Insulation - the Key to Five Star and Beyond

Cost effective tips for achieving 5 Star energy efficiency compliance under the Building Code of Australia 2006

1. Challenges and opportunities

This information has been prepared by the Insulation Council of Australia and New Zealand (ICANZ) to assist the building industry meet the new 5 Star energy efficiency requirements of the Building Code of Australia (BCA).

To address global warning, experts predict that we will need to cut our greenhouse gas (GHG) emissions by over 50% in the coming decades. Around 14% of Australia's greenhouse gas emissions comes from the heating and cooling of buildings (AGO 2005). So cutting energy use and greenhouse gas emissions from residential housing is an important part of the mix of initiatives required to meet this challenge.

With the trend to larger houses, the increasing number of air-conditioning and central heating installations, and the aging of the population, GHG emissions resulting from homes will increase.

International comparisons show that Australia's 5 star regulations are not onerous compared to other countries. Regulation in the USA, for example, is at least twice as stringent in similar climates with similar energy costs.

Information to help achieve 5 Star

As with all new initiatives, 5 star regulations have their initial challenges. ICANZ members have a major stake in the building industry and providing the best information on the most cost effective methods to meet the new regulations is a necessary and important service. This '*Five Star and Beyond*' information sheet aims to help the building industry to:

- Understand how the new energy ratings will affect the design and construction of houses,
- Identify opportunities to make further cost effective savings that were not available in the previous rating scheme,
- Address concerns regarding over-insulation in warm and hot climates,
- Develop cost effective solutions for light weight houses in colder climates and heavy weight houses in warmer climates which were identified in the original scheme as being the most difficult to achieve 5 stars

It also addresses some of the enigmas identified since the introduction of national building fabric energy efficiency regulations, including:

- Light weight well ventilated house in Townsville,
- Concrete block house on a slab in Townsville,
- South facing small timber floored house in coastal Victoria
- Lightweight timber house in East Sydney
- Typical project homes in Perth, and
- Split level timber homes in Hobart

A series of case studies show:

- Energy savings over BCA 2003
- Improvement in unconditioned comfort for 5 stars compared to BCA 2003
- Reduction in size of appliance and peak utility loads

- Contrasts modifications needed to achieve 5 stars using high insulation levels and achieving 5 stars while maintaining insulation at BCA 2003 levels
- Whether high insulation levels create a hot box in hot weather, and
- To really address the climate crisis: how to get 7 stars!

Next generation rating tools

The new 5 star regulations also introduce the next generation of house energy rating tools - CSIRO's AccuRate – computer software used to determine a home's energy rating.

Many in the building industry will be unaware of these tools and the solutions they allow. Tested extensively across Australia during 2005 the next generation AccuRate has been completely overhauled with particular emphasis on quantifying the benefits of air movement through cross ventilation and ceiling fans. Rating levels of up to 10 stars are provided for.

All the data for these fact sheets have been calculated using AccuRate to bring the industry the most up to date in formation. By using the following techniques builders can avoid more expensive alternatives and find greater design flexibility with glazing areas.

Energy ratings offer greater flexibility in design than DtS

The BCA enables the use of energy ratings because in many situations it provides more flexible and cost effective outcomes for building designers than Deemed to Satisfy (DtS) regulations. While DtS regulations establish a minimum level of insulation they do not always provide 5 star performance or give benefits for higher than minimum insulation levels.

The energy-rating tool AccuRate allows additional rating points to be earned for higher levels of insulation. As some insulation must be installed anyway, the cost of extra insulation is minimal; however, this extra performance gives designers more flexibility with glazing and allows them to use larger areas to provide aesthetic appeal or reduce costs with lower specifications in other areas.

2. Identifying new opportunities for energy savings

Internal wall insulation

The new rating scheme simulates the way in which occupants realistically heat and cool their homes.

In most Australian homes only part of the house is heated and/or cooled at any one time. For example, bedrooms and living areas are heated and cooled to different temperatures at different times of the day depending on how the occupants use these rooms.

AccuRate shows that some small but significant benefits can be gained from insulating between rooms especially when rooms are heated or cooled to different temperatures. It demonstrates that insulation provides additional comfort in these rooms but saves energy on heating and cooling, as well as providing additional acoustic benefit.

