Identifying Cost Savings through Building Redesign for Achieving Residential Building Energy Efficiency Standards: Part Two

Final Report

June 2012

Prepared by: Sustainability House

Prepared for: Department of Climate Change & Energy Efficiency

Written by Sustainability House
Published by the Department of Climate Change and Energy Efficiency

© Commonwealth of Australia (Department of Climate Change and Energy Efficiency) 2012.

This work (including Appendices) is copyright Commonwealth of Australia. All material contained in this work is copyright the Commonwealth of Australia, except where the material is a building plan, or where a third party source is indicated. Building plans are copyright of the residential home builders listed under Acknowledgments below.

With the exception of the Commonwealth Coat of Arms and any departmental logos, Commonwealth copyright material is licensed under the Creative Commons Attribution 3.0 Australia Licence. To view a copy of this license, visit http://creativecommons.org/licenses/by/3.0/au/.

You are free to copy, communicate and adapt the Commonwealth copyright material, so long as you attribute the Commonwealth of Australia (Department of Climate Change and Energy Efficiency).

Permission to use third party copyright content in this publication can be sought from the relevant third party copyright owner/s.

IMPORTANT NOTICE – PLEASE READ

This publication includes the views or recommendations of third parties and does not necessarily reflect the views of the Australian Government, or indicate a commitment to a particular course of action.

The material in this publication is provided for general information only, and on the understanding that the Australian Government is not providing professional advice. Before any action or decision is taken on the basis of this material the reader should obtain appropriate independent professional advice.

While reasonable care has been taken in preparing this publication, the Commonwealth provides no warranties and makes not representations that the information contained is correct, complete or reliable. The Commonwealth expressly disclaims liability for any loss by any person, however caused and whether due to negligence or otherwise, arising directly or indirectly from the use or reliance on information contained in this publication.

Acknowledgements

We gratefully acknowledge the following high-volume residential home builders and their franchisees that volunteered use of their plans for this study, provided standard specifications and upgrade pathways, completed a survey and provided valuable feedback and advice:

- AV Jennings Developments
- BGC Residential
- Cavalier Homes
- Devine Homes
- Dixon Homes
- GJ Gardner Homes
- Hotondo Homes
- JWH Group
- Meriton
- Metricon
- Rossdale Homes
- Stockland
- Weeks Group

About Sustainability House

Sustainability House (incorporating House Energy Rating) is one of Australia's leading companies offering energy efficiency modelling, simulation and design advice for both residential and commercial buildings. The company has been operating in this market since 2000, and has developed significant industry experience and leadership to help build better buildings. For further information visit: www.sustainabilityhouse.com.au

Overview

Part 1 of this report by Sustainability House, *Identifying Cost Savings through Building Redesign for Achieving Residential Building Energy Efficiency Standards,* assessed typical housing stock from many of the largest high-volume residential builders in Australia to look at cost-effective ways for the building shell to be redesigned to achieve 6 stars. A major research finding was that contemporary dwelling designs could be optimised using minor design changes to more affordably meet the 6-star standard Australia-wide.

The study analysed thermal performance using an automated building simulation tool, Roborater, which rapidly assessed 20 designs in all 8 capital cities with a vast combination of design and specification changes. An additional outcome from the study was extensive surplus building performance data from the Roborater simulations.

The Department of Climate Change and Energy Efficiency identified the unique opportunity this provided to investigate the highest achievable star rating with negligible cost change from a 6-star standard by data-mining the hundreds of thousands of building permutations for the best results. This resulted in the commissioning of an additional study that forms Part 2 of the Report, which investigated the highest possible star rating that can be achieved from a 6-star baseline without incurring additional construction costs.

This study found that with proper consideration of the energy efficiency implications of different dwelling designs at the building planning stage it is possible to improve the energy efficiency of new dwellings and not increase builders' costs.

Approach

Generally all methods used in Part 1 were also used for Part 2 and the reader may need to refer back to this study for further information about the approach. Consequently the same 20 designs from Part 1 were assessed in Part 2 of this report, which included a range of dwelling types (single and double storey detached houses, semi-detached houses and apartments).

