical implementation advice to ensure the upgrade is implemented well;
- Complementary retrofit considerations to make the most of opportunities as they arise;

The current guide summarises the outcomes of a number of recent research projects completed nationally by a variety of individuals and organisations, with relevance to social housing. Much of the information presented in the current resource was prepared for the CRC Low Carbon Living [Guide to Low Carbon Residential Buildings – Retrofit](#), or was developed as part of the CRC LCL research project *Mainstreaming Low Carbon Retrofits for Social Housing*. The new research was focussed on NSW, however much of the recommendations will be relevant throughout Australia.

There are compelling reasons to improve the energy efficiency of social housing dwellings. There is a pressing need to reduce carbon emission from the existing residential housing stock; and social housing properties are typically older and less energy efficient than the general stock. Social housing tenants are some of the most vulnerable members of our society. This includes being particularly vulnerable to rising energy costs, less able to maintain comfortable internal conditions in their homes, and less able cope with extreme weather conditions. Further, there is an emerging body of evidence suggesting energy efficiency interventions could yield substantial health benefits, and that the health benefits experienced by low-income occupants (particularly young children, the elderly, and

those with pre-existing health conditions) could greatly outweigh energy cost benefits from an energy efficiency upgrade. It is noted that the split incentive issue impacts low carbon retrofits to social housing, where the costs are borne by the housing provider and the cost saving benefits are enjoyed by the tenant.

A Roadmap to Low Carbon Social Housing

The current guide has been arranged to provide a clear pathway to achieving low carbon homes for social housing. A simple visual guide is provided in [Figure 1](#). The 'roadmap' has energy efficiency upgrades divided into three steps;

- Step #1.** Simple, high impact retrofits that can benefit all homes;
- Step #2.** Higher upfront cost upgrades that will benefit most homes, and;
- Step #3.** Longer payback period upgrades, that are appropriate for some homes or for providers with more ambitious low carbon goals.

Step #1 upgrades address the major weaknesses in many existing buildings thermal envelopes through air-tightness improvements and ceiling insulation. A low cost source of cooling effect is provided through ceiling fans, and LED light globes are installed. A simple action list is provided in this guide to ensure that low cost opportunities are considered during routine maintenance, planned upgrade works or vacant restorations. At this step tenants should also be supported to lower their bills through provision of energy saving tips.

Step #2 involves upgrades to the major fixed appliances in a home, namely the hot water system and the heating and cooling appliances (if appropriate). Solar photovoltaics are recommended for detached homes, villas and townhouses with their own roof space, where existing trees will not impact on solar access. These upgrades typically have a higher upfront cost, but would be expected to pay for themselves through energy savings well within the system lifetime.

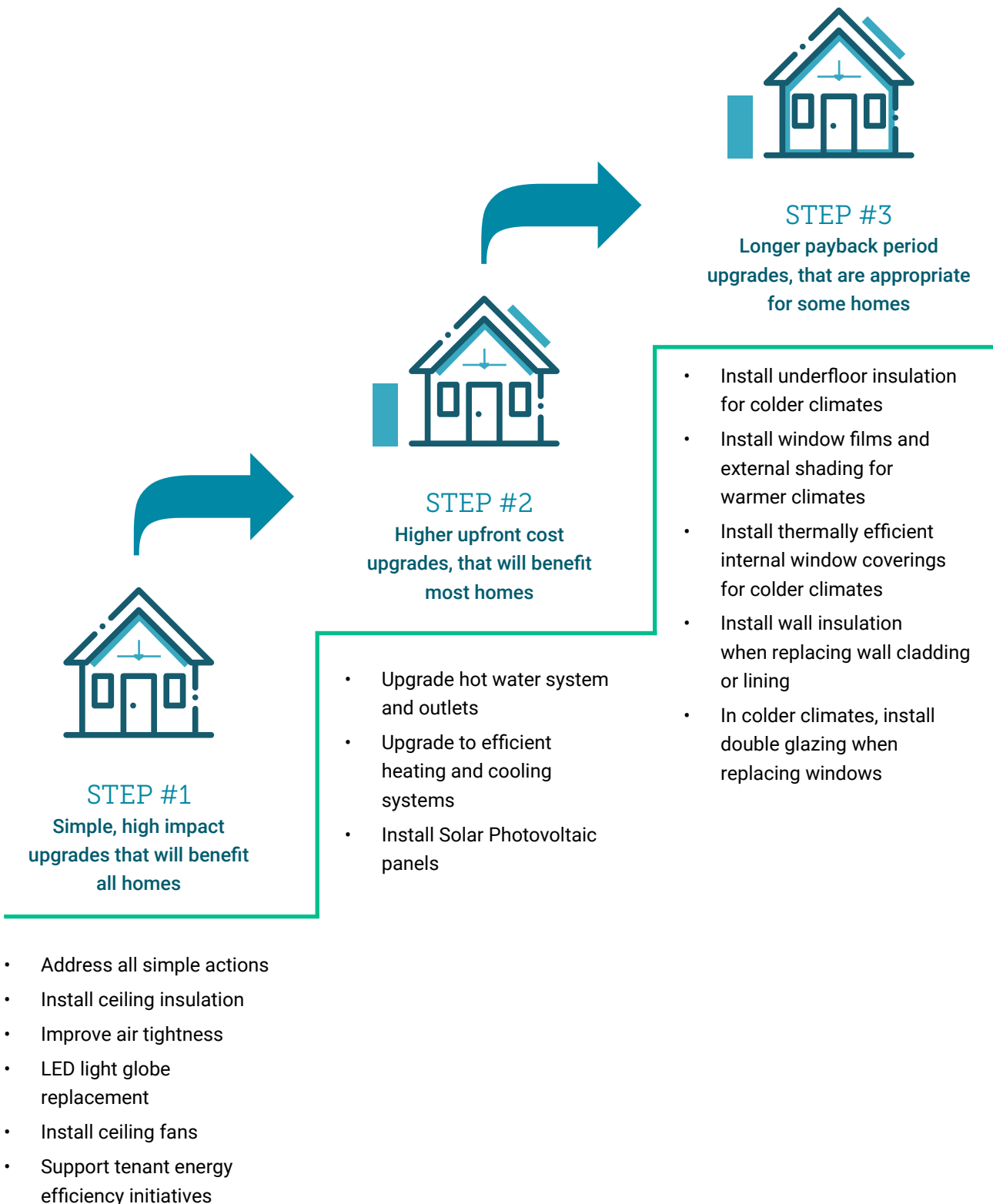


Figure 1 A roadmap to low carbon social housing.

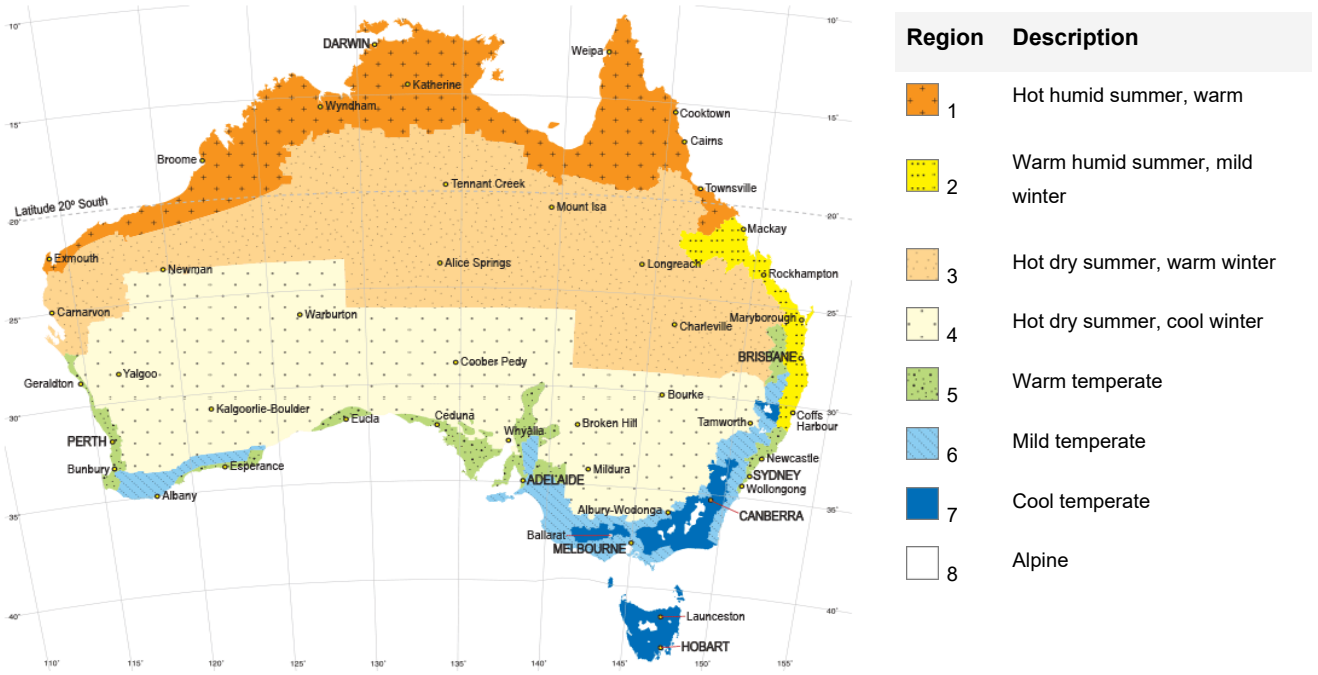


Figure 2 Climate Zones as defined in the National Construction Code.

Step #3 upgrades are those which are appropriate for a smaller subset of homes in specific climate zones, and generally will require detailed site investigation to determine if they are appropriate and cost effective. Some of these upgrades would only make economic sense when undertaken as a complement to another program of works.

Many of the upgrades listed in this guide are improvements to the thermal envelope of the building. Thermal envelope upgrades are passive retrofits that can improve the indoor thermal comfort in a dwelling regardless of whether the tenant uses heating or cooling appliances. Tenants who do use heating or cooling appliances will benefit from these upgrades through reduced energy bills; those who don't will benefit from a more comfortable indoor environment. Passive upgrades are particularly important for social housing since many tenants ration their heating and cooling use and already have very low energy consumption, despite the thermal envelope often being of lower performance than a typical home.