Preventing unwanted air leakage

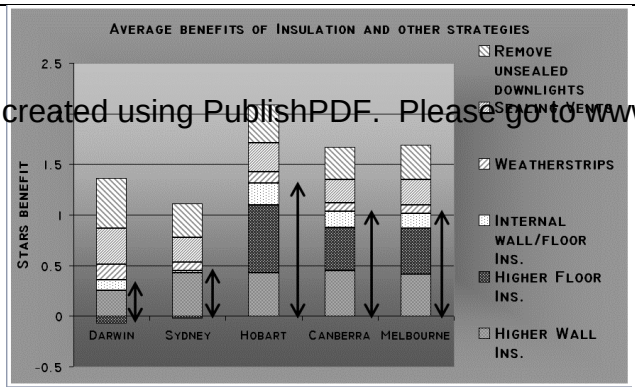
AccuRate also considers the number and type of air leakage points in each room such as open fire places, exhaust fans, vents and vented down lights. Weather strips can now be applied to individual windows and doors rather than the whole house, providing a more accurate simulation of real circumstances in the home.

A number of insulation and air leak prevention strategies have been considered for five geographic locations around Australia, and tested with regard to:

- An additional R1.0 in walls (over DtS requirements)
- An additional R2.0 in floors
- R1.0 in internal walls or upper floors between living and bedroom areas and to unheated/cooled spaces,
- Using self sealing exhaust fans,
- Weather stripping windows and doors, and
- Replacing downlights in ceilings to attic spaces with models that do not require high ventilation.

Figure 1 shows the rating points that can be gained from these insulation and leak prevention strategies for each of the five locations:

Benefits of Insulation and Air leakage strategies in five locations



Location	Stars from extra insulation	Stars from air leakage
Darwin	**0.4**	**1.0**
Sydney	**0.5**	**0.6**
Hobart	**1.3**	**0.8**
Melbourne	**1.1**	**0.6**
Canberra	**1.0**	**0.7**

Figure 1. Benefits of Insulation and Air leakage strategies in five locations

By exceeding DtS minimum requirements for insulation, the strategies show substantial energy savings that can be achieved in all five locations.

3. Insulation need not create a hot box in hot climates

Insulation offers considerable advantage in achieving 5 stars in warm climates

AccuRate shows that a ventilated house is far better suited to warm climates and that insulation will improve comfort levels. It also shows that significant improvements can still be made to houses of a concrete block design.

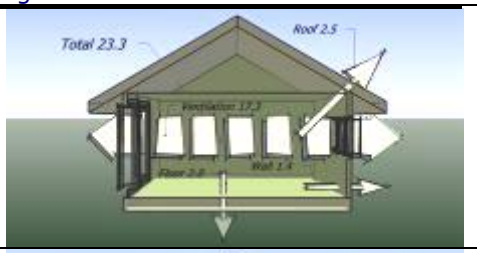
With poor ventilation and uncontrolled sun penetration insulated houses can become hot boxes. However, the new regulations ensure that sun penetration is controlled and that the house can achieve minimum levels of ventilation.

In these circumstances insulation should not create a hot box, even at very high levels of insulation. This is because insulation can slow down heat gain

during the day and can reduce the amount of heat lost at night when it is cooler.

As shown in Figure 2 insulation cuts heat gains by more than it cuts heat losses where good levels of ventilation are provided.

Figure 2. How the heat gains and losses under peak conditions are affected by insulation.

	Day Gains	Night Losses
Uninsulated		
Insulated		
Difference	Insulated 12.1 less gain	Insulated 4.7 less loss

In the Townsville and Sydney case studies that follow, AccuRate is used to predict unconditioned temperatures to show whether high levels of insulation do create a hot box. In all cases wall and floor insulation does not significantly affect summer comfort, while ceiling insulation is always beneficial.

