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Simulating the effects of Internal Wall Insulation using AccuRate software

Report Prepared By

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July 2006

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1. Introduction

This study investigated the effects of internal wall insulation on the energy performance of dwellings. The 2nd generation rating software AccuRate version 1.1 was used to modify and simulate a sample set of 132 dwellings. The simulations were run in 11 representative climates from across Australia.

2. Methodology

2.1. Selection of Dwelling Designs

The selection of dwellings focused on the dwellings from the AccuRate Validation set which rated in the regulatory impact range of 4 to 6 stars in the Brisbane, Sydney East and Melbourne climates. Dwellings were selected as representing the full range of floor areas as well as balanced numbers of single and double storey dwellings, with a small sample of three storey houses. Apartments were excluded from the sample set but townhouses were retained.

The sample is composed predominately of concrete slab on ground floor designs, with a smaller component of timber floored dwellings with enclosed subfloor design. The selected dwellings had a variety of external wall constructions and a range of external insulation.

2.2. Climates selected for study

The study utilises weather data from the new 69 climate sites in the recently updated and expanded Australian Climate Data Bank (Energy Partners, 2005). The climates in Table 1 were selected for the comparison study. These climate locations include all state and territory capital cities plus 3 other climates so that the study covers all 8 BCA climate zones.

Climate Code[1]	AccuRate Climate #	Climate Name
CZ0101	1	Darwin Airport
CZ0204	10	Brisbane
CZ0306	6	Alice Springs
CZ0411	27	Mildura AMO
CZ0504	13	Perth
CZ0510	56	Mascot RO (East Sydney)
CZ0512	16	Adelaide
CZ0608	21	Melbourne RO
CZ0703	24	Canberra Airport
CZ0708	26	Hobart
CZ0801	25	Cabramurra

Table 1: Timber-Concrete Floor Study Climate Set

2.3. Modifying the base data files

All dwelling files were individually reviewed to determine the main construction type and to evaluate the internal thermal zoning. All internal walls were modified to be plasterboard on stud construction and the upper floor in two-storey dwellings was changed to lightweight construction if necessary.

Each dwelling was divided into areas of three zone types:

- day-time conditioned
- night-time conditioned
- unconditioned.

[1] Proposed new climate numbering system for AccuRate. The first two digits are the BCA climate zone, the last two digits are the Northerly ranking of that location within that BCA climate zone.

Insulation was added into the walls that separated these zone types. In multi-storey dwellings insulation was added into the ceiling/floor between different zone types. This insulation strategy put insulation in walls between the living room and bedroom, for example, but not between the living room and kitchen. This method reduces the total insulation material and labour required.

Three levels of insulation were simulated in the study:

- No additional internal insulation;
- R1.0 internal insulation;
- R2.0 internal insulation.

Air gaps were used to fill the 90mm stud widths where the insulation thickness was insufficient to fill the entire space (20mm air gap / R1.0 glass fibre batt insulation / 20mm air gap).

A number of dwellings had the internal walls to a garage zone which contained insulation. This insulation was retained.

The AccuRate software simulates conditioning in different zone types at different times of the day and to different temperatures. In daytime conditioned zones (Nominated in AccuRate as 'Living', 'Living/Kitchen', and 'Other Daytime Conditioned'), heating and cooling are available from 0700 to 2400. In night-time conditioned zones, heating and cooling are available from 1600 to 0900. The thermostat settings for heating are 20°C in the day-time conditioned zones and 15°C to 18°C in the night-time conditioned zones. The cooling thermostat setting varies depending on climate, ranging from 23°C in Cabramurra to 26.5°C in Darwin. The thermostat settings for each of the 11 climates in the study are included in Appendix 1.

3. Results

3.1. Results Overview

Across the 11 climates studied, the average star rating difference between a dwelling with no additional internal insulation and the same dwelling with R2.0 insulation in internal walls between differently conditioned zones was 0.15 stars. The average difference between the non-insulated and R1.0 version was found to be 0.13 stars. The size of this benefit varied slightly across the 11 climates, with the benefit of internal insulation being greatest in the cooler climates of Cabramurra and Hobart, and smallest in the Brisbane climate. A summary of the results for is shown in Table 2.