Where a home is located climatically will determine what retrofit options are most beneficial. Australia's National Construction Code defines eight distinct climate regions

which impact a building's energy requirements for heating and cooling. **Figure 2** shows how these zones are distributed across Australia.

Though climate regions vary, many of the higher-impact retrofit solutions are suitable and beneficial across several regions, with only minor variations. Poor quality building thermal envelopes will generally perform poorly in both heating and cooling seasons.

The low carbon retrofit opportunities recommended in this guide are summarised in Table 1, with an indication of relative level of costs and benefits, as well as key considerations.

Table 1 Summary of major retrofit opportunities for social housing. It should be noted that energy savings and home comfort improvement will vary substantially depending on climate and occupant behaviour. Site inspection identifies whether a site visit is necessary to determine whether the upgrade is appropriate prior to engaging a contractor. If no, typically asset management data should be sufficient to undertake initial screening or suitability

Retrofit Option	Up-Front Cost	Site Inspection	Energy Cost Savings	Home Comfort	Benefits	Considerations
Ceiling/Roof insulation	☺☺	Yes	⚡⚡	🌡️🌡️🌡️	Proven energy and/or thermal benefits when installed in uninsulated ceilings.	Determining whether insulation has been previously installed can require a site visit; Asset records may not be reliable.
Air tightness	☺☺	No	⚡⚡	🌡️🌡️	Proven energy and/or thermal benefits; low material cost makes it an ideal co-upgrade.	Air-tightness testing a sample of the housing stock may help determine any unexpected leakage points.
LED lighting	☺	No	⚡		Very low cost if someone is already on site, long globe lifetime.	Typically tenant responsibility. The very long service life is particularly beneficial for mobility impaired tenants.
Ceiling fans	☺	No	⚡	🌡️🌡️	Low capital and running cost source of cooling; can supplement or reduce need for AC (if required).	There is a limit beyond which fans will not be sufficient to maintain thermal comfort. Use fans with a summer/winter modes. Consider existing ceiling heights, particularly in bedrooms.
Hot Water System	☺☺☺	No	⚡⚡⚡		Robust energy consumption and bill reductions.	Numerous upgrade pathways to consider; hot water systems with off peak circuits will experience less cost savings.
Efficient Reverse Cycle Air Conditioners	☺☺☺	No	⚡⚡	🌡️🌡️🌡️	Can result in substantial energy and bill savings for households with high heating energy consumption.	Can increase consumption (in summer) and thereby increase bill stress. Consider installing solar photovoltaic panels to assist offset day time energy usage costs.
Solar Photovoltaic panels	☺☺☺	No	⚡⚡⚡		Robust energy bill reductions.	Age and type of roof, orientation and shading due to trees. No direct impact on thermal comfort or energy efficiency. Tenant education recommended to encourage use of electrical appliances during daytime hours.
Underfloor insulation	☺☺	Yes	⚡⚡	🌡️🌡️	Reduced heat loss and gains through the floor.	Suitable underfloor access required.
Window film	☺	No	⚡	🌡️	Reduced solar heat gains in summer.	Reduced beneficial solar heat gains in winter.
Window external shading	☺☺	Yes	⚡	🌡️🌡️	Reduced solar heat gains in summer.	Diverse range of options may require bespoke solution.
Window internal coverings	☺☺	Yes	⚡	🌡️🌡️	Improved thermal comfort, and potentially reduced winter energy bills.	Typically tenant responsibility. Especially cost effective for apartments with fewer windows and external wall area.
Wall insulation	☺☺	No	⚡⚡	🌡️🌡️	Reduced heat loss and gains through the walls; reduced condensation on walls and associated mould issues.	Only if replacing wall cladding or lining.
Double glazing	☺☺☺	No	⚡⚡	🌡️🌡️	Improved thermal comfort, and potentially reduced winter energy bills.	Only colder climates where window replacement already required.

SECTION

01

Low Carbon Upgrade Options: Step #1

Simple actions to save energy

Poor energy efficiency or thermal comfort performance of an existing dwelling will be typically related to either poor initial building design, poor construction quality, or inadequate property maintenance. Fixing existing faults, where practical, is an important prerequisite to ensure new upgrades function adequately. A short checklist is provided below:

Checklist of pre-existing issues	Low carbon retrofit impact
Are all operable windows able to be opened conveniently for natural ventilation, and readily closed for security? Are windows jammed, painted shut, or difficult to reach (for example above a bath or other obstruction)	Allows the occupant to utilise the window for natural ventilation
Do all operable windows have appropriate insect and/or security screens?	Allows the occupant to utilise the window for natural ventilation
Are there any broken windows or glass?	As well as a safety issue these can be a major source of air-leakage.
Is the hot water storage tank water temperature set at 60 °C?	To address the risk of legionella. Higher storage temperatures increase the energy consumption.
Is the hot water outlet temperature (at least for showers, baths and personal hygiene hand basins) no higher than 50 °C? (Tempering valves are generally used to comply).	To greatly reduce the risk of scalding the skin. Lower temperature may compromise dishwashing performance.
Are low flow water outlets fitted to all showers and hand basins? (See recommendations under Hot Water Systems).	Reduces hot water energy consumption.
Are there any water leaks?	May reduce hot water energy consumption.
If the ceiling has existing insulation, are the batts still in-place with complete coverage?	Having just 5% gaps in the insulated roof space can reduce the effective R-value by up to 50%
Are all internal doors in place and operable?	Effective zoning of living spaces during heating and cooling can greatly reduce energy consumption.
Are all external doors operable, well-fitting to the frame and able to be closed securely?	Changes to the shape of external door frames over time can be a major source of air leakage.
If the property has an air-conditioner, ensure the indoor unit air filter is regularly cleaned.	Dirty filters can increase air-conditioner energy consumption.

Ceiling Insulation, and roof replacement and insulation

Background

Ceiling insulation is one of the most cost-effective retrofits to make a home more comfortable. Historically, Australian homes have lacked adequate insulation. Its inclusion in new homes is now mandated to improve thermal comfort, and/or reduce cooling and heating costs. Ceiling insulation is highly recommended to rollout for all homes where this retrofit is practical.

In the 2014 Census, 68% of households in Australia reported having some form of insulation, while 14% of households did not have any form of insulation (18% did not know). There is limited information regarding the proportion of social housing properties with ceiling insulation. Statistics from Victoria¹ showed that only 3% of owner-occupied properties in that State did not have some form of insulation, while 17% of public rental properties had no insulation.



How well insulation performs is indicated by its R-value. The R-value indicates the thermal resistance of the insulation material (specifically, the resistance to conductive heat flow between indoors and outdoors).

For example, insulation with an R-value of R4.5 will resist heat flow more effectively than insulation with R2.0. However, the improvement associated with higher R-values is not endless. Each climate has a recommended R-value above which the benefits from the reduced heat flow become diminished. The National Construction Code (Part 3.12) provides minimum R-value requirements for new homes in different climate zones, and is a helpful reference to define the minimum starting point to specify insulation levels for your climate.

There are a variety of effective insulation materials, all of which must meet Australian standards. Two products with the same R-value will provide the same insulation benefit, regardless of the material used; some products will use recycled or more eco-friendly materials.

Modelling studies have repeatedly shown the effectiveness of ceiling insulation. Modelling completed for the Insulation Council² found that retrofitting insulation to previously uninsulated ceilings had a lifetime benefit-cost ratio greater than 1 for all studied locations, and a simple payback of 5 years or less in NSW, Victoria, ACT, Tasmania and SA. In terms of thermal comfort, a recent study focussed on low income older people in the Illawarra reported an increase in average indoor temperature for a given outdoor temperature due to installation of ceiling insulation of between 1°C and 2°C³.

Since the roof of a building is such a key component of the thermal envelope of a building, a roof replacement provides a major opportunity to improve the thermal performance and energy efficiency of a building through careful selection of the colour of the replacement roof, as well as considering the provision of complementary upgrades including roof/ceiling insulation, exhaust fans, and skylights.

¹ Department of Health and Human Services 2016, Victorian Utility Consumption Household Survey 2015, Roy Morgan Research Ltd, State Government of Victoria, Melbourne

² Energy Efficient Strategies (2011). The Value of Ceiling Insulation: Impacts Of Retrofitting Ceiling Insulation To Residential Dwellings In Australia, ICANZ.

³ Cooper, P., R. Gordon, G. Waite, D. Petkovic, N. Burroughs, M. Tibbs, K. Butler, K. Roggeveen, C. McDowell, G. Kokogiannakis, L. Ledo and C. Magee (2016). EE3A: Pathways and initiatives for low-income older people to manage energy: Final Report.

Should I implement this upgrade?

It is recommended that ceiling and/or roof insulation be installed in all homes where there is no practical obstacle preventing its installation. The primary considerations when installing ceiling insulation are the accessibility of the roof cavity and the uncertainty of the existence and quality of any ceiling insulation. A site inspection may be required to confirm the status of ceiling/roof insulation. Adding insulation to ceilings is simple in houses with accessible roof cavities.

If a house has a flat roof or raked ceilings, there will be no access into the cavity except by removing and reinstalling the roofing or the ceiling lining. In these cases, the installation of ceiling insulation would only be recommended when a roof and/or the internal ceiling lining is being replaced.

An alternative to bulk ceiling insulation is to install insulation directly below roof sheeting or tiles during a roof replacement or as part of a larger renovation project. Under roof insulation minimises 'ghost leaks' forming from condensation on the underside of roofing material. If a property with ceiling insulation is having its roof replaced, it is worthwhile installing both roof insulation and ceiling cavity insulation in-line with building code recommendations.

How do I implement this upgrade well?

As a minimum, it is recommended that insulation be installed to meet minimum R-value requirements for new homes in different climate zones, as specified in the NCC (Part 3.12).

Ensuring there are no gaps between insulation batts is crucially important to realising benefits from this upgrade; having just 5% gaps in the insulated roof space can reduce the effective R-value by up to 50%.

Take care to ensure that minimum clearances around halogen or incandescent downlights are maintained and that transformers are not covered by the insulation (see LED downlight section).

Complementary energy efficiency upgrade opportunities

When replacing a roof, it is important to **consider the colour of the replacement roof**; darker colours collect more heat in winter in cold climates, while lighter colours reflect the sun's energy in summer. Specifically engineered 'cool' paints can reflect heat in hot climates.