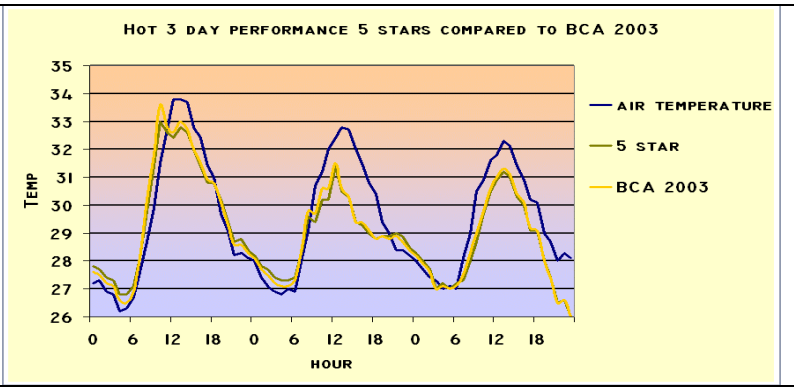
Well ventilated lightweight house in Townsville

House:	**Well ventilated lightweight house in Townsville**
Plan	
Elevation facing south	

5 Star: energy savings	***30%***
5 star: reduction in appliance size/utility load	***20%***

Changes to achieve 5 stars: high insulation	***Changes to achieve 5 stars: low insulation***
R3.5 roof insulation R1.5 floor insulation R2.0 wall insulation Trim 2.4 m^2 from glazing area	R1.5 insulation + foil in roof R0.0 in floor (uninsulated) R1.0 in east and west unshaded walls Reduce glazing size by 11.5 m^2 High shading coefficient glass using an 'eclipse blue' tint or equivalent Weather-strips to all windows and doors as well as self-sealing exhaust fans. 2-metre verandas all around the house.

Impact on Comfort
High insulation slightly improves comfort. No hot box effect because ventilation is excellent.



Seven Star design changes

- Use ceiling fans: 2 x 1200 mm in living and 1 x 1200 mm in bedrooms
- Use heavier window tint such as 'super grey'

House Construction

The house has a light coloured metal deck roof with foil underneath and R1.5 insulation on the ceiling. Walls are constructed from weatherboard and are uninsulated except for east and west walls, which contain R1.0 insulation. The floor is assumed to be particleboard with timber veneer sheet over. Windows are constructed from lightly tinted louvres in an aluminium frame. Cross ventilation is excellent with one room deep plan and windows on either side. This house is similar to the classic well- ventilated houses constructed in the northern territory such as the C19*.

High insulation levels make compliance easier

If high insulation levels are used, compliance is cheaper and less restriction is placed on the design.

Note: Weather stripping *may* also require casement windows to be used rather than louvre windows if the window is to achieve an effective seal.

High insulation levels won't create a hot box in Townsville

The graph shows temperatures in the living room without air conditioning over a three-day hot period in Townsville. It compares the house constructed to the specifications of the BCA 2003 DtS and the modification outlined in Table 1 using high insulation levels to achieve the new 5 star requirements.

The graph shows virtually no difference between temperatures on the hottest three days period of the year. The 5 star houses are slightly cooler during the day and slightly warmer overnight (less than a degree). Over the whole year the 5 star houses reaches a temperature of over 30 degrees around 50 hours less than the house specified to BCA 2003 level.

Why does insulation reduce the energy required for cooling energy but not affect comfort?

In a well-ventilated house without air conditioning the temperature inside is about the same as outside air temperature, though it may feel cooler if there is air movement. If there is no temperature difference between inside and outside there is no heat flow, so the insulation has little effect in walls and floor. Insulation in the roof will improve comfort even though there is no air temperature difference because the sun shining on the roof can have an effect equivalent to a 40 degrees air temperature difference.

If the house is air-conditioned the temperature in the house is reduced creating a temperature difference between the inside and outside. This temperature difference causes a heat gain through the walls and floor. Under these circumstances adding insulation makes a difference because insulation can reduce this heat flow.

A construction issue worth noting

Where platform floors are laid prior to wall and roof cladding, rainfall will increase the moisture content of the floor. Installation of some insulation types will retain some moisture and make it more difficult to dry out. Even without insulation builders should avoid using unprotected platform floors where significant rainfall is expected. There are insulation products available that do not retain moisture and can be used in this application.

Seven Star design changes

Note that ceiling height would need to give a 2.4 m clearance to the underside of fans, however this house has a 2.4 m ceiling height. To install fans safely would require cathedral/raised ceilings and/or higher external walls. Ceiling fans were therefore overlooked as part of the 5 star solutions due to the extra cost this would involve.

