ACHIEVING 6 STAR ENERGY EFFICIENT HOUSING COST EFFECTIVELY IN AUSTRALIAN TEMPERATE CLIMATES.

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Summary

This paper reports the results of studies a study on the cost implications of achieving greater energy efficiency as measured by House Energy Rating(HER) 'stars' for new housing in Australia. 12 house designs typical of the housing options available from volume new home builders were modeled using the 2nd generation Building Code of Australia (BCA) accredited energy rating assessment tool AccuRate. Where the model predicted a rating below the minimum rating (6 star) proposed under the recently agreed Commonwealth of Australia National Energy Efficiency strategy, the designs were modified in order to improve the rating to 6 stars using a combination of specification changes and energy efficient technology options.

These changes or options were then priced at prevailing building suppliers and subcontractors retail cost levels in order that an average 'extra cost to 6 star' and range of indicative costs to achieve 6 star housing compliance could be articulated. The results revealed that standard and currently available technologies, such a reflective foil barriers, increased insulation and low emissivity 'e' type glazing provide a means to achieving 6 star ratings at a relatively modest additional cost above the current 5 star standard. For a typical house and land package in the order of A$325,000 these costs represent just under 2% of overall total construction and development costs. A further simple cost/benefit analysis reveals that operational savings from predicted reduction in annual energy demand show a payback period for the additional investment in achieving the new 6 star standard of approximately 25 years.

Keywords: 6 star costs, housing energy efficiency

1 Introduction

In Australia, the regulation of energy efficiency of buildings is covered by a range of Commonwealth, State and Territory agencies. In April of 2009 specific measures to increase energy efficiency of buildings were set out in a Council of Australian Governments [1] communiqué, and specifically for residential class buildings proposing :

- the phase-in of mandatory disclosure of residential building energy, greenhouse and water performance at the time of sale or lease, commencing with energy efficiency by 2011; and
- an increase in energy efficiency requirements for new residential buildings to six stars, or equivalent, nationally in the 2010 update of the Building Code of Australia with full implementation by all states by 2011.

A question for housing industry regulators, policy makers and industry participants arises in identifying additional capital costs associated with improving existing house designs to meet the new 6 star standard as per the latter proposal listed above. Housing energy efficiency as measured in 'stars' relates to the nationally adopted Home Energy Rating(HER) rating system and the use of software modeling as a route to verification for compliance with the energy efficiency requirements of volume two (residential class 1 & 10) of the building code. This software simulation method allows for the modeling of energy performance of a house in both heating and cooling loads. Software used to assess housing designs is accredited under the ratings protocol of the Australian Building Codes Board(ABCB) [2].

This research paper demonstrates a case study approach for predicting the additional housing capital costs for achieving six star housing in a temperate climate and mature housing market such as found in South Australia. An existing housing development *"Playford North"* provided a source of typical housing designs where builders and suppliers could be queried on costs of energy efficiency measures and dwellings could be assessed for HER star ratings. The modeling of building envelope improved thermal performance was limited in scope to typical temperate climate modifications around the elements of wall and roof insulation and glazing as has been shown in a number of recent studies by Constructive Concepts Pty [3] and earlier by Burghardt [4] to improve thermal performance in Australian housing and dwelling units. The focus on these elements is also supported by the prescriptive deemed to satisfy(DTS) measures for energy efficiency as adopted by the Australian Building Codes Board[5]

In relation to costing the design modifications, the home builders were queried as to likely 'upgrade' costs and these costings were cross checked by the authors using current 2010 market information and construction cost publications.

2 Home Energy Rating (HER) – Calculation of the Star Rating, Heating and Cooling Loads

The need for heating or cooling a house relates to the total effect of all heat flows in and out of the building. The sum of the total heat flow determines the internal temperature, and artificial heating or cooling is needed to reach comfort temperatures [6]. This is the method applied by AccuRate to determine the heating and cooling energy needed for a house design, from which the star rating is determined. An increase in star rating results in a lower energy demand in order to achieve assumed thermal comfort levels. Once the data for a house has been entered the report features of the software can be used to generate two specific reports as below;

- A summary report listing the project, client and rating assessor details. The heating and cooling requirements (as measured in mega joules per m2) and most fundamentally a star rating in compliance with the BCA/Nathers protocol.
- A more detailed Building Data Report which lists data on the construction elements for individual zones, sizes, openings etc.