However, rather than 5 stars providing the base star rating, as in Part 1 of this report, initial specifications were upgraded to 6 stars in all capital cities for this study. The star ratings of the original designs were improved using standard upgrade pathways provided by high-volume residential builders, in accordance with the method employed in Part 1. Using this approach all dwellings achieved a minimum of 6 stars in at least one orientation in each capital city as designed. The exception to this was Dwelling 6 (a single storey detached house with timber floor) for which it was not possible for the original design to achieve 6 stars with high performing specifications alone (without the need for redesign in terms of glazing area reductions or other structural modifications). In this case the highest achievable star rating without redesign was used as the baseline for comparison. A graphical representation of the relationship between Part 1 and 2 is displayed in Figure 1.

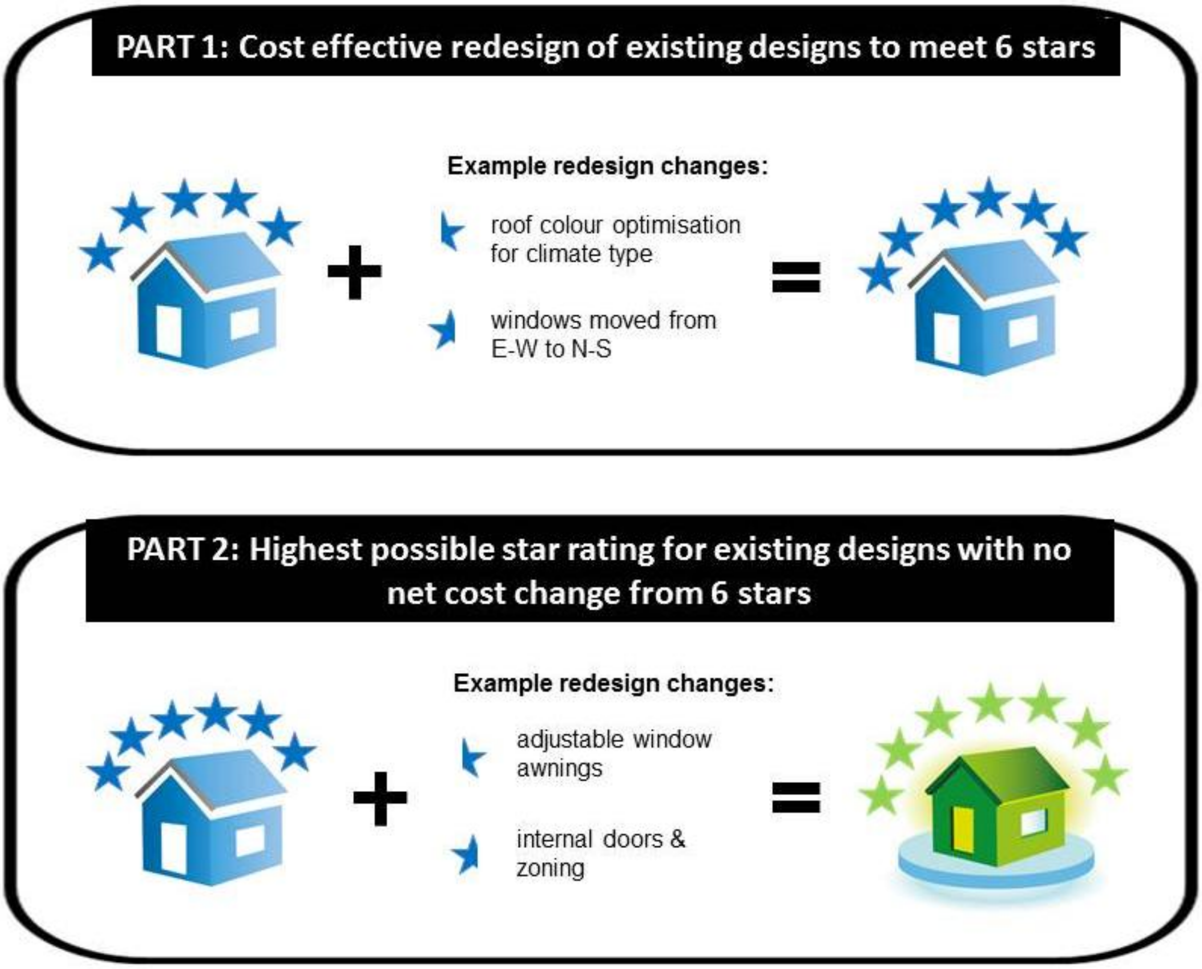


Figure 1: Graphical summary of key aims for Part 1 and 2 of the Report.

