Impacts of Variable Air Infiltration Rates and Insulation Installation on Residential Energy Performance

Case Studies using NatHERS Predictive Energy Modelling Software

September 2013

Prepared for:

Department of Resources, Energy and Tourism
2 Phillip Law Street
Canberra ACT 2601

Prepared by:

Sustainability House
Unit 8/938 South Road
Edwardstown SA 5039

Contact: Sally Thompson
Phone: 03 8844 5505
Email: sally.thompson@sustainabilityhouse.com.au

Table of Contents

Phone:1300 308 525
www.sustainabilityhouse.com.au
research@sustainabilityhouse.com.au

INTRODUCTION

The Department of Resources, Energy and Tourism (DRET) commissioned Sustainability House to investigate the impact of variable air infiltration rates and insulation installation on residential energy performance. This investigation was specifically aimed at dwellings designed to the six star standard, as this has now been adopted as the minimum compliance level for most states and territories in Australia.

The aim of this research was to investigate the impact of different rates of air infiltration and insulation installation on the thermal performance of most new homes. Being limited to just two 'typical' designs, this research is not exhaustive, but can be used instead as an indication of what small, medium and large air leaks, gaps and draughts can do to the overall thermal performance of a dwelling designed to otherwise rigorous standards.

By using Nationwide House Energy Ratings Scheme (NatHERS) software to assess this impact, this research examines the calculated effect of air infiltration rates in simulation software, rather than undertaking practical testing in real homes. While onsite inspections of various houses could offer more precise data on these effects, simulation software offers the possibility of examining a larger range of scenarios in a much shorter time frame, which can then inform further research and compliance options.

This research has found that the impact on thermal performance of not building to design standards can range from the minor to the major. Large air infiltration rates and major reductions in insulation can reduce the star rating of a dwelling by several stars, while smaller faults can have little to no change. There is evidence, however, that minor faults combined can have a very large negative impact on the thermal performance of the dwelling, and therefore build quality relating to energy efficiency is an important issue which is not currently addressed in Australian regulation. Further research is required across Australia to quantify the discrepancy between as-designed and as-built energy efficiency performance in order to gain insights into the extent of this issue.

METHODOLOGY

Two typical six-star house designs were chosen to undertake this research. The first is a lightweight design with weatherboard external walls and elevated timber flooring. The subfloor space is a standard depth of 600mm, and the house features three bedrooms, with an open plan kitchen, meals and family area at the rear of the house. The living and entry area are at the front of the house, and all external walls are shaded by the 300mm gable. The dwelling features a small 1500m wide verandah to the front entry area.

The second dwelling is a single-storey four-bedroom dwelling of brick veneer and concrete-slab-on-ground construction. The house features a double garage, an open plan kitchen, meals and family area, as well as a separate living/entry area. All walls are shaded by 450mm eaves.

These dwellings were initially rated in AccuRate using standard insulation levels and construction specifications, and then improved to achieve 6.0 stars in at least one climate zone. The automated simulation software RoboRater was then used to assess all possible variations in air infiltration levels and insulation levels, assessing each design in eight climate zones for each Australian capital city to give a broad range of possible outcomes. The climate zones used for each capital city were 1 for Darwin, 10 for Brisbane, 13 for Perth, 16 for Adelaide, 17 for Sydney, 21 for Melbourne, 24 for Canberra and 26 for Hobart.

Air infiltration levels were assessed at 100% of NatHERS base assumptions, then at 105%, 110%, 120%, 150%, 200% and 300%. Air infiltration rates were selected to provide a representative range of likely as-built variability from the assumed air infiltration rates in the NatHERS software, where the maximum increase of 300% was selected based on blower door test results from a CSIRO study. These air infiltration levels were assessed as air changes per hour (ACH) for the dwelling at 50 Pascals (20 times the natural rate) and calculated using 'Infiltration Calculations in AccuRate v1.1.4.1' by Dong Chen. Each zone's ACH was calculated, and then a whole of dwelling average was calculated according to percentage volume of each zone.

While European standard of dwelling sealing can be relatively high, with initiatives such as Passivhaus impacting building sealing, Australian sealing standards are generally seen as low, with high levels of infiltration. These dwellings were assessed as per standard new home sealing practices, with sealed exhaust fans and no wall vents or fire places included in the design, and weatherstripping to all windows and external doors (except those to garages).