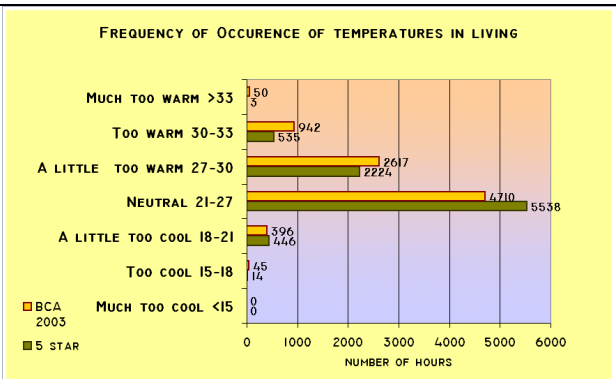
Concrete block house in Townsville

House:	**Concrete block house in Townsville**
Plan	
Elevation facing west	
5 Star: energy saving	***50%***
5 star: reduction in appliance size/utility load	***40%***

Changes to achieve 5 stars: high insulation	***Changes to achieve 5 stars: low insulation***
R3.5 roof insulation and roof ventilators, Use louvre or casement windows, that can be fully opened Blinds to west windows: 7.4 m^2, Trim 8.1 m^2 from glass area, Tinted glass such as evergreen, Ceiling fans: family and living.	All items opposite & Blinds to east windows: 10.5 m^2

Impact on Comfort

5 stars provides: 400 fewer hours over 27, 450 fewer over 30 compared to BCA 2003



Seven Star design changes

- Construct external walls using aerated autoclaved concrete block (higher R value) or insulate external walls
- Add ceiling fans to all bedrooms

House Construction

This house is typical of the concrete block spec. homes constructed on slabs in northern Australia. While insulation can only help heat flows through the ceiling in this house, using higher levels of insulation can still provide enough performance boost to reduce the cost of achieving 5 stars.

To meet BCA 2003, minimal upgrade is required because walls are shaded with eaves and are not required to be insulated. The glass area is also low enough to use standard aluminium frame clear glass. Only a R1 reflective backed blanket under the roof deck was required. It only achieves 1.5 stars. While insulating the wall would help, the cost is very high so it will not be considered for 5 star solutions.

Changes required meet 5 stars

The design changes needed to achieve 5 stars using higher insulation levels compared with the design changes required to meet the current regulatory minimum shows a small but significant benefit. Again, using high insulation levels helps to cut the cost of 5 star compliance.

Concrete slab homes compare to well ventilated homes

It is far easier to achieve 5 stars with high set, lightweight houses than in the concrete block wall and slab floor in this house. This is particularly seen in the extent of glazing.

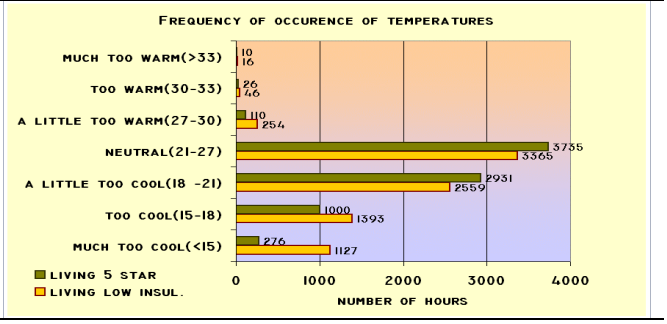
The well ventilated lightweight house is able to achieve 5 stars at a 40% glass to floor area ratio (GFR) while the concrete house must cut glass areas back to 20% GFR and use external blinds to reduce heat gains. The ventilated style allows the house to achieve comfort with more than double the heat gains through windows.

Lightweight 'passive solar' house in Sydney

House:	**Lightweight 'passive solar' house in Sydney**
Plan	
Elevation facing north	
5 Star: energy savings	***70%***
5 star reduction in appliance size/utility load	***30%***

Changes to achieve 5 stars: high insulation	***Changes to achieve 5 stars: low insulation***
R4.0 in ceiling R2.0 in walls R3.0 in floors Weather-strips to doors and windows, self sealing exhaust fans Reduce window size by 17.5 m2 from a GFR of 38% to a more average 28% Double glaze 17.5 m2 of south facing window (6 mm gap) Reduce shade to 900 on north and remove on south	R3.0 in ceiling R1.5 in walls R0.0 in floor(uninsulated) Weather-strips to doors and windows, self sealing exhaust fans Reduce window size by 17.5 m2 from a GFR of 38% to a more average 28% Double Glaze ***all windows with 12 mm air gap, low e and argon fill*** Reduce shade to 900 on north and remove on south Enclose subfloor External blinds to all north windows Ceiling Fans to Living & Family (x2) & beds.