	BCA Climate Code	AccuRate Climate Zone	Average	Maximum	Minimum	Standard Deviation
Darwin	CZ0101	01	0.16	0.35	-0.13	0.08
Brisbane	CZ0204	10	0.05	0.38	-0.27	0.10
Alice Springs	CZ0306	06	0.13	0.55	-0.62	0.14
Mildura	CZ0411	27	0.14	0.45	-0.05	0.10
Perth	CZ0504	13	0.14	0.44	-0.33	0.12
Sydney East	CZ0510	56	0.14	0.54	-0.09	0.12
Adelaide	CZ0512	16	0.17	0.49	0.00	0.11
Melbourne	CZ0608	21	0.18	0.52	-0.02	0.10
Canberra	CZ0703	24	0.17	0.49	-0.03	0.10
Hobart	CZ0708	26	0.19	0.54	-0.01	0.11
Cabramurra	CZ0801	25	0.19	0.49	0.04	0.09
Average			0.15	0.48	-0.14	0.11

Table 2: Star Rating Difference (R2.0 - Original)

Figure 1 graphically compares the star ratings of the original and the R2.0 internally insulated dwellings. The red line represents a 1:1 ratio, showing that the insulated version of the dwelling performs better in almost all cases and that there is no obvious difference in the benefit depending on the original star rating.

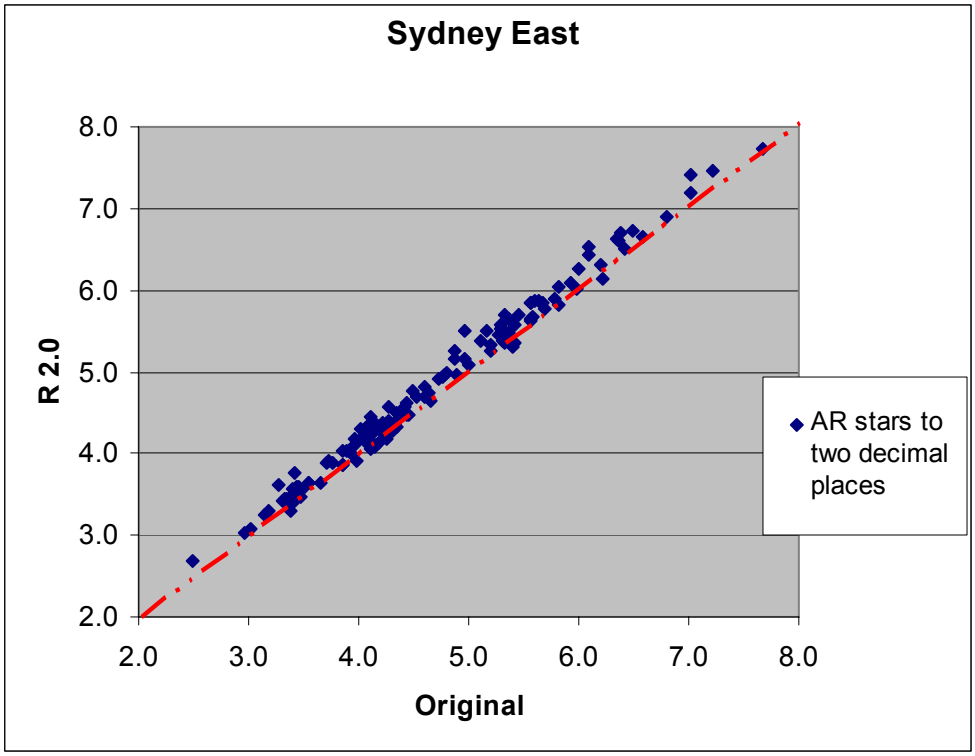


Figure 1: Comparison of AccuRate star values between the R2.0 insulation added in the internal walls and the Original house design, for the Sydney East climate.

3.2. Design and insulation of external envelope

The sample set of dwellings was made-up of a mixture of 'Enhanced' and 'Non-Enhanced' dwellings. 'Enhanced' dwellings had high levels of bulk external insulation and improved glazing added to improve the ratings of the original design. Figure 2 shows the scattering of the 'Enhanced' and "Non-Enhanced' dwellings in the results. Since most houses lie around the same star range, those with less insulation are generally of better design. The graph shows no clear trend to favour either group of dwellings in the set.