Variable insulation options were also included in this study, which were selected based on thermal imaging findings by Sustainability House and anecdotal industry feedback. This suggests that most typical insulation installation issues include discontinuity. For example, gaps in ceiling insulation can occur around exhaust fans and lights; or near the roof perimeter where attic spaces are small and it is more difficult to fit insulation; or in external walls above or beside windows where insulation batts require cutting. These scenarios were represented by 70, 80 and 90% insulation levels whereby 30, 20 and 10% of insulation was absent. Another insulation installation issue involves the absence of insulation to entire zones which was assessed in the following scenarios: insulation removed from living ceilings, all ceilings, living floors, all floors, living external walls, and all external walls.

RESULTS

Overall, the lightweight dwelling had lower performance results than the heavyweight dwelling in most climate zones. While both dwellings were assessed to a 6.0 star standard in several climate zones to begin with, the lightweight dwelling failed to achieve this in all of the warmer climate zones.

The lightweight dwelling performed particularly poorly in Perth, where it achieved only 4.6 stars. Both dwellings performed better in the colder climates.

Table 1: Construction and initial results of lightweight building in each capital city

	Specification		Star Rating
Ext Wall Type	Weatherboard	Darwin	5.8
Ext Wall Ins	R2.5 Rockwool	Brisbane	5.4
Internal Wall	Plasterboard on studs	Perth	4.6
Int Wall Ins	None	Adelaide	5.4
Ceiling Ins	R6.0 Glasswool	Sydney	5.6
Glazing	Stegbar Alum ComfortPlus Neutral	Melbourne	6.1
Floor Type	Elevated timber with subfloor	Canberra	6.1
Awnings/Ceiling Fans	To all living/bedroom glazing/areas	Hobart	6.6
Average air infiltration	19.7 ACH		

Table 2: Construction and initial results of heavyweight building in each capital city

	Specification		Star Rating
Ext Wall Type	Brick Veneer	Darwin	5.7
Ext Wall Ins	R2.0 Glasswool	Brisbane	5.9
Internal Wall	Plasterboard on studs	Perth	6.1
Int Wall Ins	None	Adelaide	6.5
Ceiling Ins	R4.0 Glasswool	Sydney	6.3
Glazing	Stegbar Alum 3mm Clear	Melbourne	6.4
Floor type	Concrete slab on ground	Canberra	6.3
Awnings/Ceiling Fans	None	Hobart	6.4
Average air infiltration	27.4 ACH		

Air Infiltration

For the lightweight dwelling, the average whole-of-house air change per hour at 50 Pascals was 19.7, higher than standard air change figures at 50 Pascals, calculated at around 15 ACH.

The habitable areas of the dwelling tended to have air change rates of around 2-5 ACH at 50 Pa, while the roof space and the subfloor space increased the average with much higher air change rates.

Table 3: Air infiltration rates at 50 Pascals per zone of lightweight building in each capital city

	Natural Air Infiltration (ACH)							
Zone	Darwin	Brisbane	Perth	Adelaide	Sydney	Melbourne	Canberra	Hobart
Kit/Mls/Fam	4.50	4.55	4.33	4.36	3.97	4.77	3.88	4.60
Living/Entry	5.44	5.50	5.23	5.28	4.81	5.76	4.70	5.56
Bed 3	4.50	4.55	4.33	4.36	3.97	4.77	3.88	4.60
Ldy/Bth/WC	7.30	7.35	7.13	7.16	6.77	7.57	6.68	7.40
Pdr	2.62	2.65	2.52	2.54	2.30	2.78	2.25	2.68
Hallway	2.62	2.65	2.52	2.54	2.30	2.78	2.25	2.68
Bed 2	4.50	4.55	4.33	4.36	3.97	4.77	3.88	4.60
Study	4.50	4.55	4.33	4.36	3.97	4.77	3.88	4.60
Master	5.90	5.95	5.73	5.76	5.37	6.17	5.28	6.00
Subfloor	33.04	33.78	30.52	31.04	25.33	36.89	23.99	34.52
Roof Space	74.02	75.04	70.57	71.28	63.46	79.30	61.63	76.05

The average standard air infiltration assumption across the house and across climate zones was 19.7 ACH. Canberra showed the lowest base assumption, while Melbourne showed the highest. The equivalent ACH figure for each air infiltration increase is shown in the table below.