Impact on Comfort
High insulation slightly improves comfort. No hot box effect because ventilation is excellent.



Seven Star design changes

- Add adjustable external blinds to north windows
- Add ceiling fans to all bedrooms and 2 each to living rooms
- Double Glaze all windows with low e clear double glazing

House Construction

This house has a 'classic' passive plan with all rooms having north windows and no east or west windows. It is constructed from lightweight timber floor and walls and therefore lacks the thermal mass (slab floor, internal brick walls) that the passive solar strategy needs to work best. The plan has excellent cross ventilation, which will help to reduce cooling needs.

Higher levels of insulation will help make up part of the performance lost through the lack of thermal mass difference but the design strategy also needs to be adjusted in other areas. The inability to store solar heat gains through windows means that less north sun can be stored to heat in winter, and heat gains in summer are felt immediately. So the house will need smaller glazing areas or higher performance glass to achieve 5 stars.

Higher insulation substantially improves comfort and energy savings

Far from creating a hot box in summer, the insulation actually slightly reduces the number of hours of discomfort because it reduces heat gains during the day. While the five star house spends 146 hours a year over 27 degrees, 27 degrees is exceeded 316 hours per year, or more than double the time over the BCA 2003 specification.

In winter the extra insulation also reduces the number of hours per year under 18 degrees by a massive 1,244 hours per year - a substantial boost to comfort.

Overall exceeding the minimum insulation levels also saves a further 30% of energy use over 5 stars.

Recipe solutions don't work for passive solar design

A passive solar house cannot be built to the same specifications when it is constructed with lightweight elements. It can still be very energy efficient but the design strategy needs to be modified to work best. In general higher levels of insulation and smaller better-shaded windows with good ventilation are essential for this type of house to work with lightweight construction.

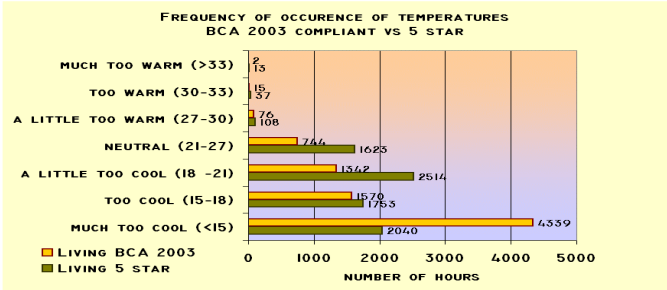
While this house contains many features of "good design" (eg. eaves, good cross ventilation, and north orientation) it needed significant modification to achieve 5sars. This demonstrates how important it is to quantify good design by using a rating tool and not just rely on recipe solutions.

Lightweight 'passive solar' house in Sydney

House:	**Lightweight south-facing house on Victorian coast**
Plan	
Elevation facing south	
5 Star: energy savings	***45%***
5 star reduction in appliance size/utility load	***30%***

Changes to achieve 5 stars: high insulation	***Changes to achieve 5 stars: low insulation***
Extra floor insulation R3.5 from R1.0 Extra wall insulation R2.5 from R1.5 Extra ceiling insulation to R4.0 from R3.0 Weather-strip all doors & windows, self sealing exhaust fans Reduce Glass area by 11.0 m^2 Double Glaze: 6 mm gap, low e 19.9 m^2	Floor Insulation R 1.0 Wall insulation R 1.5 Ceiling insulation R 3.0 Weather-strip all doors & windows, self sealing exhaust fans Reduce Glass area by 11.0 m^2 Double Glaze 12 mm gap, low e, argon filled 36.2 m^2 Increase north glass area by 4 m^2 in living room & reduce south by 4 m^2 Relocate bedroom west window to north Enclose Subfloor.

Impact on Comfort
High insulation reduces cold temperatures by over 2000 hours per year. Comfort slightly improved in summer.