The classification of houses situated in Playford North for climate data purposes under the National Home Energy rating system(NATHERS) is Climate zone 16 (Adelaide) and the relevant energy consumptions are respectively 125 and 96 Mega Joules per metre squared for 5 and 6 stars.Therefore, an increase from 5 to 6 stars represents a reduction of 23% in the energy demand of a house in the Adelaide climate zone. Whilst a target energy reduction of that magnitude might infer major building specification changes, housing design modifications around insulation and glazing and to a lesser extent shading and air movement devices are known to offer significant improvement to building thermal characteristics. Fricker [7] in his study shows that the benefit of additional insulation levels is non linear and diminishes once high levels of insulation are ‘standardised’ into housing and a recent report by the Australian Window Association [8] into the changes to a 6 star energy rating for residential buildings points to a requirement for high performance glazing as this insulation benefit reduces.

Smaller houses have a greater surface area compared to their floor area than larger houses. Because total heat flow through the building fabric is greatly influenced by the surface area, without a correction factor smaller houses of the same shape and materials will have higher energy loads per unit of floor area. This effect is exacerbated because often window areas as a percentage of floor area are often relatively larger in small houses than in larger houses, and because heat flows through windows are generally the largest. In Regulation Mode, star ratings are to be based on energy loads that have been adjusted by an area adjustment factor (AAF). The size of the adjustment depends on the conditioned floor area and the climate zone.

For Adelaide housing (Zone 5) the appropriate area adjustments used by the software in energy load calculations are:

$50m^2$	$150m^2$	$250m^2$	$350m^2$
1.2	0.3	-0.3	-0.8

3 Going from 5 to 6 stars case study – South Australia

A number of Adelaide home building companies were approached in early 2009 to be part of this research study on a strictly confidential basis. From this initial approach a modest yet representative sample of 12 house designs and specifications suitable for construction, were obtained from project home builders involved in a new housing development some 15 kms to the north of the inner city.

A typical specification for the style of housing is outlined in **Tab 1**. below with a front elevation photo illustration in **Fig 1**:

Tab.1 Typical base specification of Playford houses

Element	**Construction for Base Design**
External Walls	Brick veneer + R1.5 insulation + 10mm plasterboard
Windows/Ext. Doors	Aluminium framed single 3mm clear float glass windows Aluminium sliding door, single glazed 5mm clear float flyscreens
Internal Doors	Timber (solid)
Floors	Ceramic tiles to wet areas, vinyl to kitchen areas, carpet to bedrooms
Ceiling	10mm plasterboard + R 3.0 Glasswool bulk insulation
Roof	Concrete tiles – unsarked or Colorbond metal roof(25 deg pitch)
Weatherstrip/ Seals	All windows, external doors and exhaust fans sealed/weatherstripped
Air movement	Fans to main living room and bedrooms

Fig. 1 Playford housing – Photo of typical front Elevation

Typical brick veneer house design in Australia has very low thermal mass caused by brick or concrete within the internal space, and can be essentially treated as lightweight [9]. In modern times the level of air leakage in housing has improved, however unless it is measured it is not possible to significantly improve further, and default values are assumed. Internal loads cannot be controlled or easily determined, and generally, represent a small component of the total heating and cooling requirement. Consequently, as far as minimising heating and cooling demand for brick veneer houses the primary focus is on reducing transmission and affecting solar load.

Affecting solar loads relates to design decisions concerning the orientation of the building, window sizes and shading of windows. Transmission loads are reduced by applying various insulation technologies. Most brick veneer designs today consist of a large open plan living/dining/kitchen area with a number of contained bedrooms. The living zone represents those areas which are occupied during waking hours. The bedroom zone relates to areas occupied during sleeping hours. The living zone requires greater levels of comfort than bedroom zones and given that the living zone represents the majority of the house floor area, generally dominates the heating and cooling demand for a building. As a result effective design involves north facing windows in the living zone and ensuring all windows are shaded during summer.