Table 4: Average air infiltration rates of lightweight building in each capital city

	Air Infiltration at 50 Pascals (ACH)								
Air infilt-ration	Darwin	Brisbane	Perth	Adelaide	Sydney	Melbourne	Canberra	Hobart	Ave
100%	20.6	20.9	19.5	19.7	17.3	22.2	16.7	21.2	19.7
105%	21.6	21.9	20.5	20.7	18.1	23.3	17.5	22.2	20.7
110%	22.6	23.0	21.4	21.7	19.0	24.4	18.4	23.3	21.7
120%	24.7	25.0	23.4	23.6	20.7	26.6	20.0	25.4	23.7
150%	30.8	31.3	29.2	29.6	25.9	33.3	25.1	31.8	29.6
200%	41.1	41.7	39.0	39.4	34.5	44.4	33.4	42.4	39.5
300%	61.7	62.6	58.4	59.1	51.8	66.6	50.1	63.6	59.2

The variation between 100% air infiltration and 300% air infiltration was between 0.7 and 1.1 stars for each capital city, with the largest variation in Hobart and the smallest in Perth and Adelaide. The climate zones that performed best initially had a larger variation, while those with smaller initial ratings varied less.

Table 5: Effect of air infiltration rates on lightweight building in each capital city

Air infiltration	Star Rating							
	Darwin	Brisbane	Perth	Adelaide	Sydney	Melbourne	Canberra	Hobart
100%	5.8	5.4	4.6	5.4	5.6	6.1	6.1	6.6
105%	5.8	5.4	4.6	5.4	5.5	6	6.1	6.6
110%	5.7	5.4	4.6	5.4	5.4	5.9	6.1	6.5
120%	5.6	5.3	4.6	5.3	5.4	5.9	6	6.4
150%	5.4	5.2	4.4	5.2	5.3	5.7	5.9	6.3
200%	5.2	4.9	4.3	4.9	4.9	5.4	5.6	5.9
300%	4.7	4.4	3.9	4.5	4.5	4.9	5.1	5.3

Table 6: Star difference between different air infiltration rates for lightweight building

Air infiltration	Star Difference							
	Darwin	Brisbane	Perth	Adelaide	Sydney	Melbourne	Canberra	Hobart
100%-105%	0	0	0	0	0.1	0.1	0	0
100%-110%	0.1	0	0	0	0.2	0.2	0	0.1
100%-120%	0.2	0.1	0	0.1	0.2	0.2	0.1	0.2
100%-150%	0.4	0.2	0.2	0.2	0.3	0.4	0.2	0.3
100%-200%	0.6	0.5	0.3	0.5	0.7	0.7	0.5	0.7
100%-300%	1.1	1.0	0.7	0.9	1.1	1.2	1.0	1.3

The heavyweight dwelling performed better across all climate zones, showing general ratings of around the 6.0-star level. Air infiltration was relatively low in the living areas of the house – around 5 ACH – but the garage and roof space had much higher air infiltration rates, bringing the whole-of-house rate up.

Table 7: Air infiltration rates at 50 Pascals per zone of heavyweight building in each capital city

	Air Infiltration at 50 Pascals (ACH)							
Zone	Darwin	Brisbane	Perth	Adelaide	Sydney	Melbourne	Canberra	Hobart
Garage	10.02	10.12	9.67	9.74	8.96	10.55	8.77	10.22
Kit/Meals	5.27	5.32	5.08	5.11	4.69	5.55	4.59	5.38
Bed 4	5.27	5.32	5.08	5.11	4.69	5.55	4.59	5.38
Bed 3	5.27	5.32	5.08	5.11	4.69	5.55	4.59	5.38
Hallway	2.93	2.96	2.84	2.86	2.64	3.08	2.59	2.99
Bth/WC/Ldy	8.27	8.32	8.08	8.11	7.69	8.55	7.59	8.38
Bed 2	5.27	5.32	5.08	5.11	4.69	5.55	4.59	5.38
Master	7.07	7.12	6.88	6.91	6.49	7.35	6.39	7.18
Entry/Living	5.67	5.72	5.48	5.51	5.09	5.95	4.99	5.78
Roof Space	71.09	72.02	67.93	68.58	61.44	75.91	59.77	72.94

The base air infiltration rate was 27.4 ACH, and this ranged up to 82.3 ACH at 300% of the base assumption. Air change per hour rates were highest across the board in Melbourne, and lowest in Canberra.

Table 8: Average air infiltration rates of heavyweight building in each capital city

Air infilt-ration	Air changes per hour (whole of house)								
	Darwin	Brisbane	Perth	Adelaide	Sydney	Melbourne	Canberra	Hobart	Ave
100%	28.4	28.7	27.2	27.4	24.7	30.2	24.0	29.1	27.4
105%	29.8	30.2	28.5	28.8	25.9	31.7	25.2	30.5	28.8
110%	31.2	31.6	29.9	30.1	27.1	33.2	26.4	32.0	30.2
120%	34.0	34.5	32.6	32.9	29.6	36.3	28.8	34.9	32.9
150%	42.5	43.1	40.7	41.1	37.0	45.3	36.0	43.6	41.2
200%	56.7	57.4	54.3	54.8	49.3	60.4	48.0	58.2	54.9
300%	85.1	86.2	81.5	82.2	74.0	90.6	72.1	87.2	82.3

Variations between 100% and 300% air infiltration were much higher than the lightweight building, with variations averaging over 1.1 stars. The lowest variation could be seen in Brisbane, Perth and Adelaide, while the other capital cities had over 1.1 star variations. While the largest variation for the lightweight building was seen in Hobart, with Darwin the next largest, the heavyweight building had the last variation in Hobart, with Darwin the next largest.