The redesign approach followed that used in the previous study (Part 1) including use of the automated building simulation software Roborater, which has been developed by Sustainability House and is available for use by energy assessors and the wider building industry. To capitalise on existing Roborater data, dwellings were redesigned in the same orientation with the same "manual" redesign changes as in Part 1, unless otherwise specified. Details of these changes can be found on the redesigned floor plans in Part 1 and include internal room layouts, glazing relocation and targeted area reductions, zone identification for floor covering changes or additions of internal doors, ceiling fans or roof ventilators.

In addition to these changes, specification and design changes from Roborater analyses were optimised in Part 2 of this report to achieve the highest star rating with negligible cost change (within a net cost range of $0-500). Roborater changes typically included glazing type and area, roller shutters, insulation levels, floor coverings, eave width, concrete slab type and external cladding colours. This by no means represents the full suite of design changes possible using the Roborater tool as its capabilities have been advanced since commencement of this report. In addition, a conservative range of variables was employed to meet budgetary and time constraints in completing the report.

An immense task was presented in identifying the highest possible star rating with negligible cost change for 160 design-location combinations based on the vast number of Roborater iterations. To complete this research within the given timeframe, and to improve study outcomes, an automated costing tool was applied to Roborater results to identify design permutations that achieved the highest possible star rating with negligible cost change. Cost data provided by national quantity surveyor Davis Langdon was used to cost both the original and redesigned dwellings in each capital city, which allowed the comparison of cost change.

Redesigned dwelling costs were selected as close as possible to the original cost of dwellings at the 6-star specification level and were, as a general rule, within a $500 margin. Occasionally redesigned costs deviated beyond this margin in instances where specifications were already maximised or there were limited redesign options, as was the case for some apartments. Redesign costs were also manually calculated and these results are presented in a table for each dwelling report to provide transparency in results.

Results

Design optimisation to improve the energy efficiency of the dwellings in all states and territories with negligible cost change resulted in an average increase of 1.2 stars from 5.9 to 7.1 stars.

The result from Part 2 was 0.2 of a star higher on average than achieved in Part 1 of this report, where overall designs were improved by 1 star from 5.3 to 6.3 with a cost saving of 1.6%. This finding is contrary to the typical trend for diminishing returns as higher star ratings are sought and can be attributed to two main factors. The first of these is the influence of Canberra and Adelaide results on the overall averages in Part 1, where the study primarily aimed to reduce the construction costs of achieving the already existing requirement of 6 stars in these locations. If results for these locations are excluded from Part 1 the average star rating improvement from a 5-star standard was the same as for Part 2 at 1.2 stars. Secondly, this result can be partially explained by the methodology changes between Part 1 and Part 2. In Part 2 an automated costing tool was applied to Roborater results to identify the most energy efficient design for the same cost as the original design, which was a more effective approach than the primarily manual approach that was used in Part 1.

As detailed in the methodology for Part 1 and Part 2, Roborater was used to assess redesigned dwellings with a range of specifications to identify the best results in terms of star rating and costs. Figure 2 provides an example of a costed Roborater result summarising the range of star ratings and costs achieved by a single storey detached house (Dwelling 5) in Sydney after manual redesign changes. For this example more than 62,000 simulations were run by Roborater and each of these results is shown as a data point for star rating and cost achieved with one possible combination of specifications. From this graph it can be seen that the specification changes that were included in this Roborater assessment resulted in a range of star ratings (5.8 to 7.9) and costs ($245,000 to $265,000). The star rating and cost that was selected for reporting achieved 7.3 stars for the lowest cost possible. Interestingly the lowest achievable cost for each star rating increased significantly for this particular dwelling when moving from 7.4 to 7.5 stars. This can be attributed to the increased cost in moving from 3mm clear to 6.38mm Comfort Plus glazing.