4 The Accurate Results for the Case Study Houses

When modelled in simulation mode using AccuRate current version 1.4, the results of the base designs energy performance is listed in **Tab. 2** below. Lot numbers refer to individual house designs unique to each allotment that builders provided the required design information.

Tab.2 House star and thermal load information

Lot	Base Star Rating	Unadjusted Load, MJ/m^2		Ratio of Heating to Total Load	Floor Area, m^2
		Heating	Cooling		
16	4.9	78	63.8	0.55	175
17	4.9	94.9	61	0.61	130
23	5.8	58.8	53	0.53	142
26	5.9	75.1	42.9	0.64	104
13	5.4	53.4	63.5	0.46	170
29	4.9	62.8	65.1	0.49	211
184	4.9	59.5	77.4	0.43	188
45	5.2	60	68.1	0.47	180
901	5.1	70	68.5	0.51	167
8	5.3	60.5	69.9	0.46	173
902	5.4	51.7	62.5	0.45	224
194	4.9	68.9	70.6	0.49	190

Using the list of technology options listed in **Tab. 3** and **Tab. 4**, the star rating was increased to 6 stars for each house design. A condition of the upgrade in energy efficiency was that major changes to the floor plan, changes to window location or overall window and door sizes were deemed too great a divergence from an acceptable design solution for each lot. As a result the principle focus in increasing the star rating relates to technology options affecting the transmission heat flow through the house.

Lot 17 was one of the poorest designs with a base star rating of 4.9. As shown in **Tab. 2** it had the highest heating load due to large southern windows and the northern windows shaded by the building preventing winter sun. As a result, in addition to adding the maximum levels of insulation in the building, the southern windows needed to be double glazed and the windows throughout the house required low emissivity glass.

Lot 26 was the best design with a base star rating of 5.9. Although the house required more energy to heat, per unit of floor area, than some other houses, due to its smaller floor area it was penalised less than other houses, and as a result achieved a higher rating. The house has minimum southern windows preventing heat loss, no eastern and western windows preventing the sun in the summer and northern windows providing for winter sun. To achieve 6 stars all that was required was foil in the roof.

Lot 184 was a typical design in that it conformed to the deemed to satisfy provisions of the BCA and achieves a star rating in the simulation method of 4.9. The building requires more cooling than heating and this is due to the large unshaded western windows in the living zone. Foil was added to the roof and walls, the internal wall was insulated and the roof insulation upgraded to 3.5. Low emissivity glass was applied to most of the glass doors/windows.

In addition to the development of the 6 star designs, the impact of the technology options was systematically investigated for each house design. Applying the list prescriptively, **Tab. 3** and **Tab. 4** show the absolute and incremental impact on the star rating of the design, respectively.

In total, except for Lot 17, all other designs achieved 6 stars with the average house design reaching 6.4 stars. This result indicates that in general there is scope to reduce these measures, while maintaining the 6 star rating. Furthermore, although insulation options have been exhausted, there is scope to increase the star rating for those designs which achieve a significantly lower star rating. These measures include (in order of application):

1. applying low E single glazing to all other windows/doors in the house
2. applying double glazing to the living zone windows/doors
3. applying double glazing to all windows/doors in the house

Tab.3 Cumulative star rating impact of each technology measure for each Lot

Lot	**Updated Star Rating with Technology Option**				
	Foil in roof	**R2.5 ext walls**	**R4 roof**	**R1.5 internal walls**	**Low E glass in living zone**
16	5.2	5.4	5.6	5.9	6.4
17	5.1	5.2	5.2	5.4	5.6
23	6	6.1	6.3	6.4	6.7
26	6.1	6.3	6.5	6.6	6.8
13	5.7	5.8	5.9	5.9	6.3
29	5.2	5.4	5.4	5.4	6.1
184	5.2	5.3	5.4	5.6	6.2
45	5.4	5.6	5.8	6	6.6
901	5.3	5.4	5.6	6	6.6
8	5.5	5.6	5.6	5.8	6.5
902	5.7	5.8	5.8	6.1	6.6
194	5.1	5.1	5.2	5.4	6