Table 9: Effect of air infiltration rates on heavyweight building in each capital city

Air changes per hour	Star Rating							
	Darwin	Brisbane	Perth	Adelaide	Sydney	Melbourne	Canberra	Hobart
100%	5.7	5.9	6.1	6.5	6.3	6.4	6.3	6.4
105%	5.6	5.9	6.1	6.5	6.3	6.4	6.2	6.4
110%	5.6	5.9	6.1	6.4	6.3	6.4	6.2	6.3
120%	5.4	5.9	6	6.4	6.2	6.4	6.2	6.3
150%	5.2	5.6	5.9	6.3	5.9	6.2	5.9	6.1
200%	4.9	5.3	5.7	6	5.7	5.8	5.7	5.7
300%	4.2	4.9	5.2	5.5	5.1	5.2	5.2	5.1

Table 10: Star difference between different air infiltration rates for heavyweight building

Air changes per hour	Star Difference							
	Darwin	Brisbane	Perth	Adelaide	Sydney	Melbourne	Canberra	Hobart
100%-105%	0.1	0	0	0	0	0	0.1	0
100%-110%	0.1	0	0	0.1	0	0	0.1	0.1
100%-120%	0.3	0	0.1	0.1	0.1	0	0.1	0.1
100%-150%	0.5	0.3	0.2	0.2	0.4	0.2	0.4	0.3
100%-200%	0.8	0.6	0.4	0.5	0.6	0.6	0.6	0.7
100%-300%	1.5	1.0	0.9	1.0	1.2	1.2	1.1	1.3

For both dwellings, increasing air infiltration rates had a fairly even impact across the board for heating and cooling loads.

For the lightweight dwelling in Darwin, the effect of increasing air infiltration rates from 100% to 300% had a minuscule impact on the raw heating load, taking it from 0 to 0.01 MJ/m^2. The raw cooling load increased by 75.19 MJ/m^2, while the area adjusted total load increased by 68.3 MJ/m^2.

In Adelaide, the raw heating load increased by 30.13 MJ/m^2 while the raw cooling load only increased by 4.48 MJ/m^2. The area adjusted total increased by 29.4 MJ/m^2.

In Hobart, like in Darwin, more extreme changes in heating and cooling loads could be seen. The raw heating load increased by 65.68 MJ/m^2 while the raw cooling load increased by 0.03 MJ/m^2. The area adjusted total increased by 55.7 MJ/m^2.

Table 11: Lightweight building heating and cooling loads in Darwin

Air infiltration	Raw Heating Load	Raw Cooling Load	Raw Total Load	Area Adj. Total Load	Star Rating
100%	0	399.27	399.3	362.7	5.8
105%	0	400.63	400.6	363.9	5.8
110%	0	404.91	404.9	367.8	5.7
120%	0	409.05	409.1	371.6	5.6
150%	0	422.73	422.7	384	5.4
200%	0	439.36	439.4	399.2	5.2
300%	0.01	474.46	474.5	431	4.7

Table 12: Lightweight building heating and cooling loads in Adelaide

Air infiltration	Raw Heating Load	Raw Cooling Load	Raw Total Load	Area Adj. Total Load	Star Rating
100%	58.67	73.57	132.3	112.3	5.4
105%	59.34	73.48	132.8	112.8	5.4
110%	60.4	73.54	133.9	113.7	5.4
120%	61.72	73.76	135.5	115.1	5.3
150%	66.58	74.54	141.1	119.8	5.2
200%	73.83	75.49	149.3	126.8	4.9
300%	88.8	78.05	166.9	141.7	4.5

Phone:1300 308 525
www.sustainabilityhouse.com.au
research@sustainabilityhouse.com.au

Table 13: Lightweight building heating and cooling loads in Hobart

Air infiltration	Raw Heating Load	Raw Cooling Load	Raw Total Load	Area Adj. Total Load	Star Rating
100%	146.92	5.25	152.2	129	6.6
105%	148.29	5.25	153.6	130.2	6.6
110%	150.94	5.14	156	132.2	6.5
120%	153.63	5.14	158.7	134.5	6.4
150%	164.56	5.09	169.7	143.9	6.3
200%	179.94	5.09	185	156.8	5.9
300%	212.6	5.28	217.9	184.7	5.3

For the heavyweight dwelling in Darwin, there was absolutely no change in the heating load, which remained at 0 MJ/m^2 regardless of the increase in air infiltration rates. The raw cooling load, on the other hand, increased by 100.29 MJ/m^2, which resulted in a total area adjusted load change of 96.2 MJ/m^2.