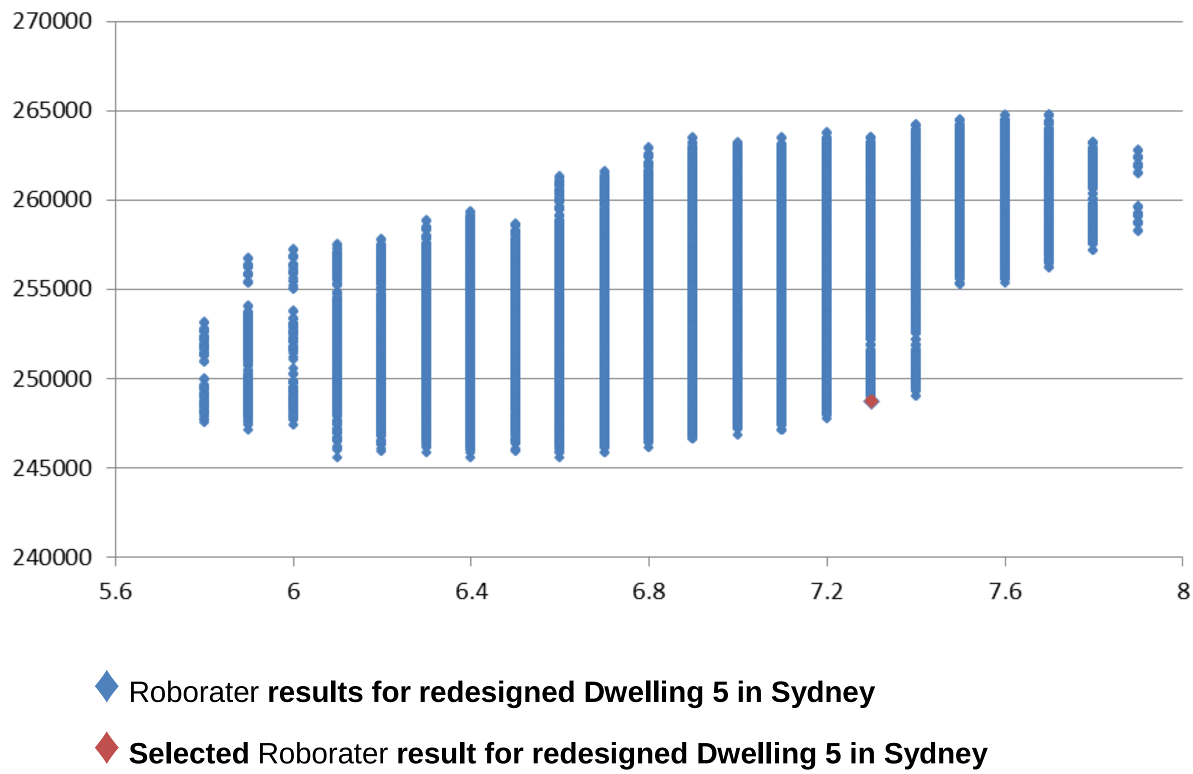


Figure 2: Roborater simulations (62,191 in total) for redesigned Dwelling 5 (single storey detached house) in Sydney summarised by star rating and total construction cost.

Across all dwelling-locations the negligible cost change for this study resulted in an average cost increase of $37. This marginal cost change was greatly facilitated by the automated costing tool and met the overall objectives for Part 2 of the Report.

Although only one orientation was redesigned for each design-location, as per the Part 1 approach, a range of best, worst and intermediate performing orientations were selected for redesign. On average the selected orientation for redesign was 0.3 of a star higher than the worst performing orientation and 0.4 lower than the best performing orientation.