Tab.4 Incremental increase of star rating (rounded to one decimal) by impact of each technology measure for each Lot

Lot	**Star Rating Increase with Technology Option**				
	Foil in roof	**R2.5 ext walls**	**R4 roof**	**R1.5 internal walls**	**Low E glass in living zone**
16	0.3	0.2	0.2	0.3	0.5
17	0.2	0.1	0	0.2	0.2
23	0.2	0.1	0.2	0.1	0.3
26	0.2	0.2	0.2	0.1	0.2
13	0.3	0.1	0.1	0	0.4
29	0.3	0.2	0	0	0.7
184	0.3	0.1	0.1	0.2	0.6
45	0.2	0.2	0.2	0.2	0.6
901	0.2	0.1	0.2	0.4	0.6
8	0.2	0.1	0	0.2	0.7
902	0.3	0.1	0	0.3	0.5
194	0.2	0	0.1	0.2	0.6
Average	**0.24**	**0.13**	**0.11**	**0.18**	**0.49**

Based on the average increase, each technology option produces a meaningful increase in the star rating. The incremental increase that each technology option generates will be different depending on the order of application. Therefore, the average increase determined should only be used as a guide. **Tab. 4** shows the average increase each technology option measure provides. Low E single glazing is the most effective at 0.49 stars followed by the foil in roof, internal wall insulation and then the bulk insulation measures in the building envelope. This result reflects the fact that bulk insulation is already present in the house design and therefore any increase in the R rating will have less of an impact compared to glazing, where the original glazing has a very poor thermal resistance. The performance of the foil, reflects the increased impact of the cooling demand on higher star rated homes, and is an important measure for higher star rated houses. Internal wall insulation isolates the living zone from the rest of the house and effectively reduces the conditioned area.

5 Capital Cost Analysis– Cost per star, Cost per technology option.

Costs were determined based on retail costs not including GST. The actual cost increases for each lot relates to the specific design choices and combinations of technology options around insulation and glazing. These design choices were made in order to minimise cost. **Tab. 5** below shows these upgrade costs.

Tab.5 Cost estimates to upgrade existing designs to 6 stars ($Aus June 2009 prices).

Lot	**Base Stars**	**Estimated Upgrade Cost**	**Normalised Cost**	
			Total	**Cost/star**
16	4.9	3958	3872	3520
17 improved	4.9	4801	6321	5747
23	5.8	433	521	2607
26	5.9	134	220	2199
13	5.4	863	869	1448
29	4.9	7880	6392	5811
184	4.9	5516	5022	4566
45	5.2	2678	2546	3183
901	5.1	1422	1457	1619
8	5.3	2243	2219	3170
902	5.4	1469	1122	1870
194	4.9	6404	5770	5245
17 as provided	**4.9**	**6590**	**8677**	**7888**
Average	**5.2**	**3150**	**3028**	**3415**

Overall, the range of costs was large, with a minimum of $134 and a maximum of $7880, and the average being $3150. This range is significant and reflects design choices made which affected the need for a glazing solution. Where a glazing solution was not required cost increases were negligible. Two options are provided for Lot 17, the as provided value represents what was advised to builders, however, this was able to be significantly improved on, and this value is presented. To compare each house correctly, the costs were normalised to the average floor area of 171 m^2, and the cost per star was determined

For example, Lot 23 has a floor area of 142m2 (see **Tab. 2**)

Upgrade cost/floor area	\$433/142m2	=	\$3.05/m2
Normalised to Average size house	171m2 x \$3.05	=	\$521

For the 12 houses in the study the average cost per star is \$3415 +/- 46%. All average values only consider the improved arrangement for Lot 17.

The study assumes that a cost minimisation approach is available to the builder and that in the absence of being able to make specific design choices, the cost of upgrading, applying the measures listed in **Tab. 3** and **Tab. 4** can be conducted (**Tab. 6**). This costing exercise is based on applying the list of measures in full irrespective if it achieves a higher star rating than 6. Based on the average of each measure the highest cost is clearly the glazing solution followed by foil, internal wall insulation and finally the external wall and roof insulation being the least costly. This is expected as currently external walls and roof already are insulated, and therefore the cost is the cost of upgrading.