In Adelaide, the heavyweight building experienced an increase in the raw heating load of 26.86 MJ/m^2, while the raw cooling load only increased by 2.34 MJ/m^2. The total area adjusted load increased by 26.7 MJ/m^2.

In Hobart, the raw heating load increased by 64.35 MJ/m^2, the raw cooling load increased by just 0.06 MJ/m^2 and the area adjusted total load increased by 58.6 MJ/m^2.

Table 14: Heavyweight building heating and cooling loads in Darwin

Air infiltration	Raw Heating Load	Raw Cooling Load	Raw Total Load	Area Adj. Total Load	Star Rating
100%	0	386.14	386.1	370.5	5.7
105%	0	388.63	388.6	372.9	5.6
110%	0	393.82	393.8	377.8	5.6
120%	0	397.7	397.7	381.6	5.4
150%	0	415.78	415.8	399	5.2
200%	0	440.37	440.4	422.6	4.9
300%	0	486.43	486.4	466.7	4.2

Table 15: Heavyweight building heating and cooling loads in Adelaide

Air infiltration	Raw Heating Load	Raw Cooling Load	Raw Total Load	Area Adj. Total Load	Star Rating
100%	39.58	49.94	89.5	82	6.5
105%	40.18	50.06	90.3	82.7	6.5
110%	41.2	50.08	91.3	83.6	6.4
120%	42.03	50.01	92	84.3	6.4
150%	46.4	50.24	96.6	88.5	6.3
200%	52.86	50.81	103.7	95	6
300%	66.44	52.28	118.7	108.7	5.5

Table 16: Heavyweight building heating and cooling loads in Hobart

Air infiltration	Raw Heating Load	Raw Cooling Load	Raw Total Load	Area Adj. Total Load	Star Rating
100%	147.17	3.38	150.6	137.4	6.4
105%	148.58	3.45	152.1	138.7	6.4
110%	151.24	3.49	154.7	141.1	6.3
120%	153.16	3.44	156.6	142.9	6.3
150%	163.93	3.39	167.3	152.6	6.1
200%	179.5	3.28	182.8	166.8	5.7
300%	211.52	3.44	214.9	196	5.1

Insulation

Reductions in insulation showed a wide range of impacts on both dwellings, reducing star ratings to under 1.0 star in some instances.

Reductions in ceiling and external wall insulation of up to 30% did not result in drastic reductions in star ratings, with reductions ranging from 0 to 0.4 stars. The impact of these changes differed, however, for each building type.

The lightweight building saw reductions of 0.1 to 0.2 stars when ceiling insulation was reduced by 30%, while the heavyweight building saw reductions of 0.1 to 0.4 stars for the same change. The lightweight dwelling, however, averaged changes of 0.2 stars when the external wall insulation was reduced by 30%, while the heavyweight building saw zero change to star rating in four climate zones for the same reduction.

When ceiling or external wall insulation was removed entirely, star ratings plummeted for both dwellings. Star ratings ranged from 0.8 to 2.1 for both dwellings without ceiling insulation, while removing external wall insulation had less impact, especially for the heavyweight dwelling, which benefits from the high thermal mass of its external wall construction.

Table 17: Lightweight building ceiling insulation loss results in all capital cities

Ceiling Insulation Loss	Star Rating							
	Darwin	Brisbane	Perth	Adelaide	Sydney	Melbourne	Canberra	Hobart
100% Living	5.8	5.4	4.6	5.4	5.6	6.1	6.1	6.6
90% Living	5.8	5.4	4.6	5.4	5.5	6	6.1	6.6
80% Living	5.7	5.4	4.6	5.3	5.4	5.9	6.1	6.6
70% Living	5.7	5.3	4.5	5.3	5.4	5.9	6	6.5
0% Living	1.3	1.2	1.3	1.8	1.2	2.3	2.3	2.8
0% T/out	1.0	0.8	0.9	1.3	0.8	1.7	1.7	2.1

Phone:1300 308 525
www.sustainabilityhouse.com.au
research@sustainabilityhouse.com.au