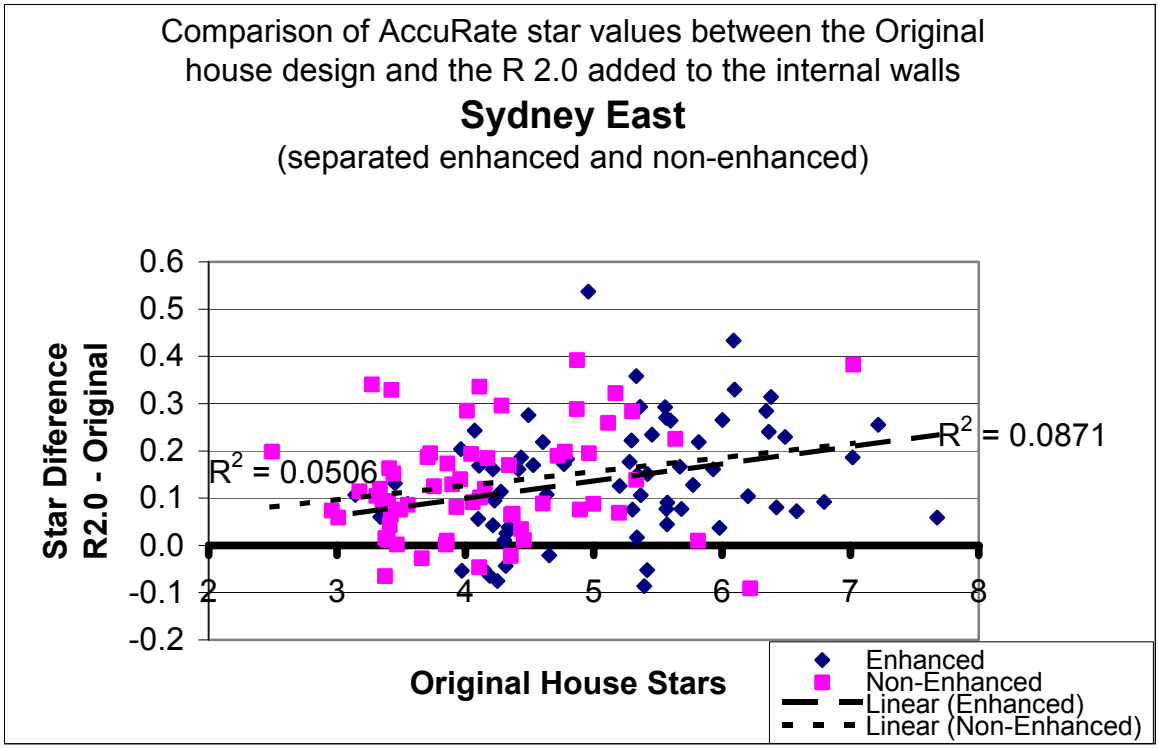


Figure 2: Scatter graph of R2.0 – Original Star difference, in Sydney East Climate

This figure is plotted from the Sydney East climate zone results, chosen as the representative climate on a population basis. The plots for the other climate zones are similar in results, with no strong trends showing.

Comparison plots where also completed in testing for further relationships between the star difference and key housing characteristics. Tests were completed for the characteristics of Total Glazing, Northerly Glazing, NCFA, External CFA, and External wall area. Appendix 2 contains all of these plots, which show no strong trends.

3.3. Single and multi-storey dwellings

The results were analysed to see whether the number of storeys affected the performance of the internal insulation. Although the internal floors and ceilings were insulated with the same method and to the same levels as the internal walls, the heat transfer through the internal floors is different to that through the walls as it is in a vertical rather than horizontal direction. Table 3 compares the average differences between the original

dwellings and those with R2 internal insulation with results separated into single and multi-storey sets.

	BCA Climate Code	AccuRate Climate Zone	Average: Single-Storey	Average: Multi-Storey
Darwin	0101	01	0.16	0.15
Brisbane	0204	10	0.07	0.02
Alice Springs	0306	06	0.15	0.11
Mildura	0411	27	0.15	0.13
Perth	0504	13	0.16	0.12
Sydney East	0510	56	0.16	0.10
Adelaide	0512	16	0.18	0.15
Melbourne	0608	21	0.18	0.18
Canberra	0703	24	0.17	0.17
Hobart	0708	26	0.17	0.23
Cabramurra	0801	25	0.19	0.15
Average			**0.16**	**0.14**

Table 3: Average Star Ratings of Single & Multi-storey dwellings

Although the average effects are similar the differences within certain climates are significant. Internal insulation improved the star ratings of single-storey dwellings by more than the multi-storey dwellings in the majority of climates, while the star-ratings of multi-storey dwellings improved more than single-storey dwellings in only the Hobart climate. The combination of cool temperatures and relatively low solar gain in Hobart may cause this result. The other climates show that the internal wall insulation is generally less effective when there are the additional surfaces of internal floors and ceilings for the heat to escape.

3.4. Common dwelling characteristics

The results for each climate were sorted by the difference between the original and the R2.0 internally insulated version. The dwellings that consistently gave high or low

differences were individually investigated in order to check for certain characteristics causing the results. Table 4 summarises the characteristics of these outlying dwellings.

A significant characteristic from this table is the percentage of internal insulated wall area to external wall area. For dwellings that showed large improvements this percentage was more than twice that of the dwellings that gave the least improvement. Also noted was that more multi-storey dwellings gave lower improvements.