Tab.6 Cost increase of each measure for each Lot

Lot	Cost Increase of Technology Option, \$Aus				
	Foil in roof	**R2.5 ext walls**	**R4 roof**	**R1.5 internal walls**	**Low E glass in living zone**
16	526	213	168	478	3322
17	358	190	53	389	2458
23	433	77	136	422	3309
26	320	204	100	251	3225
13	518	87	163	539	4264
29	743	286	202	520	4767
184	578	276	180	498	4720
45	550	244	173	638	4114
901	460	239	160	582	4318
8	475	77	71	558	3873
902	618	101	92	750	4543
194	530	88	78	774	4935
Average	**509**	**173**	**131**	**533**	**3987**

Tab. 7 presents the total cost of applying the measures with the average being \$5334. The average total based on normalising the cost to the average floor area of 171 m^2 was \$5377 +/-12%. This cost is significantly higher than the actual upgrade cost presented in **Tab. 5.** This difference represents the cost minimisation process.

Where a process of optimisation can be applied in the modelling, an average cost saving of \$1962 or average rate of \$11.47/m2 GFA can be achieved. This variation of the average total cost of applying the measures in **Tab. 7** represents the different choices in window/sliding door area and living room areas which will affect the cost. Generally the cost variation is small for applying all the measures. As shown in Tab. 3 the application of these measures delivers varying increases in star rating often well above 6 stars.

Tab. 7 also presents the cost of 1 star increase for each lot with the average being \$4921 +/-27%. The variation shows the impact of the design and relate to the base star rating. Although this represents the true cost of going from a 5 to 6 star design in practice it will depend on whether designers are able to implement a portion of a measure. For example, apply R3.5 in the roof as opposed to R4, or apply low emissivity glass to some of the glass doors and windows in the living zone.

Tab.7 Total cost and total normalised cost to a 171 m^2 floor area.

Lot	Total Cost	Normalised Cost	
		Total	**Cost/star**
16	4708	4605	3070
17	3448	4540	6486
23	4377	5276	5862
26	4100	6747	7497
13	5571	5609	6233
29	6518	5287	4406
184	6251	5692	4378
45	5718	5438	3884
901	5759	5902	3935
8	5054	5000	4167
902	6103	4663	3886
194	6404	5770	5245
Average	**5334**	**5377**	**4921**

A retail market based approach was used in costing the various material and technology combinations modeled to improve the star rating. Suppliers and subcontractors in the SA building home market who were willing to provide indicative supply prices at a retail price i.e. without any mark downs that can often be negotiated by volume purchases or companies using long term customer relationships as price bargaining leverage.

In a comparative cost benefit study of energy efficiency measures for housing in the Australian state of Victoria (temperate zone) by Energy Efficient Strategies [10], data regarding costs of such products as insulation, foils and barriers etc. revealed two separate rate levels. A lower rate applicable to volume builders and a higher rate applicable to non volume builders. The analysis revealed across a range of building products and various house improvement measures that volume builders generally enjoyed lower costs (in the order of 10%).

Therefore it could be said the figures used in the analysis may slightly overstate the increased cost effect of additional measures or higher specification in the houses variations.

Appendix A (Tab. A.1 and A.2) resents the list prices as provided by company A for various batt sizes and foils, and companies C, D and F for windows with a discount incorporated. A survey of prices in a major hardware store showed a discount of 46% for batts and a discount of 62% for foils (ignoring GST). These are discounts from normal retail prices and it was explained by Company A, that volume home builders would achieve an additional 10% discount. Appendix A also provides installation prices at prevailing labour rates that are consistent with current construction cost data publications such as Rawlinsons[11]

6 Cost/Benefit Analysis

The relevant energy consumption predicted by the HER rating software are 125 and 96 Mega Joules per metre squared for 5 and 6 stars respectively. An increase from 5 to 6 stars represents a reduction of 23% in the energy demand (heating and cooling) of a house in the Adelaide climate zone. South Australian houses typically have a combination of gas/electric powered heating and cooling including reverse cycle and fully ducted evaporative cooling systems. This mix of energy usage from gas and electricity varies, as studies by Saman et.al. [12] have shown.