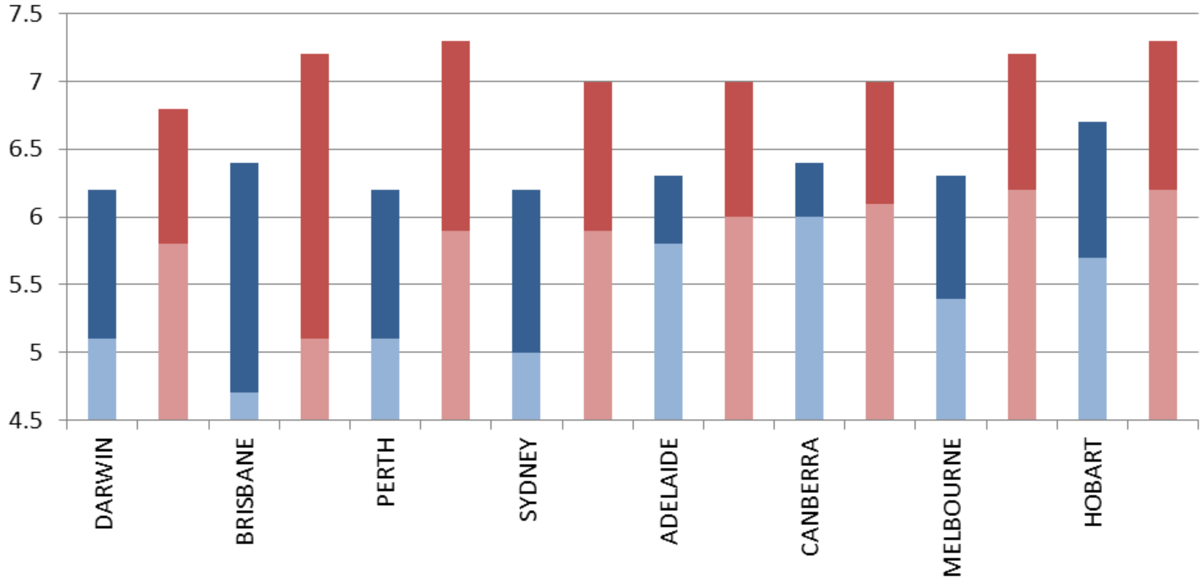
In total 17 of the 160 dwelling-locations could not be easily improved to achieve a higher star rating with negligible cost change. In calculating averages for this study all of these no-improvement results were included. The majority of these cases were accounted for by semi-detached houses and apartments which presented reduced options for redesign with no cost change where they were already performing well or it was not possible to readily balance cost benefits. Table 1 provides details for dwelling-locations that were not redesigned in Part 2 of the Report.

Table 1: Dwelling-locations that were not redesigned in Part 2 of the Report, as indicated by "x".

	Dwelling number					
Capital city	**6**	**16**	**17**	**18**	**19**	**20**
Darwin					●	●
Perth			●			
Sydney		●	●			
Adelaide		●	●			
Canberra	●	●	●	●		
Melbourne		●	●	●		
Hobart		●	●	●		

Comparison of the average star rating improvement by capital city for Part 1 and 2 of the Report revealed that a higher star rating improvement was achieved in Part 2 across all locations except Darwin and Sydney (Figure 3). In these locations dwellings were improved by 0.1 of a star less in Part 2 than in Part 1. In Adelaide and Canberra this study improved star rating by 0.4 stars higher than in Part 1 where the original design in these locations already achieved 6 stars and they were primarily redesigned to reduce construction costs. Analysis by capital city also revealed that the average star rating achieved by redesigned dwellings in Part 2 of the study was 7 stars or higher in all capital cities except Darwin where the average was 6.8 stars. The highest average star rating for redesigned dwellings in Part 2 of the study were achieved in Perth and Hobart at 7.3 stars. In Brisbane, where orientation can have a pronounced effect on star rating, the initial star rating was on average significantly lower than in other capital cities at 5.1 stars. However redesign in this location improved star rating by 2.1 stars on average and in doing so demonstrated the dramatic improvement that can be achieved in Brisbane as a result of simple redesign changes. When Brisbane was excluded in calculating the average star rating improvement this study still achieved an average improvement of 1.1 rather than 1.2 stars.