Since the temperature differences will be greater between conditioned and unconditioned zones these internal walls are expected to be more significant than those between the day-time and night-time conditioned zones. Generally the dwellings giving high differences had greater internal wall area between the day-time conditioned zones and the unconditioned zones.

Filename	Int Wall Insul (m^2)	Area Non Insul Int Wall (m^2)	Area of Ext Wall (m^2)	Int Wall Insul/Ext Wall Area	Floor Area (Excluding garage, m^2)	# of Floors	Glazing Area (m^2)	Ceiling Insul (R-Value)	Unconditioned space (m^2)				
									Walls to Day Cond	Walls To Night Cond	Ext Walls	Floors to Day Cond	Floors to Night Cond
Maximum 10 Outliers													
4CDC1614	67	52	171	0.39	204	1	27	3	32	11	49		
4HDCE621	114	89	142	0.80	226	1	37	5	39	4	57		
4WDLE502	126	99	330	0.38	251	1	55	5	46	21	90		
5LACE662	70	34	116	0.60	92	2	21	5	26	12	21	8	13
2MAC2004	94	50	66	1.43	146	2	18	3	51	15	11	9	14
4HDCE626	144	62	150	0.96	204	1	35	5	63	20	62		
4SDS1583	90	12	145	0.62	143	1	31	2	38		52		
4WDLE501	52	45	131	0.40	194	1	27	5	10	19	22		
5BAC1639	37	15	59	0.63	72	1	11	4	19	7	9		
5WDB1696	150	94	173	0.87	215	1	57	3	48	22	49		
Max	150.33	99.30	329.66	1.43	251.02	2.00	57.17	5.00	63.29	22.32	90.40	9.03	14.11
Min	37.00	12.00	59.05	0.38	72.42	1.00	10.73	2.00	10.29	4.37	9.06	7.85	13.34
Mean	94.55	55.18	148.37	0.71	174.76	1.20	31.99	3.85	37.32	14.65	42.19	8.44	13.73
Std Dev	38.56	31.10	74.67	0.32	59.02	0.42	14.91	1.27	15.92	6.44	25.96	0.83	0.54
Minimum 10 Outliers													
9IAB2935	88	34	173	0.51	171	2	55	5	35	4	43	9	16
4TDSE576	48	95	191	0.25	139	1	36	5	19	19	54		
4WDTE503	80	78	323	0.25	302	2	66	5	41	7	51		30
5NABE675	27	10	63	0.43	83	2	24	5	9	5	6	1	
9CDTE049	60	84	220	0.27	195	1	47	5	12	37	94		
9IACE248	56	57	177	0.32	163	2	32	5	24		48		10
3DDCE404	72	80	158	0.46	115	1	27	5	25	12	15		
3EDB2903	56	40	261	0.21	206	2	33	3	35		53	5	15
3EDCE406	114	111	232	0.49	272	2	66	5	23	16	18		
4BDCE593	56	30	261	0.21	191	2	33	5	35		44	5	15
Max	114.00	111.00	323.00	0.51	302.00	2.00	66.00	5.00	40.50	37.00	93.80	9.20	29.60
Min	27.00	10.00	63.00	0.21	83.00	1.00	23.50	3.00	9.00	4.00	6.00	1.30	10.00
Mean	65.70	61.90	205.90	0.34	183.70	1.70	41.82	4.80	25.66	14.33	42.48	4.88	17.28
Std Dev	24.04	32.62	71.12	0.12	66.60	0.48	15.65	0.63	10.45	11.49	25.04	3.25	7.31

Table 4: Characteristics of maximum & minimum outliers

4. Conclusion

Adding insulation into internal walls between differently conditioned zones should help maintain the required temperatures within the zone while minimising losses into unconditioned or unused areas. This also means that useful "crossover" heat between conditioned zones that may reduce the temperature differential at start-up would be reduced.

The sample set of dwellings contained houses of various sizes with various sized internal walls between zones. This variation led to significant variations in the amount of added insulation. The dwellings that gave the greatest positive star rating improvement were found to have twice the percentage of internal insulated wall area to external wall area as the dwellings that gave the least improvements.

The average benefit of internal insulation on the energy star rating of the dwelling was found to be 0.15 stars for R2.0 insulation and 0.13 stars for R1.0 insulation. A small number of negative differences were found in the warmer climates which may be due to the internal insulation reducing the ability to dissipate heat that builds inside the zone when it is not being conditioned. The results showed the trend that internal insulation has a greater affect in cooler climates such as Hobart and Cabramurra.

The effect of internal insulation was found to be greatest in single-storey dwellings in most climates. The exception to this was the Hobart climate where the energy performance of multi-storey dwellings improved more significantly than that of single-storey dwellings with internal wall insulation. This may be due to the impact of shorter winter day length in Hobart compared to other cool climates such as Canberra and Cabramurra.