Nevertheless, a simple theoretical costing of the predicted annual saving in reduced energy demand can be calculated using both current retail energy tariffs and a energy (gas/electricity, 40/60) mix inferred from data and modelling of consumption and appliance prevalence in the various Australian state energy markets by OTER [13] and ABCB [14].

For the average of house areas in the study (171m^2) house total annual energy reduction is calculated as 29MJ x 171m2 = 4,959 MJ per annum.

Costing in gas:	4,959 MJ @ 2.004[1] c per MJ	=	\$99.38
Costing in electricity:	4,959MJ/3.6[2] = 1,377.5 KWh @18.26c[3]	=	\$251.53

Assuming a 40/60 split in gas/electricity the predicted annual saving is therefore;

(99.38 x 0.4) + (251.53 x 0.6)

Which equals **\$190.67** per annum

In the study outlined in this paper (see **Tab. 7**) the average cost to increase from 5 to 6 stars based on the average 171m2 house is \$4921.

Simple Payback or Years Purchase amount is: capital cost/ annual saving

Therefore for 5 to 6 stars 'average':

Payback/Years Purchase = \$4921/\$190.67 = **25.81** years.

7 Conclusions

With moves towards the 6 star energy efficiency rating for houses, the cost implications need to be analysed. The study of Adelaide houses shows a range of indicative costs for housing that meets the current standard but requires modification to achieve 6 stars. The average capital cost of an increase from 5 star to 6 star rating was found to be A\$4921 for an average house size area of 171m2. Given typical homebuyer house and land packages

[1] Origin Energy Retail tariff Jan 2010
[2] One **kilowatt hour** is 3.6 megajoules
[3] AGL standard (non peak) tariff Mar 2010

are in the order of A$325,000 this represents a 1-2% cost increase for a housing consumer with anticipated benefits of greater thermal performance built into the house. A simple year's payback calculation of this benefit indicates a very modest 25 year return on investment.

Many of the designs in the study actually exceeded the current 5 star standard when modelled in simulation mode whilst some where slightly below. The average cost increase to achieve 6 stars for the 12 existing designs was found to be $3150 though significant variability was evident as a range in cost increase occurred, from $134 to $7880 due to the required application of various technology options. The principle cost increase is the application of the new glazing solution, low emissivity glass. The most cost effective measures was increasing bulk insulation in the external walls and roof, however this was due the associated costs only being an upgrade cost. Applying reflective foil in the roof together with internal wall insulation was the next most cost effective option achieving 0.24 and 0.18 increase in stars. The most effective increase in star rating was the glazing option increasing the star rating by an average of 0.49.

The development of an effective methodology by which designers can readily achieve 6 stars is an important consideration in the current moves to increase thermal performance of housing in Australia. A step by step approach was investigated which involves applying various insulation options and then applying the lowest cost glazing option. Applied as a guide this was used on 12 house designs upgrading the designs to 6 stars, through an optimisation process aimed at minimising cost. In this study basic design modification principles were identified which can mitigate the costs associated with upgrading to 6 stars. The results infer that currently capital cost increase to 6 stars can be described as modest or minor with modest operational cost savings.

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Appendix A

Tab. A.1 Retail prices for insulation (non GST)

Insulation Product	**$/m^2**
R2 bulk insulation	4.29
R2.5 bulk insulation	4.87
R3 bulk insulation	5.07
R3.5 bulk insulation	5.62
R4 bulk insulation	6.03
R1.5 bulk insulation	3.19
Single sided reflective foil	1.00
Double sided reflective foil	1.05
Installation cost	1.50

Tab. A.2 Retail prices for windows (non GST)

Window	**Company**	**$/m^2**
Standard clear single glazed window	C	223
Standard clear single glazed door	C	278
Standard clear single glazed window	D	118
Standard clear single glazed door	D	168
Low E single glazed window	C	426
Low E single glazed door	C	466
Standard double glazed window	D	307
Standard double glazed door	D	526
High performance double glazed window	F	450
High performance double glazed door	F	940