Air tightness improvements should be implemented wherever practical and the benefits are particularly complimentary to ceiling and roof insulation, so while contractors are on site, this is a prime opportunity to add extra value with a small additional cost.

Existing **exhaust fans** create some of the largest single penetrations of a building's thermal envelope with substantial impact upon the air permeability of a building. Any exhaust fans should be fitted with a self-sealing flap valve that opens with the fan air flow and closes to an air tight seal when the fan is off. The building code requires that exhaust fans now be vented to the outdoors so that moist exhaust air is not concentrated in a ceiling cavity.

Underfloor insulation may be installed by the same contractors, providing potential cost saving benefits.

Many dwellings may have **existing skylights**. Whilst skylights provide natural light during the day, they can often represent thermal weaknesses in the building envelope and make it difficult to keep the home at a comfortable temperature. In many cases, the best course of action during a roof replacement will be to replace the existing skylight with a thermally efficient tubular skylight. These systems use rigid tubes with high internal reflection to transmit a large amount of daylight through a small diameter, well-sealed and thermally efficient diffuser. An alternative is to remove the skylight and ensure adequate LED lighting is installed, although this will remove some harder to quantify benefits associated with daylight access.

It is recommended that **Halogen downlights** be replaced with LED downlights to reduce the need for ceiling air leaks around downlights.

FIND & FIX GAPS

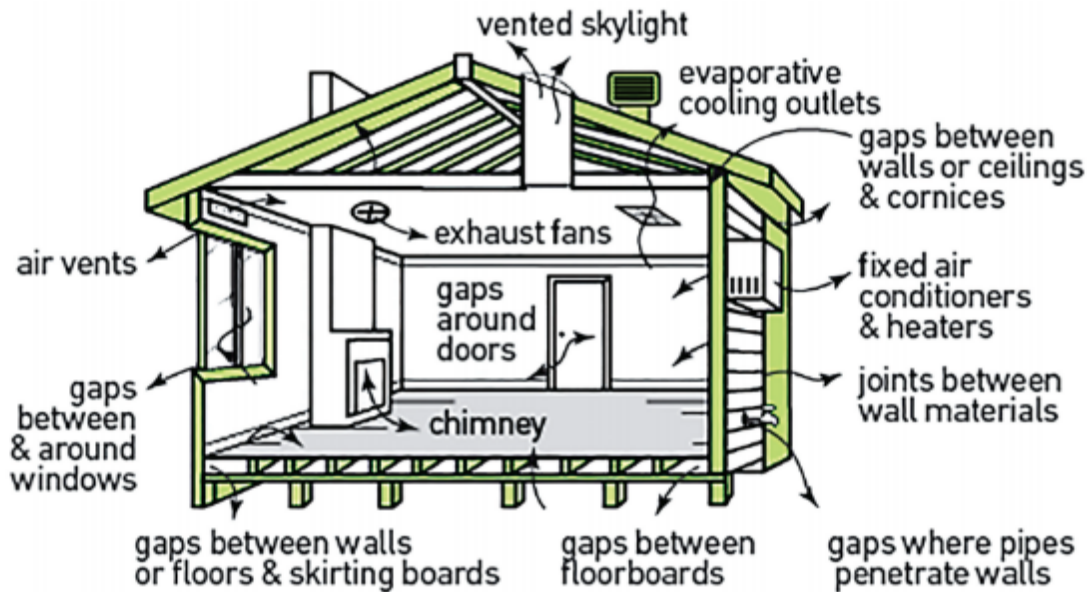


Figure 3 Source: Sustainability Victoria

Improved air tightness

Background

Improving the airtightness of dwellings is regularly reported as one of the most cost effective low carbon retrofit opportunities, and it can substantially reduce heating and cooling energy use and improve indoor thermal comfort. This is particularly the case in cooler climates, and for older homes, which tend to be draughty. Improving air tightness is one of the few high impact retrofit options that can be easily applied to apartments and may also be at least partly addressed by tenants.

Unwanted air-leakage will reduce thermal comfort in both conditioned and unconditioned homes, in both summer and winter. Your Home estimates air-leakage accounts for up to 25 % of winter heat loss.

Sustainability Victoria completed comprehensive draught sealing for a sample of homes in Victoria, and were able to reduce air-leakage by 54% on average, at an average cost of \$1,001. After ceiling insulation, draught sealing was found to be the most cost effective thermal envelope retrofit.

Air leaks commonly originate from around windows and doors, fireplaces and chimneys, exhaust fans, ventilation bricks, penetrations for services such as plumbing, downlights, and gaps around architraves and floorboards.

Windows and doors often fit loosely within their frames and are usually unsealed. Fitting self-adhesive sealing strips to hinged window and door frames can significantly boost airtightness and thermal performance. Care should be taken to check that the windows and doors can still be readily closed. Weather strips should be used to seal gaps under hinged external doors. Internal garage access doors should be treated as external doors. Aluminium windows and sliding doors are typically quite well-sealed.

Fireplaces are common in older homes and unused chimneys are significant sources of air leaks and should be sealed. An operable damper may be installed to seal a chimney shaft when it is not in use. A lower cost option is to use an inflatable bladder.

Ventilation bricks, usually located high on walls, were once mandated to improve ventilation when un-flued gas heaters were common and for moisture control but are now largely redundant and should be covered and sealed.

Gaps around **plumbing pipes and architraves** should be sealed using gap filler.

Older **floorboards**, even when covered by carpet, can be the source of air leakage, especially in homes that are suspended off the ground or have open air cavities below. Sanding and sealing floors will minimise leaks,

while underfloor insulation can improve airtightness and thermal performance.

Replacing hot, ventilated **halogen downlights** with cooler, sealed LED alternatives will increase airtightness and give the added benefit of allowing the ceiling insulation to be installed directly over the downlights. The fire regulations around halogen downlights requires large gaps in the ceiling insulation around the downlights, reducing insulation effectiveness. Upgrading to sealed LED downlights is therefore expected to improve air tightness, insulation and reduce fire risk.

Should I implement this upgrade?

Improving the airtightness of dwellings is regularly reported as one of the most cost effective low carbon retrofit opportunities, and is generally recommended for all homes. Older homes in particular are likely to benefit from this activity. The material cost of many draught sealing solutions are very low, however the cost to have a contractor implement the works can be high. Where possible, it may be best to have maintenance contractors complete simple draught proofing works as part of planned maintenance or vacant restoration works.

Air tightness retrofitting can also be included as a supplementary activity when appropriate contractors are attending a property for other planned maintenance. If undertaking a major rollout or air tightness improvements, it is recommended to first prioritise climatic regions with hot summer or cold winters.

The main thing to consider when improving air tightness is the potential to exacerbate condensation and mould issues. It is not recommended to implement this upgrade in properties with existing mould or condensation issues, until the cause of the mould has been diagnosed and remedied. Do not retrofit door seals on fire rated doors without specialist advice about appropriate fire rated door seals.

How do I implement this upgrade well?

Identifying important leakage points in a home can be difficult without the proper test equipment. Blower-door

testing, where a contractor temporarily pressurises the house by fitting a fan to an external door, can be a useful exercise to locate leakage points. A mist generator can be used while the house is pressurised to pinpoint the exact source of any leaks. Completing this on a small sample of typical homes can help identify expected leakage points in your portfolio. In the absence of blower door testing, the best way to identify leaks and draughts will often be to simply ask the tenant where noticeable draughts occur.

A particularly effective strategy is to conduct a blower door test with the air tightness contractor/maintenance staff on-site at the same time, prior to undertaking draught sealing works. There are several advantages to completing a blower door test. It is often difficult to identify leakage points visually, and it is therefore difficult to develop a specification that will result in effective draught sealing at a reasonable cost. There will often be similar leakage pathways in properties built during similar periods, with similar features. Completing the test on-site allows the leakage points to be positively identified, and an appropriate and cost-effective solution to be agreed upon. It can also be a valuable upskilling exercise for maintenance contractors or internal maintenance staff. Many draught sealing solutions have a very low material cost, however the cost to get contractors to implement upgrade works can be high.

It can be very difficult to specify requirements and maintain quality for comprehensive draught sealing works to be undertaken by an external contractor for a large number of properties. If specifying works, there are several activities that should be included in any scope of works:

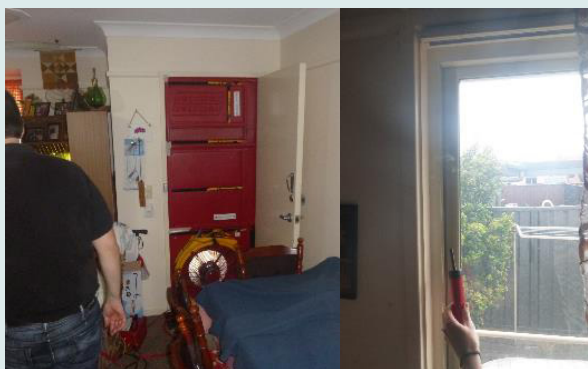
- Draught-stripping: door and window seals. It is important to ensure draught proofing works do not impede usual operation of the doors and windows, particularly for older tenants with accessibility issues. Weather strips at the bottom of external doors should snugly fit the width of the door and be carefully adjusted to properly seal when closed.
- Sealing large gaps around door and window frames. This may require removal of surface finish to

effectively access the leakage points.

- Downlight covers (where appropriate): Supply and install downlight covers to allow greater insulation on ceiling (in roof void) and reduce draughts and heat loss through ventilated downlights.
- Sealing extraction fans. Extraction fans can be retrofitted with non-return dampers or replaced with self-sealing extraction units.

Case Study: Blower door testing with contractors in Port Kembla

As part of the recent CRC Low Carbon Living RP3044, air tightness testing and improvements were completed for properties in Port Kembla. The properties were town houses, with a number of very similar properties adjacent to each other. Blower door testing was employed as both a research tool (to evaluate the air tightness of the buildings) and as a practical tool to help the housing providers maintenance team to identify the major leakage points in the properties.