The study found that adding insulation to internal walls between differently conditioned zones can improve the energy star rating by up to 0.5 stars in all but the warmest climates.

Appendix 1

The AccuRate software uses the following information for heating and cooling simulations.

- In zones of type 'Living', 'Living/Kitchen', and 'Other', heating and cooling are available from 0700 to 2400.
- In zones of type 'Bedroom', heating and cooling are available from 1600 to 0900.

AR Climate Zone	Typical Location	Heating (Zones of type 'Living', 'Living/Kitchen', 'Other, 'Garage')	Heating (Zones of Type 'Bedroom') Lower value applies to 0000-0700, higher to 0800-1000	Cooling All conditioned zones
		(°C)	(°C)	(°C)
1	Darwin	20.0	15.0 or 18.0	26.5
10	Brisbane	20.0	15.0 or 18.0	25.5
6	Alice Springs	20.0	15.0 or 18.0	26.5
27	Mildura	20.0	15.0 or 18.0	25.0
13	Perth	20.0	15.0 or 18.0	25.0
56	Sydney East	20.0	15.0 or 18.0	24.5
16	Adelaide	20.0	15.0 or 18.0	25.0
21	Melbourne	20.0	15.0 or 18.0	24.0
24	Canberra	20.0	15.0 or 18.0	24.0
26	Hobart	20.0	15.0 or 18.0	23.0
25	Cabramurra	20.0	15.0 or 18.0	23.0

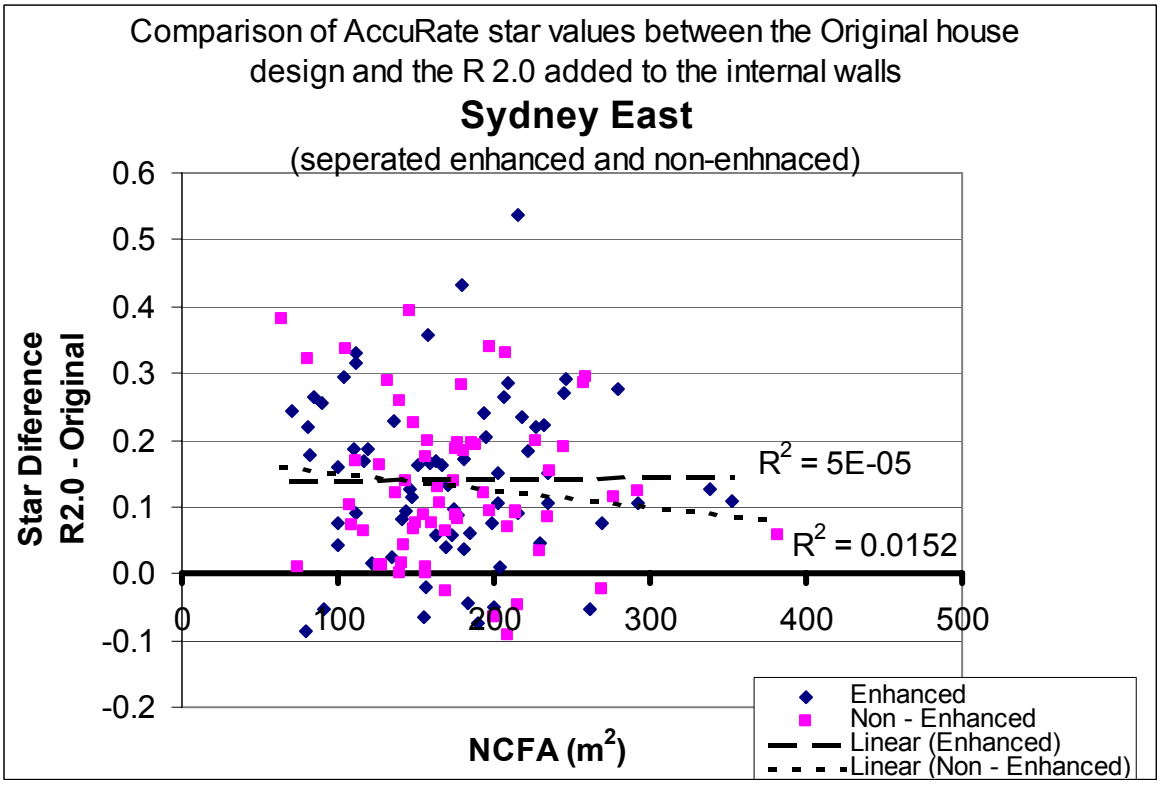
Table 5: AccuRate thermostat settings and operation times