Seven Star design changes

- Use double-glazing with 12 mm air space and argon fill in addition to the low e coating on the inner pane.
- Enclose sub floor
- Provide external blinds to all north, east and west windows.

House Construction

The house is constructed from timber framed walls, with timber floor over an unenclosed subfloor. It is assumed to have R3.0 ceiling insulation, R1.5 wall insulation and R1.0 floor insulation for BCA 2003). Glass areas of original design have been trimmed to comply with BCA 2003 (though not adopted in Victoria many other locations are in the same climate e.g. Adelaide Hills).

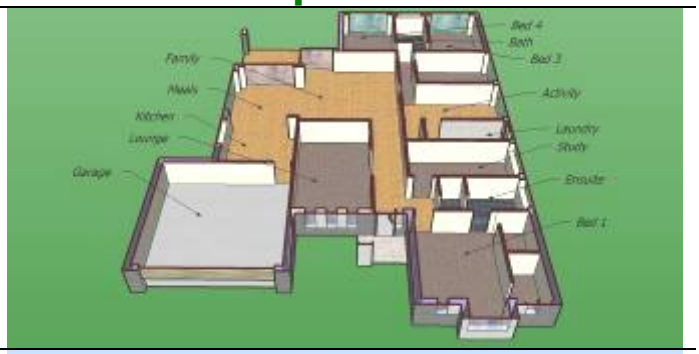
Using high insulation levels makes it affordable for south facing light weight houses to achieve 5 stars

This style of house has been expensive to modify to achieve 5 stars. This example shows high insulation levels are the key to containing costs. Using higher levels of insulation substantially reduces the cost and complexity of achieving 5 stars. A greater area of high standard double-glazing must be used together with other design changes if high insulation levels are not used.

5 star rating significantly improves comfort - even without air-conditioning and heating

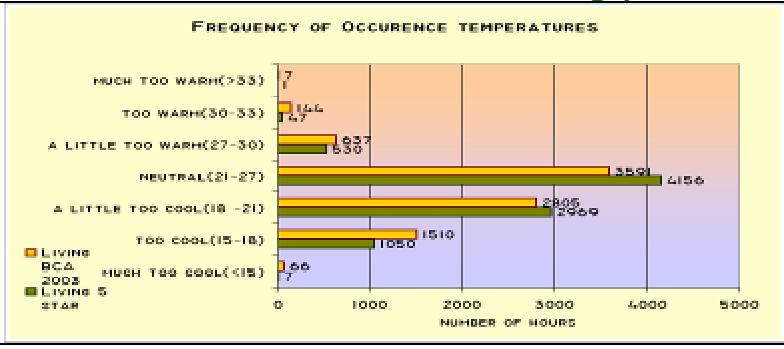
A 5 star house will be above 15 degrees for around 2300 hours or almost 100 days more each year than the house with low insulation levels! The house will be as much as 5 degrees warmer in winter. In summer the additional insulation slightly improves comfort and certainly does not create a hot box.

Spec house in Perth

House:	**Spec house in Perth**
Plan	
Elevation facing north	
5 Star: energy savings	***40%***
5 star: reduction in appliance size/utility load	***30%***

Changes to achieve 5 stars: high insulation	***Changes to achieve 5 stars: low insulation***
Extra ceiling insulation to R4.0 from R2.0 Weather-strip all doors & windows, self sealing exhaust fans Select window with 'improved' aluminium frame Reduce Glass area by 3.8 m^2 External blinds to selected east and west windows 20.0 m^2	Ceiling insulation R2.0 Weather-strip all doors & windows, self sealing exhaust fans Select window with 'improved' aluminium frame Reduce Glass area by ***7.9*** m^2 External blinds to selected east and west windows 20.0 m^2 ***Double Glaze with 6 mm gap: 16 m^2***

Impact on Comfort
Significant reduction in hot temperatures in summer, substantial improvement to cool temperatures in winter.



Seven Star design changes	• Insulate Brick Cavity walls to at least R1.0 **OR** • Double Glaze two thirds of the windows (excluding utility areas)

House Construction

Like most homes in Perth this house has uninsulated cavity brick external walls, brick internal walls and a concrete slab floor. The BCA 2003 house is assumed to use R2.0 ceiling insulation and its glass areas comply without modification.