Once the research test was completed a 'smoke stick' (a small puffer which creates fake smoke) was used to identify major points of air-leakage. These were progressively sealed with temporary measures (e.g. duct masking tape) to estimate the likely effect of sealing these gaps. Unsealed exhaust fans were identified as the single largest leakage point in these properties. Large skylights with loosely fitting diffusers were also an important leakage point. Several specific leakage points were also identified around the door and window frames.

Ceiling Fans

Background

Once the most cost effective passive measures have been explored, ceiling fans are the next recommended priority. While fans do not lower the air temperature of a room, they circulate air to remove body warmth and can improve a room's thermal comfort by around 3°C on warm days.

Fans should be the first option for mechanical cooling in homes. Fans are energy efficient, with energy consumption being a fraction of that required to run even the best performing air conditioners, and with lower associated carbon emissions. Modern, efficient fans have extremely low power usage, often well below 50 W at maximum speed. Fans with DC motors generally have lower power consumption; consideration should also be given to noise levels and airflow.

This is particularly important in social housing, where many tenants do not feel comfortable to use an air-conditioner, due to fears of high energy bills. Tenants can be strongly encouraged to use fans extensively without worrying about increasing bills; using an efficient fan at full speed for 24 hours would cost approximately 20 cents.

Fans and air conditioning can be used effectively in tandem; the increased circulation of air makes the temperature feel cooler and the air conditioner's thermostat can be set at a higher level. The very small amount of energy used to run the fan is more than offset by the reduced output required from the air conditioner.

Should I implement this upgrade?

Fans should be the first option for mechanical cooling in homes, and are recommended for all climates. When no air-conditioner is required, installing a ceiling fan will slightly increase energy consumption, but will provide a very low cost convenient cooling effect as required. Ceiling fans would be expected to reduce cooling demand in all climate zones, with a relatively short payback period. In climates with extremely hot summers, ceiling fans are best installed in tandem with air-conditioners.

How do I implement this upgrade well?

Fans need to be installed at least 2.1 m above floor level, which is fine for a typical 2.4 m ceiling. Lower ceiling heights may make installation impractical.

When selecting a ceiling fan opt for a fan with a DC motor for lower energy consumption. Fans generally come with an option to have a light fitting, and a remote or wall controller. A wall controller is recommended as the most robust option for rental properties, although this will add an additional upfront cost.

Ceiling fans should be selected to include reversible functionality for summer/winter settings. The summer setting provides maximum air velocity directed down at the occupants for a wind chill effect. For the winter setting, the fan blades operate in reverse and draw the cooler air upwards and gently redistribute the warmer air from the ceiling back down the walls to floor level with minimal air velocity impact upon the occupants.

Complementary energy efficiency upgrade opportunities

Fans are recommended as a complementary upgrade whenever air-conditioners are installed. When used in tandem with air-conditioners the set-point temperature can be raised, thereby saving energy while maintaining similar levels of thermal comfort. While the electrical trade is onsite installing that ceiling fan it is a good opportunity to complete an LED lighting upgrade and halogen downlight replacement.

SECTION

02

Low Carbon Upgrade Options: Step #2

Hot water systems (HWS)

Background

In an average Australian home, the hot water system is responsible for approximately 21% of total household energy consumption and is the second largest contributor of energy use and carbon emissions. Low income households tend to have hot water energy consumption as a much higher proportion of household energy use, with one low income study finding almost 35% of household energy consumption being attributable to hot water systems. Monitoring of energy consumption in social housing properties has found that hot water consumption can contribute more than 50% of a frugal social housing tenant's energy usage.

Most older homes have electric storage HWS installed; alternative HWS technologies now with proven reliability can greatly reduce the energy consumption in supplying hot water to a home. Recommended technologies for new HWS in social housing include heat pumps, and continuous gas or electric systems.

Heat pump hot water systems heat water in much the same way a reverse cycle air conditioner heats air in a home, and results in theoretical energy saving of around 70% compared to electric storage systems. Though more expensive upfront than electric storage systems, increased demand has seen prices reduce, and the operational savings will repay the additional up-front cost over a relatively short repayment timeframe⁴.

The efficiency of heat pump HWS has increased greatly in recent years, early models typically achieved a coefficient of performance (COP) of around 2.5, required an additional electric element to operate in frosty conditions and had some issues with reliability and noise levels; many current models have significantly improved the COP to around 4.5. These current models are rated to operate successfully down to -10°C, which

makes them suitable for all Australian climate regions, although the efficiency of these systems is higher in warmer climates.



The considerable leaps forward in heat pump technology for energy performance and reliability have made heat pumps an increasingly favourable HWS replacement in many scenarios. The main disadvantages of heat pumps are that they need to be located outside and have reduced performance in cold climates. As well as increasing efficiency, modern heat pumps also have substantially lower noise levels (typically lower than 50 dB, with some models down to 37 dB).

Continuous (Instantaneous) hot water systems do not store hot water in a tank and may be located close to where hot water is used, and therefore they have zero

⁴ Noting that in this case, the benefits will accrue to the tenant and not the provider.

standing losses (during periods of no hot water usage). Gas continuous systems (with star ratings typically ranging from five to seven stars) are an obvious upgrade solution for an existing gas storage system (which are typically three to five stars for new systems).

Electric continuous systems may be a sensible option, particularly for single occupant homes with no off peak supply meter installed⁵. In households with low hot water usage, standing losses become a much higher proportion of total HWS energy consumption. The main disadvantage of electric continuous systems is the limited flowrate; a typical system for single-phase house is able to provide just enough hot water for a single low flow shower head, without other hot water outlets operating at the same time. Larger flowrate systems are available but require three-phase power.

Solar hot water systems are currently the most expensive HWS to install and the most complex to operate and maintain. However, because they utilise free energy from the sun, they can offer the best lifecycle energy cost. However, if much of the hot water is consumed in the evening when the sun is not reheating the water, then the booster element may automatically switch in and consume considerable energy. A major HWS replacement program for low-income homes in Victoria found electricity savings of only 4% when installing solar HWS, compared with 29% for heat pump HWS. The complexity and replacement cost may make these systems less favourable to social housing providers, particularly in comparison with heat pump hot water systems which are simpler, lower cost and similar energy consumption.

Should I implement this upgrade?

HWS are the major energy consuming appliances regularly replaced under the responsive maintenance program in social housing. Whilst it may be possible to progressively upgrade HWS under the responsive maintenance program, in order to ensure that the more

complex technology selection decisions are properly considered it is better to upgrade HWS as they approach expected end-of-life (10 to 15 years) using a planned approach. The economic feasibility of a high efficiency HWS is higher when they are towards the end-of-life.

Deciding on the appropriate HWS upgrade for a given property will depend on several key factors; including the energy source of the existing system (gas, electric or solar), the availability of off peak metering and the size of the household.

It often makes sense to **keep the same energy source** when upgrading a HWS, for example to replace an existing gas HWS with a new gas HWS. Whilst this can minimise the need for ancillary works, the diameter of the gas supply pipe may need to be increased if replacing a gas storage system with a high flow gas continuous system. Further, there is a reasonably strong argument to consider moving away from gas appliances in many scenarios. Natural gas is not a renewable energy source, and rising gas prices increase the energy cost pressure on households. If gas appliances can be eliminated from a property altogether (including for heating and cooking), then the fixed gas supply charge of around \$250/year can be saved by the household.

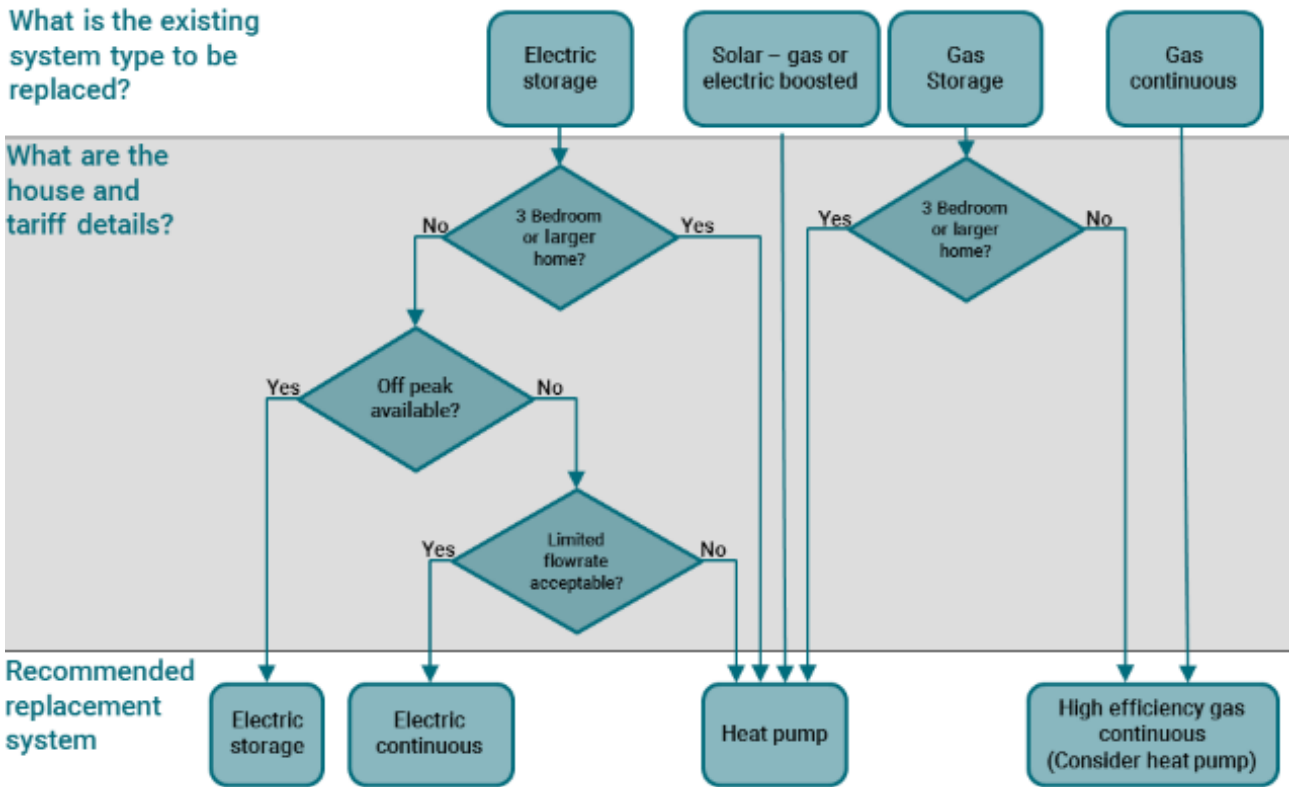
Many social housing properties have an existing electric storage HWS with **an off peak electricity meter** set up for control load, which means they are paying a lower rate for energy for their HWS. This will affect the economics of upgrading their system; whilst the energy savings will be the same, the cost savings to the tenant will be substantially lower for those with off-peak supply. For example, a recent study considering heat pump HWS replacements of electric storage systems found energy consumption savings of 31%, whereas bill savings were only 19%, due to the presence of off-peak power.