Table 18: Heavyweight building ceiling insulation loss results in all capital cities

Ceiling Insulation Loss	Star Rating							
	Darwin	Brisbane	Perth	Adelaide	Sydney	Melbourne	Canberra	Hobart
100% Living	5.7	5.9	6.1	6.5	6.3	6.4	6.3	6.4
90% Living	5.6	5.9	6	6.4	6.3	6.4	6.2	6.4
80% Living	5.6	5.8	5.9	6.4	6.1	6.4	6.2	6.3
70% Living	5.5	5.7	5.8	6.3	5.9	6.3	6.1	6.3
0% Living	0.9	1.2	1.4	1.8	1.2	2.3	2.2	2.5
0% T/out	0.9	1.1	1.1	1.4	1.1	1.8	1.6	1.9

Table 19: Lightweight building external wall insulation loss results in all capital cities

Ext Wall Insulation Loss	Star Rating							
	Darwin	Brisbane	Perth	Adelaide	Sydney	Melbourne	Canberra	Hobart
100% Living	5.8	5.4	4.6	5.4	5.6	6.1	6.1	6.6
90% Living	5.7	5.4	4.6	5.3	5.4	6	6.1	6.6
80% Living	5.7	5.3	4.5	5.3	5.4	5.9	6	6.5
70% Living	5.6	5.2	4.4	5.2	5.3	5.9	5.9	6.4
0% Living	3.4	3.2	2.8	3.3	3.2	3.9	3.9	4.4
0% T/out	2.8	2.6	2.2	2.6	2.5	3.2	3.1	3.6

Table 20: Heavyweight building external wall insulation loss results in all capital cities

Ext Wall Insulation Loss	Star Rating							
	Darwin	Brisbane	Perth	Adelaide	Sydney	Melbourne	Canberra	Hobart
100% Living	5.8	5.9	6.1	6.5	6.3	6.4	6.3	6.4
90% Living	5.7	5.9	6.1	6.5	6.3	6.4	6.2	6.4
80% Living	5.6	5.9	6.1	6.4	6.3	6.4	6.2	6.4
70% Living	5.6	5.9	6	6.4	6.3	6.4	6.2	6.4
0% Living	5.3	5.7	5.4	5.9	5.7	5.9	5.7	5.9
0% T/out	4.9	5.4	5	5.4	5.3	5.4	5.3	5.4