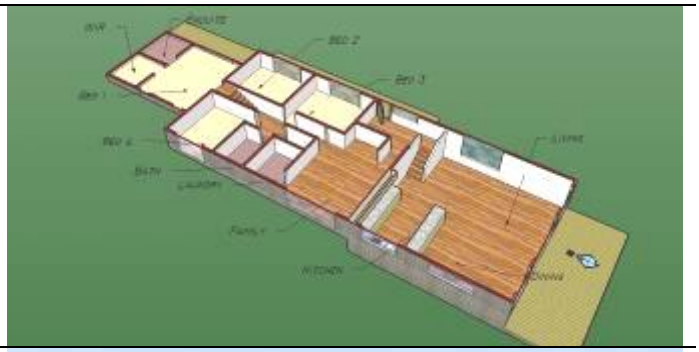
Using high insulation levels makes it more affordable to achieve 5 stars

Significant design changes are required to achieve fire star if only minimum levels of insulation are used. However, insulation has only limited potential to assist in this case because brick cavity walls are significantly more expensive to insulate and slab floors generally need no insulation.

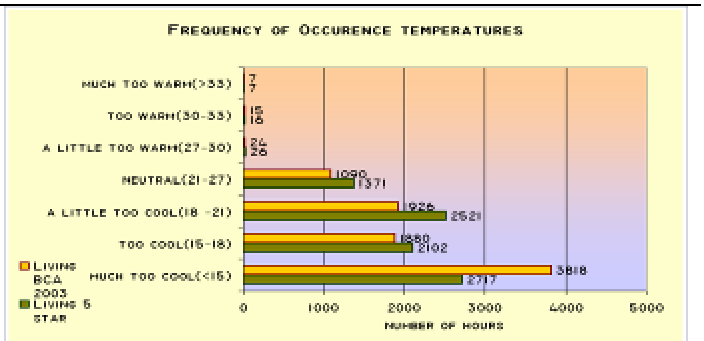
Five star rating significantly improves comfort - even without air-conditioning and heating

5 stars makes a huge difference to comfort year round. The five star house will be above 15 degrees inside for around 500 hours more each year than the house meeting BCA 2003. In summer the number of hours where temperatures exceed 27 degrees is reduced by 200, so the additional insulation has not created a hot box. At 5 stars the house is perfectly comfortable for almost half the year without any heating or cooling at all.

Split level south-facing house in Hobart

House:	**Split level south-facing house in Hobart**
Plan	
Elevation facing north	
5 Star: energy savings	***40%***
5 Star: appliance size/utility load	***20%***

Changes to achieve 5 stars: high insulation	***Changes to achieve 5 stars: low insulation***
Extra floor insulation R3.0 from R0.5	Floor insulation R0.5
Extra wall insulation R2.0 from R1.5	Wall insulation R1.5
Extra ceiling insulation to R4.0 from R3.0	Ceiling insulation R3.0
Weatherstrip all doors & windows, self sealing exhaust fans	Weatherstrip all doors & windows, self sealing exhaust fans
Select window with 'improved' aluminium frame	Select window with 'improved' aluminium frame
Reduce Glass area by 3.3 m^2	Reduce Glass area by 3.3 m^2
Double Glaze: 6 mm gap 19.9 m^2	Double Glaze: ***12*** mm gap ***42.1 m^2***

Impact on Comfort Cold temperatures reduced by over 1000 hours per year.	
Seven Star design changes	• Double Glaze all of the windows (excluding utility areas) using 8mm gap with low e coating and timber or UPVC frame • Enclose the subfloor

House Construction

Consistent with the requirements of the BCA 2003, the house is assumed to have R3.0 ceiling insulation, glass areas complying with BCA 2003 (glass area is 27% of floor area), walls are weatherboard insulated with R1.5 batts, the floor has R0.5 insulation and all doors and windows are weather-stripped.

Using high insulation levels makes it more affordable to achieve 5 stars

Significant specification changes are required to achieve fire star if only minimum levels of insulation are used compared to higher levels of insulation. By using high insulation levels, the cost of achieving 5 stars is significantly reduced.

5 star rating significantly improves comfort - even without air-conditioning and heating

5 stars makes a huge difference to comfort. The 5 star house will be above 15 degrees inside for around 1,100 hours more each year than the house meeting BCA 2003.