Household size, as a proxy for hot water consumption, is also important when deciding on an appropriate upgrade. A high usage household will recover the

⁵ Continuous systems cannot be supplied from an off-peak meter.

What is the existing system type to be replaced?

What are the house and tariff details?



Recommended replacement system

Figure 4 Suggested HWS decision tree, to support selection of appropriate technologies. Note that this should be considered a general guide, and will not be appropriate in all situations.

higher capital cost investment required for a heat pump system relatively quickly, while a cheaper continuous supply system may be more appropriate for a smaller household with lower hot water consumption.

To summarise these factors, a decision tree for a typical situation is proposed in Figure 3. It must be noted that there are many contextual factors which will influence this decision, which cannot be captured in a high level summary.

How do I implement this upgrade well?

Location of the HWS should be as close to the main hot water outlets as practical to reduce energy wastage and to reduce delays in hot water delivery. Heat pump hot water systems need to be located outdoors and consideration should be given to the low level noise of the fan unit both for the tenant and the neighbours.

Insulating hot water pipes immediately adjacent to the storage tank minimises standing energy losses from the tank. Insulation lagging should be fitted to hot water pipework downstream from the storage tank, especially for the first two metres or to the nearest wall penetration. Lagging should be fitted on all recirculating pipework (for heat pump split systems and solar

systems). The appropriate R-value will vary by location, refer to Section 8 in AS/NZS 3500.4.

It is beneficial to require **the hot water outlet pipe to form a heat trap** (downward U-bend in the outlet pipe of at least 250 mm before rising) as close to the tank outlet as practical. The heat trap prevents a heat loss syphoning effect of recirculating hot water from the tank outlet to reduce convection up the pipe. This is not required if a heat trap is integrated within the storage tank.

Complementary energy efficiency upgrade opportunities

When replacing a HWS, there are a number of complementary works that can be completed to maximise energy and cost savings.

Fixing leaky fittings is another simple yet beneficial maintenance action. Water leakages are always a problem, but when hot water is involved, the problem is magnified. Repairing or replacing leaking hot water fittings reduces energy use and will lead to lower energy bills.

Replacing shower heads and taps with low flow fittings is one of the most effective ways to reduce HWS energy consumption. Showers with a Water Efficiency Labelling

and Standards (WELS) rating of 3 (less than 9 litres/minute) are the minimum complying specification for social housing properties. Some shower heads are rated at 6 litres/minute, however some tenants may find these to deliver inadequate water flow and so are not recommended as a general rollout.

In the case where a gas hot water system is being replaced with an electric HWS, it is worth considering the potential to **eliminate the gas supply connection** by also upgrading any other gas appliances (e.g. cooking and heating). The preferred alternative to gas heaters is an efficient reverse cycle air-conditioner, which is discussed in detail below.

Research Case Study: Heat Pump Hot Water Systems Upgrades

As part of the current project, monitoring and evaluation was undertaken of a small number of Heat Pump Hot Water System (HP HWS) installations, replacing electric storage systems. Monitoring was undertaken on four properties in Northmead and North Parramatta. The properties were found to use relatively little energy (three of the four properties used less than the Australian Energy Regulator benchmark value), and energy used for water heating was found to be a dominant end-use, comprising 56% of the pre-retrofit total household consumption.



The HP HWS upgrade was found to be effective at reducing energy consumption for water heating. The average energy saving was 64% of the HWS consumption, or 31% of total household energy consumption. However, as the householders HWS were off-peak, the economic impact of the upgrade was less substantial. The average bill saving was 19%, and in households where water usage was lower, the cost savings did not justify the up-front cost (using typical discount rates and system lifetime).

Air-conditioning upgrade

Background

Air-conditioning systems, like other heat pump appliances (including hot water heat pumps and refrigerators), have become remarkably more energy efficient over recent years. Depending on the climate and occupant behaviour, heating and/or cooling can be one of the largest energy end uses in a home. In most climates some degree of heating will be required to maintain comfortable internal conditions even once cost-effective thermal envelope upgrades have been implemented (i.e. ceiling insulation and draught proofing). Likewise, homes in extremely hot climates will require a source of cooling to maintain summer comfort, even with ceiling fans and thermal envelope upgrades.



Reverse cycle air-conditioning is the most energy efficient form of heating available, with lower running cost and greenhouse gas emissions when compared to gas heating. Substantial savings can also be realised by replacing older air-conditioners with newer, more efficient models. This will be particularly so when the systems are used regularly, and especially in more extreme climates. Historically, the provision of heating and cooling systems in social housing has been limited to properties in more extreme climates or with tenants who have particular medical needs. Some housing providers have commenced a roll-out of energy efficient air-conditioners, either as a replacement for existing gas or electric fixed heaters in colder climates, or as a replacement for older, inefficient window wall air-conditioners in hotter climates.



Many tenants in hot climates will have installed their own air-conditioning systems, often either portable air-conditioners or window units that can be easily removed. These air-conditioning systems are typically less efficient than split systems, but cheaper to purchase and install. Window units are often poorly installed, resulting in significant air-leakage around the air-conditioning system. Providing these tenants with efficient split systems is more costly up-front, but will reduce on-going running costs if they are used in place of the old inefficient systems.

Air-conditioner efficiency will be different for heating and for cooling and is expressed as the co-efficient of performance (COP⁶), which is the ratio of heating or cooling power output available from the system to the electrical power input required. Air-conditioners sold in Australia must carry an energy rating label, which converts the COP (and any standby power consumption) to a star rating, from 1 to 10 stars for heating and cooling; the more stars the more efficient the device. New zoned energy labels being introduced in 2019 will provide different star ratings and capacities according to the climatic location. The highest star rating currently available is 7 stars for both heating and cooling, however this is only available for small capacity systems. In larger capacity systems (more than 5 kW) the highest star rating available is 4.5 star for cooling, and 5 star for heating. A minimum 3 star is recommended for larger capacity systems; smaller units are recommended to be at least a 5 star energy rating.

⁶ Energy Efficiency Ratio (EER) is often used to differentiate cooling energy efficiency performance, while COP is used for heating energy.

Should I implement this upgrade?

A reverse cycle air conditioner with a 5 star energy rating will be approximately five times more energy efficient compared to an electric heater, which may translate to very substantial bill savings for tenants who use a lot of heating energy.

It is important to recognise that installing air-conditioning systems in a social housing dwelling, particularly one that did not have a pre-existing system, has the potential to increase energy bills, especially in summer. Whilst an efficient reverse-cycle air-conditioner is better than an older inefficient system, if installed in a leaky, uninsulated building, and used extensively there is the potential to exacerbate energy stress.

Local climatic conditions are the main determinants for whether a reverse-cycle air-conditioner for winter heating are an appropriate upgrade. Heaters are typically provided in NCC climate zones 7 and 8. As noted, reverse-cycle air-conditioners are the most efficient source of heating, and it is recommended as the replacement whenever an existing heater is replaced. This includes both gas and electric heaters.

Similarly, the main determinant of whether an air-conditioner for summer cooling is appropriate will be the local climate. Whilst passive thermal upgrades and ceiling fans will go some way to ameliorate summer overheating, in extreme climates, it is likely that many homes will need air-conditioning to maintain comfortable conditions. Properties in NCC climate zones 1-4 will typically need air-conditioning for summer comfort. In NSW, the Aboriginal Housing Office uses Isotherm 33 to determine which properties are eligible for air-conditioning. This information is available from the Bureau of Meteorology. The area within Isotherm 33⁷ will vary year to year, however in recent years the area, and therefore number of homes, has increased substantially in Australia.

⁷ The area with an average January temperature above 33°C, which is typically a more extreme climate than the NCC zones 1-4.

How do I implement this upgrade well?

To achieve acceptable thermal comfort, it is important that the replacement system is appropriately sized, and well-located. A system that is undersized for a particular space will need to work harder to heat or cool the space without being able to achieve the temperature set point, and will not be operating at its most efficient. Sizing a system can best be done by the installing contractor; the Australian Institute of Refrigeration, Air conditioning and Heating (AIRAH) provide a free online '**fair air**' calculator that provides sizing recommendations. Particularly when removing existing heating systems, a reduction in heating capacity as a result of the replacement can result in decreased perceived thermal comfort for the tenant, and likely dissatisfaction with the program. This can result in the tenants using supplementary electric heaters, and thereby reducing the effectiveness of the upgrade.

Similarly, if the upgraded system is not placed in a position that will provide heating and cooling to the spaces used by the tenants, the system may not be effective. **Appropriate positioning** of the internal and external units may require longer pipe and cable runs. The specification, budget and contract for these associated ancillary works should be designed to encourage the appropriate installation positioning of the system.






In order to achieve bill savings, the tenant needs to change their behaviour to use the upgraded air-conditioning system as opposed to their pre-existing system. The best way to ensure this occurs is **to decommission the older inefficient system**. Care must be taken when managing the tenant interaction in this regard, as the tenant will generally own the existing systems. However, it is important that this removal be completed, and it is recommended that agreeing to have the older system decommissioned be part of the eligibility requirements to receive a new system.

It is important that **tenants receive appropriate training** in the use of the upgraded system. It is recommended that several different instruction methods are used, for instance personal instructions when the system is installed, provision of a simplified operation manual


appropriate for the tenants, and provision of a straightforward wall plaque or sticker.

LAHC developed a **simple wall plaque** to be attached next to the wall controller during installation with a small number of instructions for efficient usage, shown below.