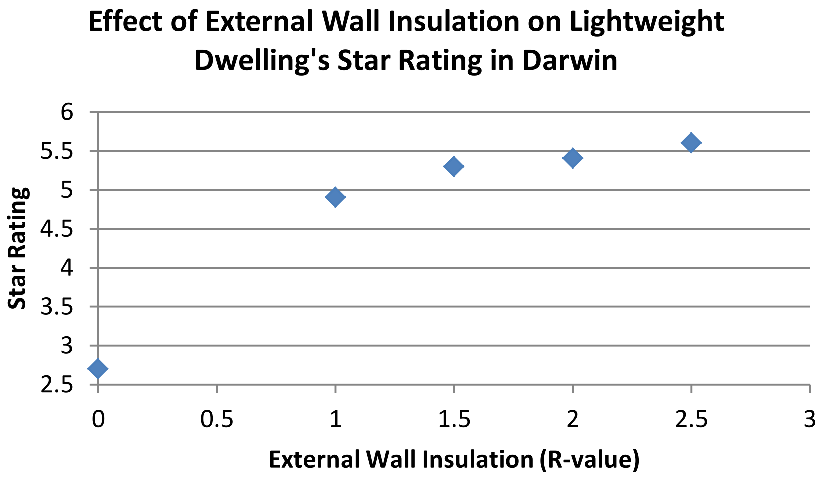

Figure 1: Lightweight building external wall insulation loss results in Darwin

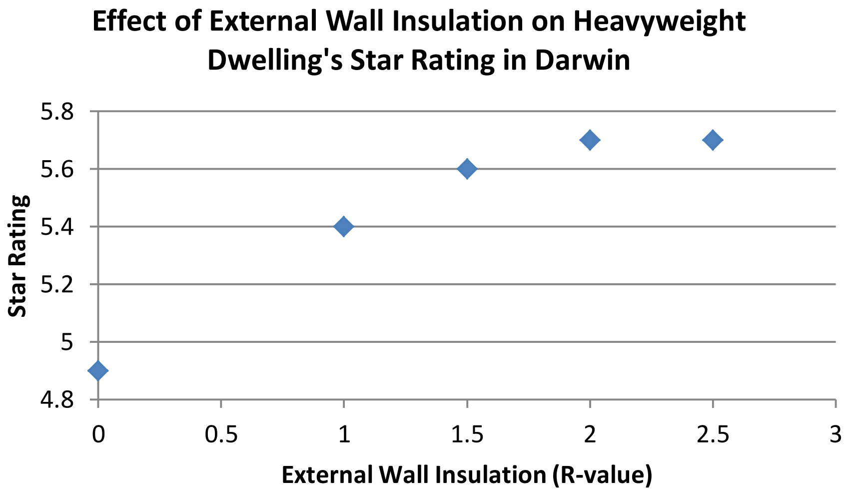

Figure 2: Heavyweight building external wall insulation loss results in Darwin

Combined Changes

Combining increases in air infiltration and reductions in insulation levels also proved to have a large impact on the star rating of both dwellings.

When the lightweight dwelling’s ceiling and external wall insulation were reduced to 70% (R2.8 to ceilings and R1.4 to external walls), all star ratings reduced by the same amount (within a 0.1 star margin), meaning that the change in insulation had little to no effect on air infiltration impacts. The impact of reduction of insulation was fairly proportional for the heavyweight dwelling as well, but there was a larger deviation of 0.1 stars for most capital cities, and 0.2 stars in Sydney.

These changes combined did, however, result in a large star rating difference from the as-designed dwelling.

With a 50% increase in air infiltration rates and 70% insulation, the lightweight building had star rating decreases of 0.2 to 0.5 stars, while the heavyweight building had decreases of 0.2 to 0.4 stars. At 200% of standard air infiltration rates, this became a decrease of 0.3 to 0.7 stars for the lightweight building, and 0.4 to 0.7 stars for the heavyweight building.

Phone:1300 308 525
www.sustainabilityhouse.com.au
research@sustainabilityhouse.com.au

The largest change was at 300% air infiltration. For the lightweight dwelling this meant a reduction of 1.5 stars, from 6.6 stars to 5.1 stars, while the largest change for the heavyweight dwelling was 1.7 stars, from 5.7 stars to 4.0 stars. Again, the largest changes were in the more extreme climate zones (Darwin and Hobart), with milder climate zones averaging 1.2 and 1.4 stars difference for the heavyweight dwelling. The lightweight dwelling showed a wider variation in changes, with the low initial-rating Perth only changing by 0.8 stars, while relatively mild Sydney and Melbourne changed by 1.3 and 1.5 stars respectively.

Table 21: Effect of air infiltration rates on lightweight building in each capital city at 70% ceiling and external wall insulation

Air infiltration	Star Rating (at 70% insulation levels)							
	Darwin	Brisbane	Perth	Adelaide	Sydney	Melbourne	Canberra	Hobart
100%	5.5	5.1	4.3	5.1	5.2	5.8	5.8	6.4
105%	5.4	5	4.3	5.1	5.1	5.7	5.8	6.3
110%	5.4	4.9	4.3	5	5.1	5.7	5.8	6.3
120%	5.4	4.9	4.3	4.9	5	5.6	5.7	6.2
150%	5.2	4.8	4.2	4.9	4.9	5.4	5.6	5.9
200%	4.9	4.5	4	4.7	4.7	5.1	5.3	5.7
300%	4.4	4.2	3.8	4.3	4.3	4.6	4.9	5.1

Table 20: Star rating change to lightweight dwelling due to air infiltration rate of 300% and 70% ceiling + external wall insulation, in all capital cities

	Star Rating							
	Darwin	Brisbane	Perth	Adelaide	Sydney	Melbourne	Canberra	Hobart
AI of 100% C+EW 100%	5.8	5.4	4.6	5.4	5.6	6.1	6.1	6.6
AI of 300% C+EW 70%	4.4	4.2	3.8	4.3	4.3	4.6	4.9	5.1
Star Rating Difference	1.4	1.2	0.8	1.1	1.3	1.5	1.2	1.5

Table 22: Effect of air infiltration rates on heavyweight building in each capital city at 70% ceiling and external wall insulation

Air changes per hour	Star Rating							
	Darwin	Brisbane	Perth	Adelaide	Sydney	Melbourne	Canberra	Hobart
100%	5.4	5.7	5.7	6.2	5.9	6.3	6	6.2
105%	5.4	5.7	5.7	6.2	5.9	6.2	6	6.2
110%	5.4	5.6	5.7	6.2	5.9	6.2	5.9	6.1
120%	5.3	5.6	5.7	6.1	5.8	6.1	5.9	6.1
150%	5	5.4	5.5	5.9	5.7	5.9	5.7	5.8
200%	4.7	5.2	5.3	5.8	5.4	5.6	5.4	5.5
300%	4	4.7	4.9	5.3	4.9	5	4.9	4.9