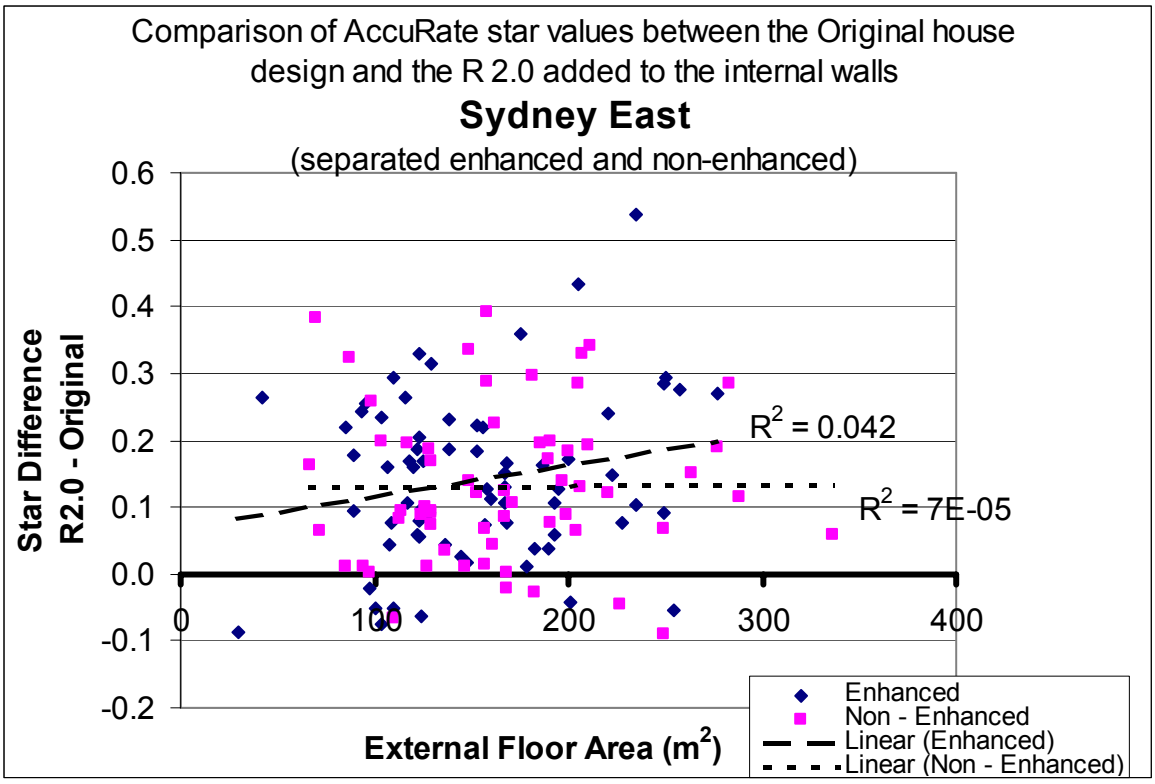
Appendix 2

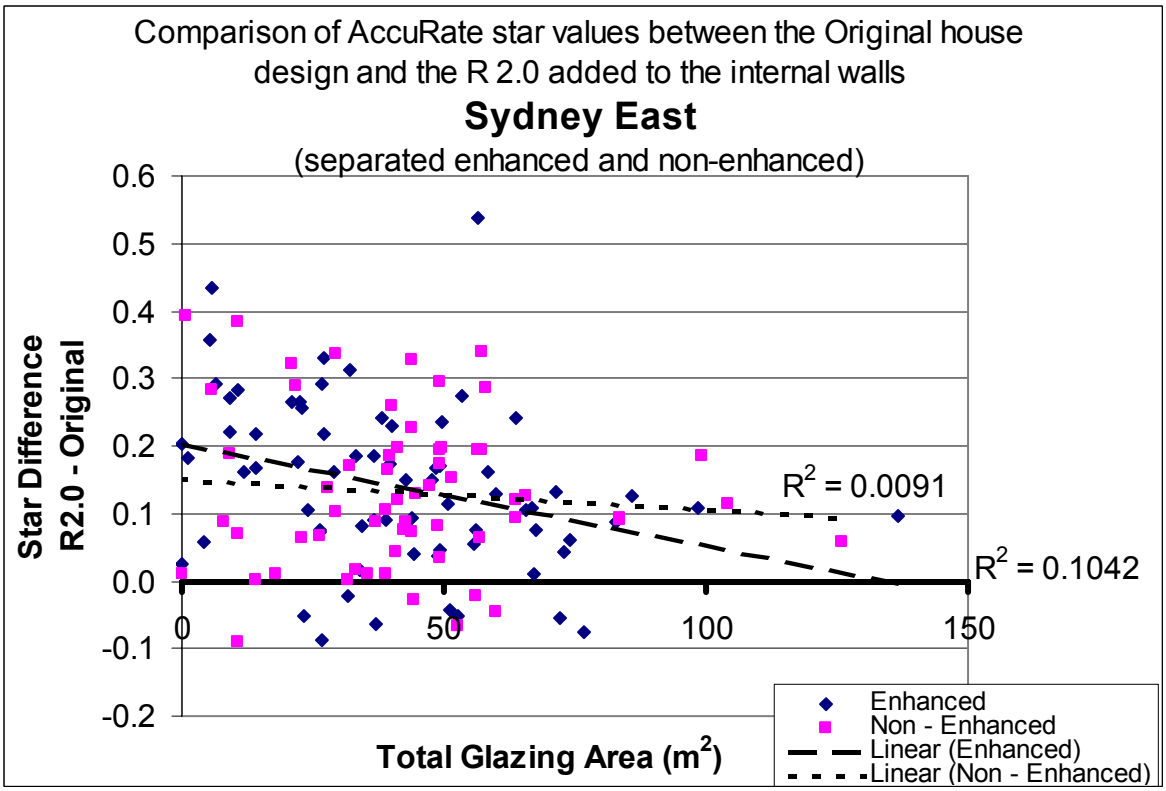
Trends were investigated by sorting the star rating difference results using the following dwelling characteristics:

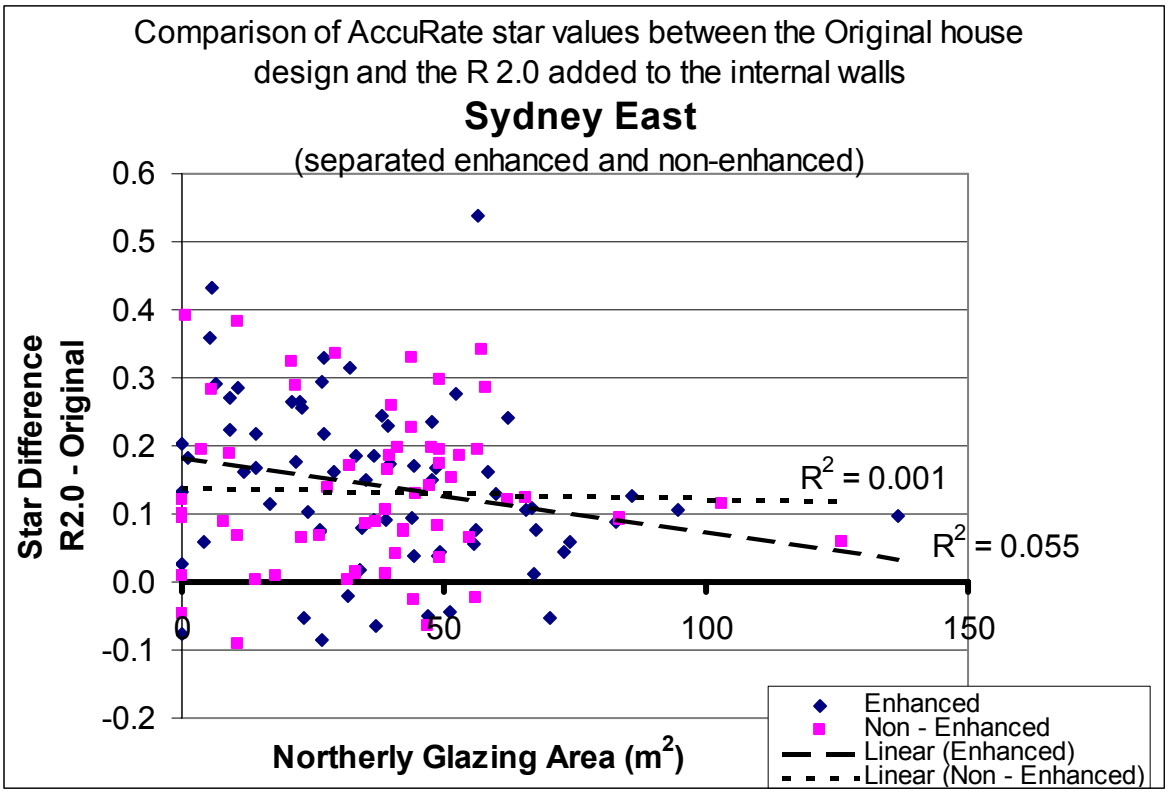
- Net conditioned floor area
- External floor area (ground floor area)
- Total glazing area
- Northerly glazing area
- External wall area