TIPS FOR USING YOUR AIR CONDITIONER

-  Use the **ON / OFF** button to start and stop the system
-  Switch off before you leave home
-  Close windows and doors when the system is on
-  Set the temperature to between **23°C and 26°C** in summer and **18°C and 21°C** in winter to save money
-  Use between **10am and 3pm** on sunny days to save money

Don't forget to clean the pre-filter once a month



Source: Land and Housing Corporation.

Key points to consider when providing instruction and information to tenants are:

General

- How to switch the system ON and OFF
- Make sure to switch the system off when not at home and when not required
- How to use the timer to help with pre-set time limits for the usage
- How to set the temperature (see above)
- Setting the temperature closer to the outdoor temperature uses less energy—warmer in summer and cooler in winter—and helps people naturally adapt to the climate. As a rule of thumb every degree extra temperature difference may be an extra 10% energy consumption.
- Close external doors and windows when the system is on
- Close internal doors to zone the heating/cooling energy to the occupied room(s)
- Closing curtains and blinds will further reduce energy wastage
- Clean the filter once a month (with demonstration on how to do this).

Summer

- Use fans first, and when the AC is also required, leave the fan(s) on the highest comfortable speed
- Set the unit to cooling only mode to prevent heating in summer when the air cools in the evening.
- Set the temperature to around 25°C to 29°C. If fans are not used, then the temperature setting will need to be around 23°C to 26°C.

Winter

- Set the unit to heating only mode to prevent cooling in winter if the sun warms the room up unexpectedly during the daytime.
- Set the temperature to around 18°C to 21°C, or slightly higher for children or the elderly or infirm.
- Use ceiling fans on the lowest speed and switched to winter (reverse rotation) mode to gently circulate the warmest air from the ceiling back down to floor level.

Complementary energy efficiency upgrade opportunities

The efficiency of an air-conditioning system in operation is strongly affected by the thermal performance of the property in which it is installed. A highly efficient air-conditioner installed in a leaky, highly glazed, poorly shaded and uninsulated house will not provide efficient heating or cooling. It is not recommended that air-conditioning be installed without first ensuring the property has **appropriate ceiling insulation**, that **basic draught-proofing** works have been completed, and that **ceiling fans** have been installed.

Any programmed replacement of gas heaters with reverse cycle air conditioners should also consider the potential **to completely disconnect the gas** from the property and thus eliminate the gas supply charge. This may require an upgrade of a gas hot water system with a heat pump HWS, and replacement of gas cooking with an appropriate electric system.

Installing air-conditioners, especially for summer cooling, may result in increased energy costs. This can be mitigated by **installing solar photovoltaic panels** for those home which receive air-conditioning.



Photo: Dee Kramer

Solar photovoltaic (PV) panels

Background

Solar PV panels have become a very cost effective and easy to install retrofit on most existing homes, yet there is a recognised widening gap between households who have capacity to implement solar panels and those households, who are perhaps more vulnerable and are being left behind.

Residential solar panels in Australia come in two forms; polycrystalline and monocrystalline. Blue-coloured polycrystalline panels are cheaper and dominate the market. The more expensive, monocrystalline panels offer greater efficiency (they require less roof area), improved performance in cloudy or hot conditions and a longer lifespan.

Should I implement this upgrade?

Whilst installing a solar panel system will not by itself improve a tenant's thermal comfort, it is one of the upgrades that will most reliably **reduce a tenants energy costs**, and may enable the tenant to increase heating and cooling usage. The upfront cost for a solar system is relatively high, however it is recommended that these systems be installed whenever there is sufficient budget, and no practical obstacle to installation.

Compared to the average Australian household social housing tenants are more vulnerable to experience energy bill stress and do not have the capability to implement solar PV panels themselves. Although solar panels represent a higher capital cost than some other retrofits options, the rapid drop in price in recent years, the direct offset of electricity cost and reduced carbon emissions make them a very important option to consider for social housing properties.

Solar panels will be most effective when installed in properties in which the tenant is regularly home and using power during the day, particularly where heating or cooling energy is consumed during sunlight hours.

Some circumstances restrict their suitability, such as heritage provisions, whether the building is overshadowed and has an inappropriate orientation and if the building is expected to require a roof replacement in the foreseeable future. When a property has a north facing roof suitable for solar panels, they offer attractive value for money. It is recommended that solar panels be flush mounted **as close to north facing as possible**, however panels mounted on west and east facing roofs are still economically attractive options. Solar panels produce the most energy when installed facing due north.

Deviation from this orientation will reduce the generation of the panels; the size of the reduction depends on the location (latitude) and the slope of the roof. Typically, generation would be expected to drop by about 5% moving to a NE or NW orientation and by 10-15% for E or W orientation. Orientation also affects when the power is generated; west facing panels will produce more power in the afternoon which can better match summer air-conditioning consumption. Mounting frame systems can be used to mitigate poor orientation, however these will increase costs and will have higher visual impact.

A second practical obstacle to solar installation is the presence of **overshading from trees or adjacent buildings**. Satellite imagery can give an indication of shading issues, and solar installers can assess to what extent overshading is likely to reduce generation.

How do I implement this upgrade well?

The Clean Energy Council has a list of approved solar retailers, and a list of **accredited installers**. Any solar PV project should use providers from these lists.

Bloomberg New Energy Finance manage a rating scheme for solar panels based on the financial status of the manufacturing company proven usage in major financed projects. It is recommended that all panels used are from a **recognised Tier 1 manufacturer**.

It is important that **tenants receive appropriate training** in the use of the new solar system. It is recommended that this includes simple instructions for:

- How to maximise self-consumption of the generated energy;
- How to **seek the best feed-in tariffs**;
- What the expected benefits will be; and
- What to do if the system is not operational.

There are a wide range of feed-in tariffs⁸ offered by different energy retailers. At the time of writing, the values ranged from 5 to 20 cents/kWh. The feed-in tariff

received by the tenant will greatly affect the financial benefits of a system to the household. All efforts should be made to encourage the tenants to switch to **a favourable retailer and tariff offer** when solar panels are installed. The energymadeeasy.gov.au website can be helpful however it is beneficial to assist tenants with this process where possible.

The choice of retailer will also impact the length of time taken for **a meter change-over**. All new solar PV connections will require the installation of a smart meter, which is managed through the retailer. Some retailers may charge the tenants to install the smart meter. Substantial delays in smart meter installation have been encountered, particularly in rural areas, and panels are not able to be energised until the new meter is installed. It is important to support the tenant through this process, and clearly explain any delays.

Complementary energy efficiency upgrade opportunities

A number of recent social housing upgrade projects have paired efficient air-conditioning upgrades with PV panels, with the aim of mitigating any additional consumption of the air-conditioning system through on-site generation. If solar is installed to offset air-conditioner consumption it can often be best to face the panels North West or West to increase generation in the afternoon period, when summer air-conditioning usage is likely to be higher.

It is worth considering photovoltaics whenever a roof replacement is undertaken.

⁸ The price retailers will pay to buy any excess power generated by solar panels.

SECTION

03

Low Carbon Upgrade Options: Step #3

Under-floor Insulation

Background

Older homes often have suspended floors with exposed subfloors. In these homes, significant cooling and heating energy can be lost through an uninsulated floor. This is less of an issue with slab-on-ground construction methods, where the thermal mass of the slab and ground underneath maintain a more stable temperature.

Typically, there is more heat loss in winter and heat gain in summer through the ceiling than through the floor; therefore ceiling insulation is a higher priority than underfloor insulation. However, underfloor insulation can substantially improve thermal comfort, especially once ceiling insulation and air tightness upgrades have already been implemented.



As for ceiling insulation, the thermal resistance of the insulation is indicated by the R-value. Underfloor insulation comes in many materials and forms; the most commonly occurring are concertina style reflective foil insulation, bulk insulation, and rigid foam insulation. All three types are installed between the floor joists, and secured with staples, wire, or, in the case of rigid foam, are self-supporting. Rigid foam boards are also used for insulating under suspended concrete slab floors.

Should I implement this upgrade?

Once higher priority upgrades have been completed, underfloor insulation is recommended for properties with suspended floors, particularly timber floors with open sub-floors, in locations with cold winters i.e. climate zones 4, 6, 7 and 8.

The main practical obstacle to installing underfloor insulation is adequate access to the subfloor space. A minimum access height of 400 mm is typically required, and 600 mm is preferable.

If underfloor insulation is not practical, a simple retrofit to gain some of the benefits of floor insulation is the inclusion of insulating underlay when replacing carpet or floor coverings in a property. This can provide some of the benefits of underfloor insulation without requiring access to the subfloor space.

How do I implement this upgrade well?

The main consideration for underfloor insulation is to ensure a quality installation, that has full coverage with no gaps, and that is well supported and will not sag or fall down over time. Each manufacturer will have custom straps or other method for retaining and supporting the insulation from below.

The stiffness and air permeability of underfloor insulation batts is more important than for ceiling and wall insulation to help self-support the weight and to help address air leaks through floor boards. Some products have an integrated wind barrier fabric underneath which can be stapled to the floor joists for air tightness.

Complementary energy efficiency upgrade opportunities

When installing underfloor insulation it is a good opportunity to identify and seal any gaps in the floor. Ceiling insulation and air tightness should be thoroughly checked.

External Shading

Background

External shading comes in a variety of forms and in hot and warm climates is cost-effective in reducing cooling energy in homes and improving indoor thermal comfort. The heat energy from the sun straight into a typical window of 1.2m high and 1.8m wide is equivalent to an electric fan blower heater in the room.

In very hot climates, window shading should be total, blocking direct sun year-round while allowing for views and natural light. In regions with warm summers and cool winters, external shading should shade windows from the summer sun, but allow direct sunlight in winter. Shading options include fixed shading that takes into account seasonal angles of the sun, and movable shading devices.

Fixed shading is often easy to retrofit to existing homes and includes awnings, pergolas, verandas, or window shading. Shading of north facing windows can be provided by horizontal shading above the window, effective fixed shading to west and east facing windows (which must exclude low angle sun in the early morning or late afternoon) can be achieved using vertical blades or louvres. In a well designed homes, appropriately sized eaves will provide effective seasonal shading to north facing windows. Fixed awnings can be retrofit to provide shading to northern windows in summer, while letting in winter sun (which is lower in the sky). Pergolas and verandas provide year-round shading for larger openings, while maintaining views and diffused light.