Phone:1300 308 525
www.sustainabilityhouse.com.au
research@sustainabilityhouse.com.au

Table 23: Star rating change to heavyweight dwelling due to air infiltration rate of 300% and 70% ceiling + external wall insulation, in all capital cities

	Star Rating							
	Darwin	Brisbane	Perth	Adelaide	Sydney	Melbourne	Canberra	Hobart
ACH of 100% C+EW 100%	5.7	5.9	6.1	6.5	6.3	6.4	6.3	6.4
ACH of 300% C+EW 70%	4	4.7	4.9	5.3	4.9	5	4.9	4.9
Star Rating Difference	1.7	1.2	1.2	1.2	1.4	1.4	1.4	1.5

DISCUSSION

The results show that the impact of air infiltration rates on star rating can be extreme, with reductions of up to 1.5 stars for a 300% air infiltration rate. While there were minor differences between the lightweight and heavyweight dwelling, the trends for changes in star rating due to air infiltration rates remained the same across the board.

Smaller changes in the rate of air infiltration were shown to have only a minor impact on both the lightweight and the heavyweight dwellings, with changes to the star rating sitting around 0 to 0.2 stars for increases of up to 20%. It was only when the rate was increased by 50%, 100% or 200% that major differences were found in the star ratings, with the largest change, of 1.5 stars, being found for the heavyweight dwelling in Darwin at 300% of the original air infiltration rate. The largest change for the lightweight dwelling was 1.3 stars in Hobart, and it was found that the air infiltration rate had the biggest impact in more extreme climate zones, such as Darwin and Hobart.

The calculations from Dong Chen's 'Infiltration Calculations in AccuRate V1.1.4.1' gave results in keeping with standard Australian air infiltration assumptions, as the air change per hour rates were calculated at standard air pressure, with most zones achieving under 0.3ACH. The impact of air infiltration in the roof and subfloor spaces had a large impact on these results, with roofspaces having a natural air change rate of over 3 ACH, and the subfloor space in the lightweight dwelling having a natural air change rate of over 1.5 ACH. These results were adapted to show air changes at 50 Pascals, and averaged to create a whole-of-house figure that took zone volume into account. Overall, the air infiltration assumptions in AccuRate were shown to be higher than the standard Australian housing stock assumption, but more data about the standard assumptions and AccuRate calculations would be required to investigate this further.

The results for insulation reductions were fairly consistent across different scenarios, showing that reductions by 10%, 20% and 30% do not have a drastic impact on the predicted energy performance, with star rating decreases of up to 0.4 stars. Anecdotal research into the effect of small reductions in insulation on monitored dwelling performance suggests a reduction in energy efficiency performance may be more significant than these predicted results and further research is required to validate these findings. Large decreases in insulation – such as removing all living ceiling or external wall insulation – were shown to reduce the star rating dramatically. Removing the ceiling insulation altogether reduced the star rating from around 6.0 stars to around 1.0 star, in all climate zones.

The impact, then, of failure to build to design standards has the potential to drastically change the assumed thermal performance of a dwelling. If gaps and cracks are not adequately sealed, the resultant air leakage can cause a major loss of performance. With an assumption of three times standard gaps and cracks, this can mean a change of well over 1.0 star. If insulation is not adequately installed, or left out altogether, changes can become extreme, with dwellings performing at the lowest possible end of the scale. These kinds of changes result in markedly less comfortable and more expensive homes to condition. However, this doesn't mean that the smaller changes do not also have an impact.

Phone:1300 308 525
www.sustainabilityhouse.com.au
research@sustainabilityhouse.com.au

For smaller increases in air infiltration, and insulation installed to 90%, 80% and 70% of requirements, impacts on energy efficiency were smaller but still marked. While decreases for these faults were not drastic, they could still amount to almost half a star by themselves. Combined with a 50% increase, these two faults caused up to an 0.5 star rating increase; a 100% increase moved this up to 0.7 stars. At 300%, the largest star difference was 1.7 stars, reducing the heavyweight building from 5.7 stars to 4.0 stars, and the lightweight building from 6.6 stars to 5.1 stars, bringing both dwellings well below the minimum star rating compliance standard.

It is recommended that further research investigate the effects of variable air infiltration rates and absence of insulation, comparing predicted and actual energy efficiency performance. Further research should also quantify the extent of insulation installation and building leakiness issues in new residential buildings throughout Australia, building on research already completed by the CSIRO.

Phone:1300 308 525
www.sustainabilityhouse.com.au
research@sustainabilityhouse.com.au