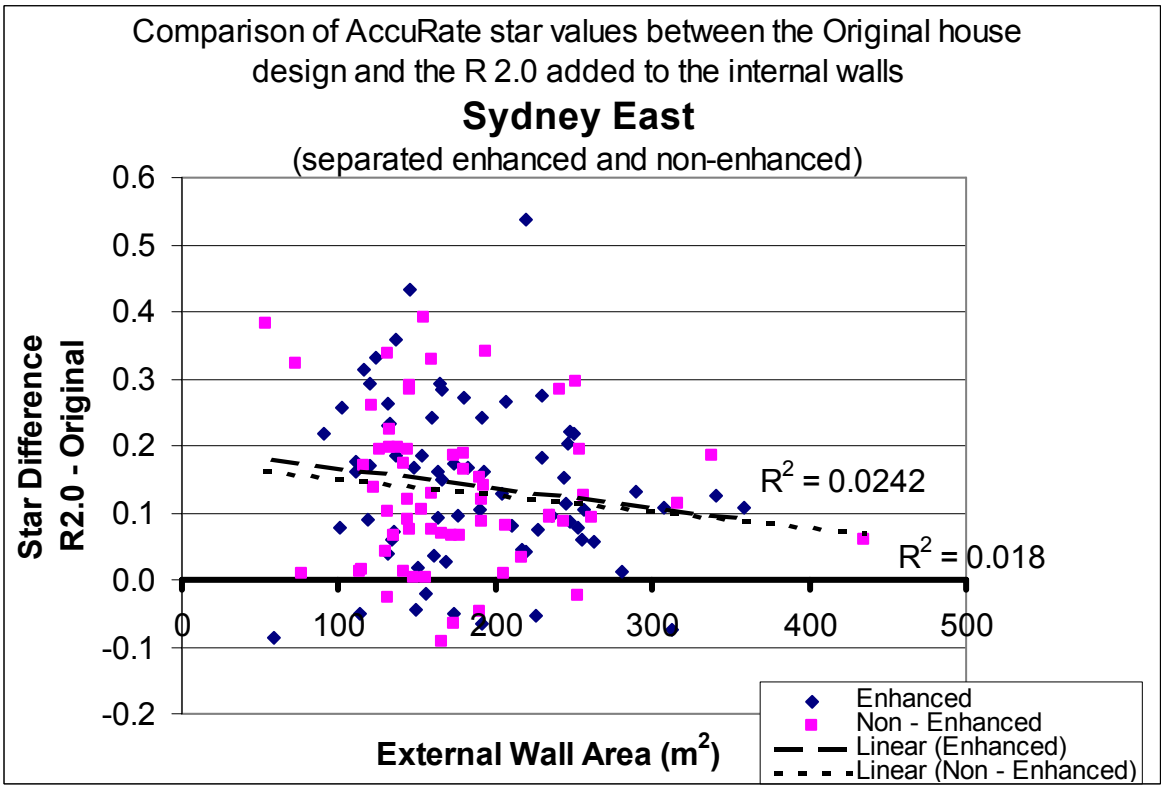
The graphs for the Sydney East climate have been included below. As the scattergraphs show, no distinct trends were found using these characteristics for this or any other climate.




Comparison of AccuRate star values between the Original house design and the R 2.0 added to the internal walls
Sydney East
(separated enhanced and non-enhanced)
Star Difference R2.0 - Original
External Floor Area (m2)
R2 = 0.042
R2 = 7E-05
Enhanced
Non - Enhanced
Linear (Enhanced)
Linear (Non - Enhanced)


Comparison of AccuRate star values between the Original house design and the R 2.0 added to the internal walls
Sydney East
(separated enhanced and non-enhanced)
Star Difference R2.0 - Original
Total Glazing Area (m2)
R2 = 0.0091
R2 = 0.1042
Enhanced
Non - Enhanced
Linear (Enhanced)
Linear (Non - Enhanced)


Comparison of AccuRate star values between the Original house design and the R 2.0 added to the internal walls
Sydney East
(separated enhanced and non-enhanced)
Star Difference R2.0 - Original
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
0
50
100
150
R2 = 0.001
R2 = 0.055
Northerly Glazing Area (m2)
Enhanced
Non - Enhanced
Linear (Enhanced)
Linear (Non - Enhanced)


Comparison of AccuRate star values between the Original house design and the R 2.0 added to the internal walls
Sydney East
(separated enhanced and non-enhanced)
Star Difference R2.0 - Original
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
0
100
200
300
400
500
R2 = 0.0242
R2 = 0.018
External Wall Area (m2)
Enhanced
Non - Enhanced
Linear (Enhanced)
Linear (Non - Enhanced)