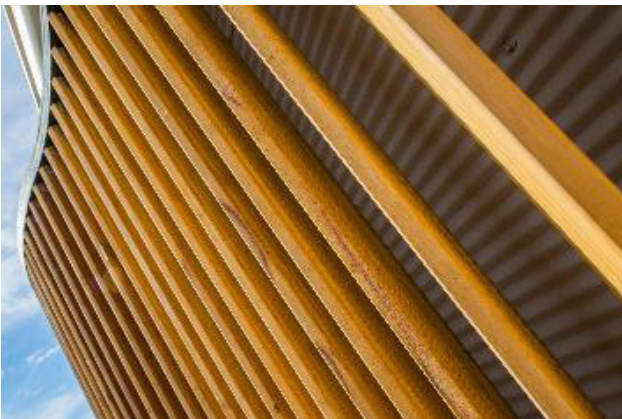


Photo: Dee Kramer

Shade cloth, adjustable louvres, awning blinds and roller shutters can be manually operated or automated. These shading devices can be adjusted to best suit the shading needs at different times of the day and year as required. They can also provide additional security, privacy to outdoor spaces and protect from wind. These solutions are particularly well suited to west and east facing windows.

In many cases low cost solutions, such as installing shade cloth, shade sails, or deciduous trees can be implemented by tenants and this should be supported where possible.

Should I implement this upgrade?

Effective use of external shading will generally require site specific analysis, and it is therefore difficult to roll-out a large-scale shading upgrade program. In specific circumstances, external shading can substantially reduce summer overheating without the need for air-conditioning. It is most appropriate for properties in hot climates, where a tenant has raised concerns about difficulty maintaining summer comfort.

How do I implement this upgrade well?

Shading of specific windows is likely to be the most cost-effective fixed shading option for social housing properties. Particular attention should be paid to large north or west facing windows in hotter climates, which are not overshadowed by adjacent buildings. Shading windows to areas that are air-conditioned should also be a higher priority. West-facing bedroom windows are also a high priority.

It is important to consider the year round impact on thermal comfort for any fixed shading devices. In areas that require heating and cooling it is important that external shading devices do not exclude valuable winter sun.

Roller shutters can be one of the most effective shading tools, essentially providing complete shading to a window. The potential for future maintenance costs for any operable shading devices should be considered.

Complementary energy efficiency upgrade opportunities

Window films can be an effective alternative to external shading where there are practical obstacles to installing a shading device. Similarly, well fitted **internal window furnishings** can mitigate overheating if external shading is not practical. **Ceiling fans** should be installed in all properties that have overheating issues in summer.

Adding wall insulation when recladding

Background

A substantial proportion of the heat loss and heat gain in a house occurs through walls. New buildings are required to achieve minimum R-values in all external walls. Whilst there are solutions that can retrofit wall insulation to almost any existing home, it is a difficult and relatively costly exercise unless the external cladding or internal lining is being removed and replaced. Recladding or relining works may be undertaken in the social housing sector to repair old, degraded, or damaged external cladding, or to remove safety risks from some varieties of asbestos cladding.

Bulk wall insulation for timber framed building is similar to ceiling insulation batts. It is possible to insulate cavity brick walls with an insulation product that is blown in to cavity, although moisture management needs to be carefully considered. Another option is to add an insulation layer to the outside of the building and clad over it, but this is unlikely to be financially viable in most Australian climate zones.

Adding wall insulation can raise the internal surface temperature of walls during winter, and in some cases will mitigate wall mould and condensation issues.

Should I implement this upgrade?

Retrofitting wall insulation is only recommended if the external wall cladding or the internal wall lining is being replaced. In these situations, it is recommended that bulk wall insulation be added to bring the wall R-value in line with current building code requirements. The NCC specifies minimum R-value ratings for wall insulation according to climate region (part 3.12.1.4).

How do I implement this upgrade well?

As for all insulation activities, it is important that any wall insulation installed has full coverage, with minimal gaps.

Complementary energy efficiency upgrade opportunities

When wall cladding or lining is removed it is a good

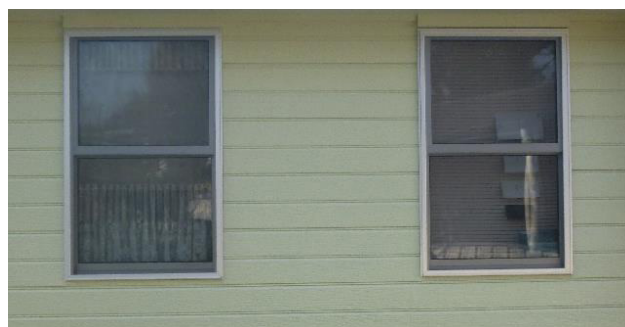
opportunity to seal any hard to reach gaps, particularly around door and window frames. Appropriate wall sarking should also be installed for moisture control and as an air tightness layer.

Window Replacements

Background

Windows represent a major weakness in the insulation performance of a building's thermal envelope, allowing substantial heat loss in winter, and heat gain in summer. Many older homes have poor performance glazing and window frames, and upgrading them can lead to substantial benefits in a critical area of a home's thermal energy loss.

However, windows are complex, and many energy efficient glazing options are expensive. Well orientated and shaded windows can provide valuable sunlight and heating during winter, without excess summer heat gain. The performance of windows is determined by many factors, the orientation of the window, the type of window system used, the frame material, the presence of external shading, and the type and usage of internal window furnishings.



The thermal performance of a window is generally expressed using two measures, the Solar Heat Gain Coefficient (SHGC), and the thermal conduction (U-value). The SHGC is a measure of how much heat from direct sunlight will pass through a window. A window with a lower SHGC will let less solar heat through a window when direct sunlight is hitting the glass. The U-value is a measure of how much heat will pass through the window system when it is not in direct

sunlight. It is similar to the R-value used to measure insulation effectiveness; however, a lower U-value corresponds to less heat passing through the window.

There are several options to improve the thermal performance of a window system when a window is being replaced.

When choosing **replacement window frames**, aluminium frames have the disadvantage of thermal bridging (temperature transmitted through the frame). Timber or uPVC frames have the reduced thermal bridging but come at a cost premium. Similarly, modern aluminium frames have been developed which are 'thermally broken', that is they have a material with low thermal conductivity separating the inside and outside parts of the frame. This substantially reduces thermal bridging, but also comes at a cost premium.

Double glazing substantially decreases the U-value of a window and therefore allows less heat transfer. Many variations of double glazing exist, with different gas used in the gap between the panes of glass, and different types of glass used in the panes. Often low-emissivity (low-e) coatings are added to double glazing to reduce heat gain or loss (depending on where it is placed in the system). Typically, double-glazed windows are most effective at reducing heating demand during the winter period. However, there is a substantial price-premium for double glazing. The potential for increased future maintenance cost in the case of breakage must be considered.

Homes in warmer climates or with overheating issues caused by large west facing windows may benefit from **the addition of films to window glass** to reduce the solar heat gain in summer. These films can substantially reduce the SHGC, and thereby the amount of heat flowing through a windows in direct sunlight. However, these films will decrease the solar gains during winter, so they should be carefully considered. These films can also be an effective retrofit to windows in apartments.

Should I implement this upgrade?

Improving the glazing of a property can be an expensive exercise, and will often require a detailed site assessment to determine the best course of action. However, efficient glazing can vastly reduce overheating issues in certain circumstances, and can greatly reduce winter heating demand.

Double-glazing and thermally broken frames are expensive, and not recommended for most social housing properties. These should only be considered in the colder climate regions (i.e. climate zone 7 and 8) and then only for living room windows that are already scheduled to be replaced for another reason.

Retrofitting window films to existing glazing is recommended in hot climates, for properties with large, unshaded west facing windows where external shading is impractical.

How do I implement this upgrade well?

When replacing windows with energy efficient windows, the quality of the installation is very important, particularly ensuring that there are no gaps between the frames and the wall.

The most appropriate solution for a particular window will be dependent on orientation, shading and local climate. The tenant can be a valuable source of information about problem windows that may be causing overheating during summer. When improving windows for winter warmth, it is best to focus on windows in area that are actively heated.

Complementary energy efficiency upgrade opportunities

An alternative to double-glazing for cold climates is to provide thermally efficient internal window furnishings, as discussed below.

For hot climates where window films are being considered, it is often better to install effective external shading if possible.

SECTION

04

Low Carbon Upgrade Options: Supporting Tenants


There are a number of ways in which tenants can reduce their own energy consumption, at relatively low cost. This can be supported by the housing provider through the provision of appropriate information, or help with the cost of materials.

If supporting tenants in areas that are typically a tenant’s responsibility, it is important to consider the ongoing maintenance costs of an upgrade, as well as the importance of quality control in effective energy efficiency upgrades. There may be third party not-for-profit organisations who are able to support tenants in these areas, while maintaining a degree of quality assurance of the installed products. The following section presents a brief summary of some key measures.

LED lighting

Home lighting has evolved considerably in recent years, with each technological change resulting in reduced energy use for the same light output and increased bulb life. **LED lighting** has become the leader in home lighting efficiency and is now the first choice for a majority of new homes due to their efficiency, low cost and long life. LED lights use only 15% of the electricity of standard incandescent bulbs for the same light output, while lasting 12.5 times longer. Initially more expensive than other lighting types, with increased popularity and mass production the cost of LED lights is now comparable to their fluorescent and halogen alternatives.

It is most cost effective to install LED fittings once their predecessors burn out; however, LED has reached a lifecycle cost point where it is worthwhile and financially beneficial to retrofit all incandescent and halogen lights, even if they are still functioning, particularly in areas where lights are used often.