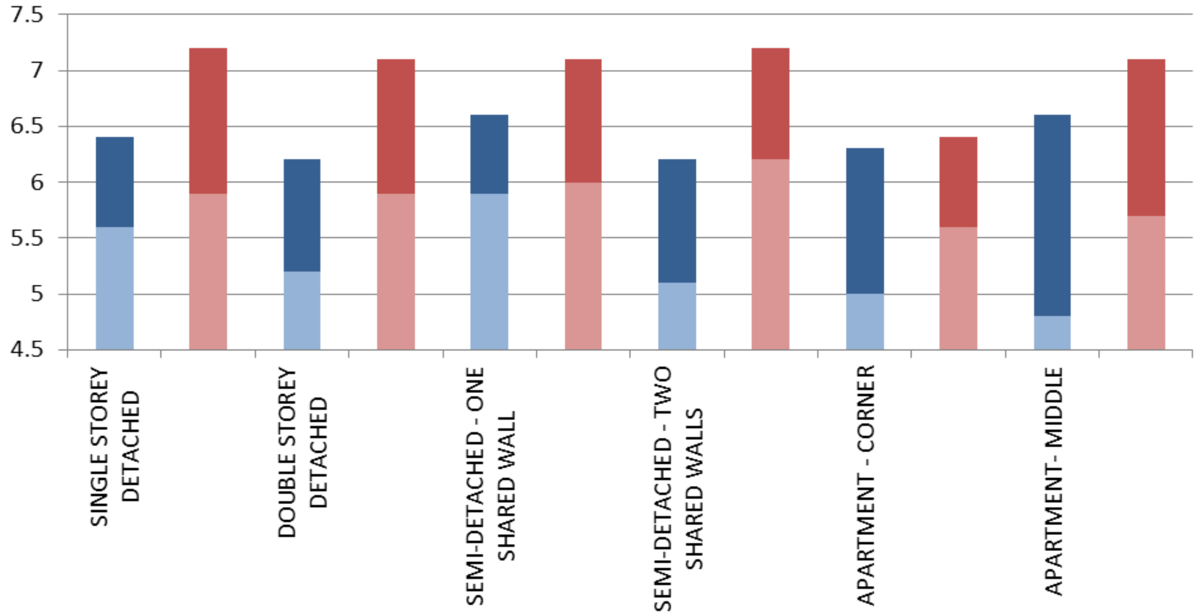
Analysis of trends in star rating improvement by dwelling type identified a larger increase in Part 2 of the study than in Part 1 for detached houses and semi-detached houses with one shared wall (Figure 4). Middle and corner apartments were improved by 0.4-0.5 stars less on average in Part 2, due to the higher initial rating for this study and the limited scope for further redesign changes. However middle apartments achieved the largest star rating improvement in the redesign of any dwelling type by utilising the natural advantages of being thermally insulated by adjacent dwellings. All dwelling types were improved to more than 7 stars on average, except corner apartments which had a significantly lower initial star rating than other dwelling types and offered less scope for improvement.



Part 1: Initial star rating, Improved star rating

Part 2: Initial star rating, Improved star rating

Figure 3: Comparison of average star rating improvement (in the same orientation) as a result of redesign changes by capital city for Part 1 and Part 2 of the Report.

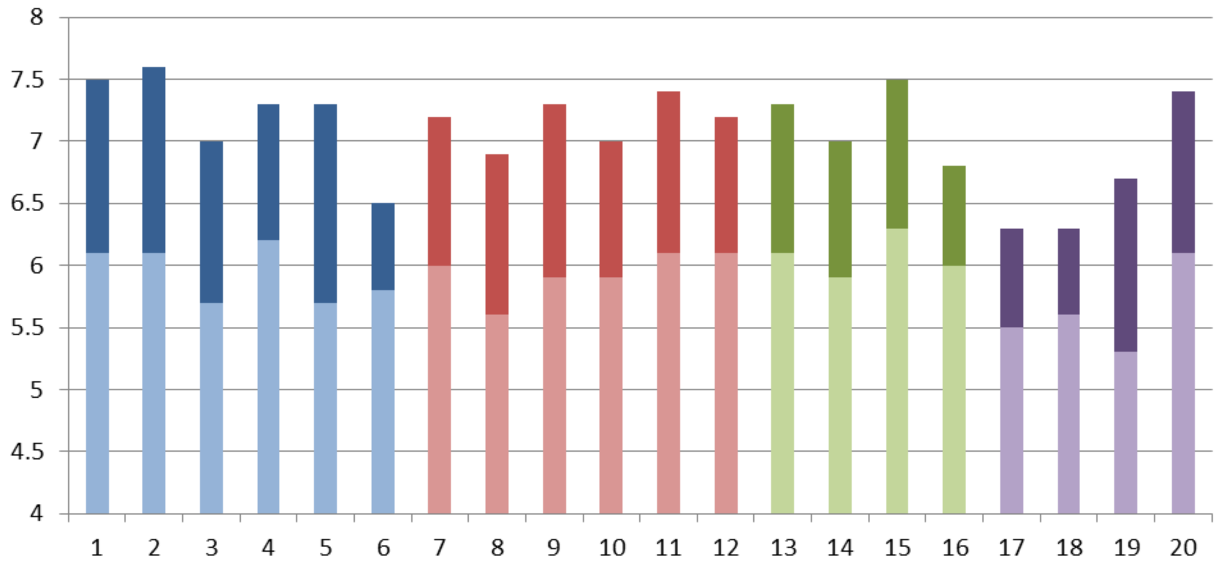


Part 1: Initial star rating, Improved star rating

Part 2: Initial star rating, Improved star rating

Figure 4: Comparison of average star rating improvement (in the same orientation) as a result of redesign changes by dwelling type for Part 1 and Part 2 of the Report.

A summary of the average star rating improvement achieved in Part 2 of the Report for each dwelling is provided in Figure 5. From this graph it can be seen that the redesigned star rating was improved to at least 7 stars for all dwellings except Dwelling 16 (semi-detached house with two shared walls) and Dwellings 17-19 (corner and middle apartments). In these cases the initial ratings were between 3.3 and 5.3 stars and, although dramatically improved, they achieved a relatively lower redesigned rating (ranging from 6.4 to 6.8 stars) which reduced the overall average star rating achieved across the pool of dwellings. Apart from these dwellings, most were redesigned to 7 stars or higher. Dwelling 6, as a single storey detached house, also goes against this trend as it was only improved by an average 0.8 stars to 6.5 with negligible cost change. Although Dwelling 8, a double storey house, also deviates from this trend by only achieving 6.9 stars as a result of redesign changes, it also had a low average initial star rating of 5.6



Single storey detached house: initial star rating, Improved star rating

Double storey detached house: initial star rating, Improved star rating

Semi-detached house: initial star rating, Improved star rating

Apartment: initial star rating, Improved star rating

Figure 5: Comparison of average star rating improvement (in the same orientation) as a result of redesign changes in Part 2 by dwelling number.

Outcomes

These redesign results demonstrate that, based on current house designs of high-volume residential builders, there is significant scope for thermal improvement beyond a 6-star standard with relatively minor design changes. Results from Part 1 and Part 2 of this report confirm that dwellings can be optimised for a specific orientation to improve thermal performance and/or reduce construction costs.

Star rating results for dwellings in the four cardinal orientations as designed demonstrate that when building a house in Brisbane it is more important to select designs that perform well, or optimise designs, for a given orientation than it is in other capital cities. Minimising west-facing glazing to living zones is crucial to good design performance in Brisbane, however benefits can be achieved in all locations.

Changes to glazing type and general reductions to area were applied across all glazing as part of the Roborater assessments, but benefits from these changes are most effective when applied to the living area. Optimising glazing to the living area only would provide a more cost-effective option to improve star rating than used in this study. In hindsight had Roborater changes provided more targeted reductions, which is within the softwares' capabilities, similar star rating improvements could have been achieved without large reductions to glazing area in the majority of cases.

Similarly adjustable vertical awnings were automatically applied to all windows or to east- and west-facing windows for some dwellings depending on location, but in reality it would be more cost-effective to apply adjustable awnings to daytime occupied zones for the largest thermal benefit and minimal incurred cost. Additional cost savings could also be achieved by using more cost-effective awning options than metal roller shutters.

The addition of vinyl as a type of hard floor covering was used in the redesign of living areas in hot and temperate climates, where the thermal mass of concrete assists in maintaining more consistent temperatures. Similar thermal benefits from vinyl floor coverings could also be achieved to varying extents with other floor coverings such as polished concrete, tiles or to a lesser extent floating timber, although these are a little more expensive than vinyl. Hard floor coverings can also be used to improve thermal performance in colder climates when used in conjunction with north-facing windows to exploit thermal mass and facilitate passive heating. However, in dwellings with expansive living areas to which solar access is limited, carpet improves thermal performance by insulating the concrete and thus minimising heat loss. In considering cost-benefits of variable improvements, vinyl was generally not used in the redesign of cold climates in Part 1 or 2 of this study.

Sustainability House recognise that builders may be limited in their ability to fully realise some of the suggested design changes due to encumbrances imposed on some developments, block orientation, buyers' preferences (e.g. for main living areas to be at the rear of the property as opposed to facing the street if this has better solar orientation), planning regulations and solar access rights. In addition, this study has been undertaken with the assumption that blocks are flat, but we recognise that sloping blocks can present increased difficulties for builders to achieve a 6-star standard. In modelling dwellings in this study the confounding effects of shading from adjacent dwellings or other structures was also disregarded, however these can provide significant benefits or detriments to the thermal performance of dwellings dependant on the climate zone. Future studies could also consider the effects of block slope and shading on star rating and construction costs.

Although this study has successfully illustrated that star rating could be dramatically improved from a 6-star standard without increasing construction costs, it is likely that this margin could have been improved further given more time.