	STANDARD INCANDESCENTS	HALOGEN INCANDESCENTS	CFLs	LED's
COLOUR RANGE	Warm White	Warm White	Warm White to Cool Daylight	Warm White to Cool Daylight
LIFESPAN	1200 Hours	2500 Hours	8000 Hours	15000 Hours
PURCHASE COST PER BULB	No longer available	\$1.80	\$6	\$11
PURCHASE COST FOR PERIOD*	No longer available	\$10.80	\$11.25	\$11
ELECTRICITY COST FOR PERIOD*	\$207	\$155.25	\$44.85	\$31.05
TOTAL COST FOR PERIOD*	--	\$166.05	\$56.10	\$42.05

*Reference period is the lifetime of an LED bulb (15years if used 3hours every night)
Prices scanned May 2015, Electricity price - \$.23/kWh

Figure 5 Source: Energy+Illawarra

Practical installation issues with lighting upgrades are common for downlight replacements, and include incompatibility with the existing transformer/converter, incompatibility with dimmer switches, existing light fitting or existing wiring, electrical interference with the TV or radio, brief startup delay, and humming. An electrician can also easily replace downlight fittings with LED alternatives for minimal capital cost. LED fittings also bring other benefits: they burn cooler than halogen bulbs, reducing the risk of recessed lighting causing fire in ceiling insulation, and they do not need ventilation, making ceilings more airtight.

Lighting quality has been observed in some low income retrofit projects to have a marked impact upon occupant well-being, improving amenity and capacity to enjoy hobbies and social engagements. So care taken to assist the tenant in maintaining or improving the appropriate quality of lighting may be well invested.

Fridge/Freezer and Television upgrades

Fridge/Freezer and TV energy efficiency has improved dramatically over the past 15 years, and newer models use much less energy than older appliances. Older fridges, freezers and TVs are a substantial opportunity to save energy. This is especially the case in low income homes, where appliances tend to be older and less efficient and tend to be replaced with low cost second hand appliances with a far higher life cycle cost when compared to a new energy efficient model.

In NSW, under the Appliance Replacement Offer, the Office of Environment and Heritage is currently providing 50% co-funding to low-income households to replace their older refrigerators and TVs with a select range of new, energy efficient models. Monitoring of the effectiveness of the fridge replacement program found that replacing old fridges resulted in annual saving of \$120 per year, and had a payback of 4.3 years based on the subsidised cost to the tenant. A Sustainability Victoria fridge upgrade trial found savings of \$169.3 and a payback of 12.3 years (or 3.8 years if done at the end of a fridges life) for the installation of high efficiency models.

Monitoring of a small sample of OEH TV replacements found that replacing plasma TV's with modern LED TV's could result in substantial savings to the tenants. Energy savings from appliance replacement are sensitive to hours of usage, so only appliances in regular use (most applicable to TVs) should be replaced from an energy perspective.

Second and third, etc. fridges have been observed to be a silent, unnoticed consumer of excess household energy. Tenants with more than one fridge/freezer could be alerted to the cost savings of rationalising appliances, or switching off additional appliances except when required at Christmas, for example.

Internal Window Coverings

Appropriate and well-design internal window coverings are an effective way to reduce heating and cooling energy. Options include internal blinds, curtains and shutters.

In hot climates, direct sunlight through windows greatly increases internal temperature. Any window that receives direct sunlight can benefit from a simple light-coloured blind that reflects heat before it is absorbed as heat into the room furnishings. It is important to remember that window coverings only mitigate heat that has already entered through the glass, so external window shading is a better solution to stop heat before it enters the home.

In cool climates, the opposite process is at work. Valuable winter heat can be easily lost through exposed glass and tightly fitted window coverings can keep heat inside the home.

Whether stopping heat entering in summer or leaving in winter, heavy curtains or well-designed blinds (such as cellular blinds) are the most effective window coverings. When additional heating is necessary, insulating curtains can reduce moisture condensing on the glass and help prevent mould build up on window frames.

To provide effective insulation, the blinds need to trap a layer of still air next to the windows, and thereby minimise convective heat transfer circulating the heat loss/gain into the room. Blinds should fit snugly inside the window frame with minimal air gaps around the whole perimeter. Curtains should be close fitting to the wall and floor and have a close-fitting enclosed box pelmet above the curtain.

If curtains are supplied at the start of a tenancy the housing providers will typically be required to maintain the curtains throughout the life of the tenancy, which may add additional maintenance costs.

Air tightness and fabric upgrades

There are a number of non-permanent building fabric upgrades that could be implemented by tenants to improve their thermal comfort and reduce heating and cooling consumption. Consideration should be given to whether property upgrades align with any existing home alterations policy (e.g. LAHC Alterations to a Home policy), or if the home alterations policy can be updated to specifically include minor energy efficiency works.

Examples of air tightness and fabric upgrades include:

- Draught stoppers of doors snakes on all external doors, as well as on all doors used to zone spaces that are heated or cooled.
- Door and window seals degrade over time and are relatively cheap to replace. This is a simple job that can be often undertaken by tenants. However the low cost adhesive door seals typically degrade relatively quickly, and a better outcome will often be achieved through a program of installing higher quality door seals.
- There are a number of reflective foil products that can be placed in windows during the summer period to reflect heat from the property. Again, when used appropriately these low cost products can be cost-effective.
- Some external shading options are also available to tenants, including planting deciduous trees on the north and west sides of the property to shade

windows, or installing temporary shade sails on the north and west sides, where practical. Consideration should be given to recommending appropriate plantings to ensure that they do not damage existing buildings or structure or require costly ongoing trimming. LAHC Alterations to a Home Policy allows trees that will grow no more than 3 metres in height when fully mature to be planted without approval at least 3 metres from any existing structure.

Communicating with tenants regarding upgrade works

The monitoring and evaluation of a range of upgrade programs undertaken as part of the CRC Low Carbon Living RP3044 has highlighted several important tasks that should be prioritised when delivering an energy efficiency upgrade project. These activities can help to engage tenants with the program and minimise the risk of dissatisfied tenants or poorly performing upgrades. It is important that all communication and education recognises the particular needs of social housing tenants, including low literacy levels, high occurrence of mental health issues, and that upgrade implementation plans are designed to minimise stress and imposition on tenants.

Tenant communication

An important consideration for implementing upgrades is maintaining effective communication with social housing tenants, which can be a challenging task. It is important to provide concise and simple to understand information about the works to be done, including:

- Provide regular updates indicating expected timetables for the works,
- Provide detail regularly and as early as possible of any actions required to be completed by tenants, and any possible disruptions to tenancy, and
- Providing transparent guidelines for if and how tenants will be supported or compensated during disruptions to tenancy.

While it is acknowledged that social housing tenants are not permanent residents, generally tenants tend to be

longer term (over 40% of public housing tenants have been in place for more than 10 years) and as such regular communication with tenants will ensure better outcomes in terms of tenant satisfaction and co-operation.

Large scale roll-out projects necessarily involve multiple actors, for example energy consultants, multiple tradespeople, energy retailers, and housing providers. This complexity creates difficulties in co-ordinating communication to the tenants between disparate groups, and the current project has identified inconsistent information as an issue for tenants. It is recommended that, as much as possible, housing providers do not rely on tradespeople and contractors to provide appropriate communication and education for tenants. Rather, this work should be completed by the housing provider, or another suitably qualified third party.

Tenant education

Several examples were encountered during the current project where a lack of tenant education or information about the upgrades they received was resulting in poor overall performance of energy efficiency upgrades. This can include tenants not knowing how to operate the new system at all or being unaware of the best way to use the new appliances to save energy. For example, in cases where reverse cycle air conditioning is installed, it is important that tenants gain a clear understanding of how to control operating mode, temperature set-points, fan modes, and timers. In cases where tenants did not understand how to control the appliance, either the appliance was being operated in an ineffective manner (i.e. in cooling mode during winter) or the tenant had discontinued use of the energy efficient appliance and reverted to using previous older, less efficient existing appliances.

It is recommended that multiple communication channels be used to educate tenants regarding use of upgrades. Whilst it may increase transaction costs, it is recommended that time be allocated to instructing the tenant on how to use the new technology at the time of installation, bearing in mind that many may have a

very limited experience of using electronic devices. It is recommended that there is a practical demonstration of the functions of the appliances. Tenants should also be informed of any changes in practices that will enhance the performance of energy efficiency upgrades. For example, how to use natural ventilation effectively to minimise the use of air-conditioning, to close all doors, windows, blinds and curtains prior to using heating or cooling.

It is recommended that the practical, personal instruction be supplemented with a simple user manual, as well as a sticker or wall plaque with key pieces of information (similar to that shown in the air-conditioner section). The user manual should explain the various modes of operation, re-iterate complementary practices, and in the case of heating and cooling devices, include a clear chart which indicates the optimal running temperatures for summer and winter. Where solar panels are installed, it is important that tenants are provided with clear guidance on how to maximise the system to lower energy costs, including shifting discretionary loads to daytime, and seeking the best feed-in tariff. Any recommended maintenance should also be included in the guide. The key pieces of information from the user manual should be re-iterated on the sticker/wall plaque, using simple infographics where possible.

There are many good examples of simple communication of energy efficiency principles that may inform an advice sheet for tenants, for instance the 'summer helpful hints' sheet available at energysaver.nsw.gov.au, or the various guides produced by the Energy+Illawarra project (available at <https://www.energyplusillawarra.com.au/>).

Further Information

There are a number of useful valuable sources that can provide greater detail regarding various sections of the current guide. Some of the more useful are:

Your Home is a federal government guide to buying, building or renovating environmentally sustainable homes. It has a large amount of information on the principles of energy efficient building design, and some information on retrofitting of existing buildings.

Energy Made Easy is a government run energy retailer comparison site, designed to help consumers select the best provider and plan for their situation.

Choice provides consumer reviews of various products, often including some assessment of the energy efficiency of appliances. This is a helpful resource for selecting upgrade systems.

Energy and Water Ombudsman. Each state has an energy and water ombudsman that can help consumers with complaints against energy and water retailers. They also have a number of useful fact sheets to help consumers and support workers to understand the energy markets, including rebates and support for vulnerable households.

Office of Environment and Heritage NSW provides up to date information on support available to NSW householders, and tips for how to save energy in your home.

Sustainability Victoria provides up to date information on support available to Victorian householders, and tips for how to save energy in your home including renovation case studies, and detailed reports evaluating a number of energy retrofit trials.



CRC for Low Carbon Living Ltd
Email: info@lowcarbonlivingcrc.com.au
Telephone: +61 2 9385 5402 Fax: +61 2 9385 5530

This research is funded by the CRC for Low Carbon Living Ltd supported by the Cooperative Research Centres program, an Australian Government initiative.



Australian Government
Department of Industry,
Innovation and Science

Business
Cooperative Research
Centres Programme